Cultural Heritage of Astronomical Observatories
From Classical Astronomy to Modern Astrophysics

Figure 0.1: *Large Refractor, Steinheil/Repsold (Hamburg Observatory in Bergedorf)*

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Gudrun Wolfschmidt (ed.)

Cultural Heritage of Astronomical Observatories

From Classical Astronomy to Modern Astrophysics

Proceedings of the International ICOMOS Symposium
in Hamburg, October 14–17, 2008

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Figure on the front cover: Observatory Tulse Hill near London, with 8″ refractor and prism spectroscope, 1860/68 (Huggins 1899, p. 4)

Figure on the frontispiece: Large Refractor, Hamburg Observatory in Bergedorf (Hamburg Observatory)

Figure on the title page: Renovated 1 m-reflector building, Hamburg Observatory in Bergedorf (Photo: A. Seemann)

Figure on the back cover: Hamburg Observatory, large refractor, elevation and longitudinal section, 1906 (Archives of Hamburg Observatory)

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Behörde für Kultur, Sport und Medien

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Contents

Foreword of ICOMOS

This new volume in the ICOMOS series *Monuments and Sites*, at the beginning of which stood the publication on *International Charters for Conservation and Restoration* (1^{st} edition 2001, 2^{nd} edition 2004), proves once again that ICOMOS as advisory body to the World Heritage Committee has already reacted several times to the global strategy for a representative, balanced and credible World Heritage List through specialised studies. In accordance with the requests of the World Heritage Committee ICOMOS presented in 2005 its publication *The World Heritage List / Filling the Gaps – an Action Plan for the Future*, the so-called Gap Report documenting with a typological, chronological-regional and thematic framework possible gaps in the existing list of World Cultural Heritage (= vol. XII of the *Monuments and Sites* series). And in 2008 it presented its publication *The World Heritage List / What is OUV?* (= vol. XVI of the *Monuments and Sites* series). With their statistics and registers both volumes, compiled by Jukka Jokilehto, are crucial resources for understanding the World Heritage List as a highly successful tool of international cultural politics.

At the 32^{nd} session of the World Heritage Committee in Quebec City in 2008 ICOMOS introduced a progress report on global thematic studies and identified some studies which ICOMOS would be ready to prepare in the coming four years, among them a thematic study on the heritage of astronomy: *This thematic study would be developed in the context of the recent interest in the review of the relationship between heritage of sciences, traditional community knowledge and the World Heritage Convention. It would, as well, be associated to the UNESCO thematic initiative 'Astronomy and World Heritage' within the framework of its integrated Implementation Strategy. ICOMOS met on 23 April 2008 with the International Astronomical Union in order to set the basis of close cooperation in the preparation of the study ...* After having examined the progress reports on thematic studies the World Heritage Committee requested ICOMOS and IUCN *to continue to develop their work on the thematic studies in relation to priorities identified in Document WHC-08.32.COM/10A* and took note *of the need for additional resources to be provided to support priority work by ICOMOS and IUCN on thematic studies.* Part of this is also the series of activities carried out within the framework of the Thematic Initiative "Astronomy and World Heritage", which is based upon the decisions of the 28^{th} and 29^{th} sessions of the World Heritage Committee (Suzhou 2004 and Durban 2005), aiming *to further explore the thematic as a means to promote in particular site nominations, which recognise and celebrate achievements in science.*

In a circular letter of 7 October 2008 the Director of the World Heritage Centre, Francesco Bandarin, then asked the members of the World Heritage Convention and the state parties to support this initiative "Astronomy and World Heritage" developed since 2003 with voluntary contributions from state parties. He also pointed out a cycle of initiatives launched not only within the framework of the above-mentioned decisions, but also in support of the International Year of Astronomy 2009, proclaimed by the 62^{nd} General Assembly of the United Nations. And as an example for the thematic studies requested of ICOMOS in accordance with the above-mentioned decision 32.COM/10A Francesco Bandarin emphasised our international symposium in Hamburg: *In line with this decision, the International Symposium 'Astronomical Observatories – From Classical Astronomy to Modern Astrophysics' will be organised by ICOMOS Germany and the University of Hamburg in October 2008.*

We may therefore consider the results of the symposium organised by ICOMOS Germany together with Hamburg University (Institute for History of Science and Technology) and the Monument Protection Office (Denkmalschutzamt) not only as a contribution to the International Year of Astronomy. They are also a contribution to the thematic studies of ICOMOS in accordance with the World Heritage Committee's decisions 28.COM/9, 29.COM/5.1 and 32.COM/10A. The articles in this volume on the topic of astronomical observatories around 1900 by specialists from all over the world can fill a gap within the thematic framework (Developing Technologies, VI 2c, see Gap Report, p. 80). Furthermore, they point at the special relevance of the Hamburg Observatory built between 1906 and 1912 at its present location in Hamburg-Bergedorf. Together with comparable observatories in other countries it has considerably contributed to the development from classical astronomy to modern astrophysics.

I wish to thank the City of Hamburg and Cultural Senator Prof. Dr. Karin von Welck as well as those who contributed to the funding of the ICOMOS symposium, e. g. the Förderverein Hamburger Sternwarte, the Buhck Foundation, the Körber Foundation, the Bergedorfer Zeitung and the Senatskanzlei Hamburg. My thanks also go to Frank-Pieter Hesse (head of the Hamburg Monument Protection Office) and Ms Ilka von Bodungen. Finally, I would particularly like to thank Prof. Dr. Gudrun Wolfschmidt, who with untiring energy prepared our symposium and as an exemplary editor also coordinated and compiled the contributions for this publication.

Michael Petzet
Honorary President of ICOMOS

Preface

From October 14 to 17, 2008 the international ICOMOS symposium about *"Cultural Heritage of Astronomical Observatories (around 1900) – From Classical Astronomy to Modern Astrophysic"* took place, organized and chaired by Gudrun Wolfschmidt, head of the Institute for History of Science of Hamburg University, in cooperation with ICOMOS Germany and the Monument Protection Office (Denkmalschutzamt) Hamburg together with Hamburg University (Faculty of Mathematics, Informatics and Natural Sciences, Hamburg Observatory and Institute for History of Science and Technology). It counted as the first event in the context of the *International Year of Astronomy* (IYA) 2009 in Hamburg.

The objective of the ICOMOS symposium was to discuss the relevance of modern observatories for the cultural heritage of mankind. On the UNESCO World Heritage List buildings of science are currently underrepresented. The discussion about "Astronomy and World Heritage" had already started in 2004 in order to establish a link between science and culture and to raise awareness of the cultural importance of astronomical sites. In October 2008 a *Memorandum of Understanding* between UNESCO and the *International Astronomical Union* (IAU) was signed.

Guests from 20 countries discussed in Hamburg the cultural heritage of observatories and presented their papers which described in detail the history of the buildings, the architectural features, the valuable instruments and the archive material of the observatories as well as the scientific achievements, inventions and discoveries. It turned out that some more research has to be done in order to get an analysis of the architectural relevance of the observatories and their urbanistic disposition, as well as an evaluation of the inherent artistic and aesthetic values.

I would like to thank very much for the help in organizing the ICOMOS symposium – first of all Ilka von Bodungen and Frank Pieter Hesse, Monument Protection Office (Denkmalschutzamt) Hamburg, but also the the collegues of the Institute for History of Science, Hamburg University, Hamburg Observatory and the *Förderverein Hamburger Sternwarte*.

Finally, the ICOMOS symposium would not have been possible without the generous financial support from the following institutions and sponsors:

- Behörde für Kultur, Sport und Medien der Freien und Hansestadt Hamburg
- Behörde für Wissenschaft und Forschung der Freien und Hansestadt Hamburg
- Hamburg University
- Senatskanzlei Hamburg
- Bezirksamt Hamburg-Bergedorf
- Bergedorfer Zeitung
- Körber-Stiftung
- Buhck-Stiftung.

Concerning the proceedings I am very grateful to Prof. Dr. Michael Petzet for his advice and suggestions and to Timo Engels for the amount of help in improving the layout according to the ICOMOS publication regulations.

Gudrun Wolfschmidt

Web Page of the Symposium:
`http://www.math.uni-hamburg.de/spag/ign/events/icomos08.htm`

Grußwort – Welcome address

Das Universum hat die Menschheit seit jeher fasziniert, die Betrachtung des Sternenhimmels in allen Kulturen Staunen und Fragen ausgelöst: Wie sind die Himmelskörper beschaffen, was bewegt sie, welchen Einfluss haben sie auf uns? Die Erforschung unseres Sonnensystems und auch die in den letzten Jahrzehnten entstandene extrasolare Planetenforschung sind bis heute eine wesentliche Voraussetzung dafür, das Universum als Ganzes, seine Entstehung und seinen Aufbau zu verstehen. Die Astronomie, die gemeinhin als älteste Wissenschaft gilt, ist damit zweifelsohne als ein wesentlicher Bestandteil der Menschheits- und Kulturgeschichte anzusehen. Kulturstätten, die außergewöhnliche Zeugnisse für die Auseinandersetzung des Menschen mit dem Kosmos darstellen oder die im engen Zusammenhang mit der Geschichte der Astronomie stehen, können deshalb einen hohen Stellenwert im kulturellen Erbe der Menschheit beanspruchen.

Bisher sind nur wenige astronomische Stätten auf der Welterbeliste vertreten. Das Welterbezentrum der UNESCO hat daher im Jahr 2004 die Initiative "Astronomy and World Heritage" gestartet, die dazu beitragen soll, weitere astronomische Stätten von außergewöhnlichem universellem Wert zu identifizieren und Maßnahmen zu ihrer Erhaltung zu unterstützen. Das internationale ICOMOS-Symposium *"Cultural Heritage: Astronomical Observatories (around 1900) – From Classical Astronomy to Modern Astrophysics"*, das anlässlich des 175jährigen Bestehens der Hamburger Sternwarte als staatliches Institut vom 15. bis zum 17. Oktober 2008 in Hamburg-Bergedorf stattfand, wurde in Übereinstimmung mit dieser Initiative des Welterbezentrums durchgeführt. Das Symposium, das vom Institut für die Geschichte der Naturwissenschaften der Universität Hamburg, von der Behörde für Kultur, Sport und Medien / Denkmalschutzamt sowie von ICOMOS-Deutschland mit Unterstützung der Universität Hamburg, der Senatskanzlei Hamburg, des Bezirksamtes Bergedorf, der Buhck-Stiftung, der Körber-Stiftung und der Bergedorfer Zeitung veranstaltet wurde, war für Hamburg gleichzeitig der Auftakt zum "Internationalen Jahr der Astronomie 2009", das die Generalversammlung der Vereinten Nationen 2007 beschlossen hatte.

Hamburg schätzt sich glücklich, eine Sternwarte zu besitzen, die für die Zeit der Wende vom 19. zum 20. Jahrhundert in den unterschiedlichen Bedeutungsebenen von moderner Anlageform, repräsentativer Architektur, instrumenteller Ausstattung, wissenschaftlichen Sammlungen und nach ihrem Erhaltungsgrad ein wissenschafts- und architekturgeschichtliches Kulturdenkmal von internationalem Rang darstellt. Ziel des von Wissenschaftlern aus 17 Ländern besuchten Symposiums war es, die Bedeutung moderner Sternwarten für das kulturelle Erbe der Menschheit zu diskutieren und weitere mit der Hamburger Sternwarte vergleichbare Observatorien als internationale Kooperationspartner für eine transnationale serielle Bewerbung zu gewinnen.

Wir freuen uns sehr, dass so viele deutsche und internationale Gäste unserer Einladung gefolgt sind und unserem Symposium zum Erfolg verholfen haben. In einer ersten Auswahl wurde vorgeschlagen, elf weitere Observatorien zu einer transnationalen seriellen Bewerbung zur Aufnahme in die UNESCO-Welterbeliste einzuladen. Wir würden uns sehr freuen, wenn wir diese Observatorien als internationale Kooperationspartner der Hamburger Sternwarte gewinnen könnten.

Allen Organisatorinnen und Organisatoren, Vortragenden, Teilnehmenden, Unterstützern und Helfenden im Hintergrund ist für die ertragreiche Veranstaltung und ihre reibungslose Durchführung herzlich zu danken. Ganz besonderer Dank gebührt Frau Prof. Dr. Gudrun Wolfschmidt (Universität Hamburg / Institut für Geschichte der Naturwissenschaften), die nicht nur das Symposium vorbereitet und geleitet, sondern auch die Schriftleitung dieser Veröffentlichung übernommen hat. Dem Beauftragten der Bundesregierung für Kultur und Medien ist für die Unterstützung zur Drucklegung zu danken.

Senatorin Dr. Herlind Gundelach,
Präses der Behörde für Wissenschaft und Forschung

Prof. Dr. Karin von Welck,
Senatorin für Kultur, Sport und Medien

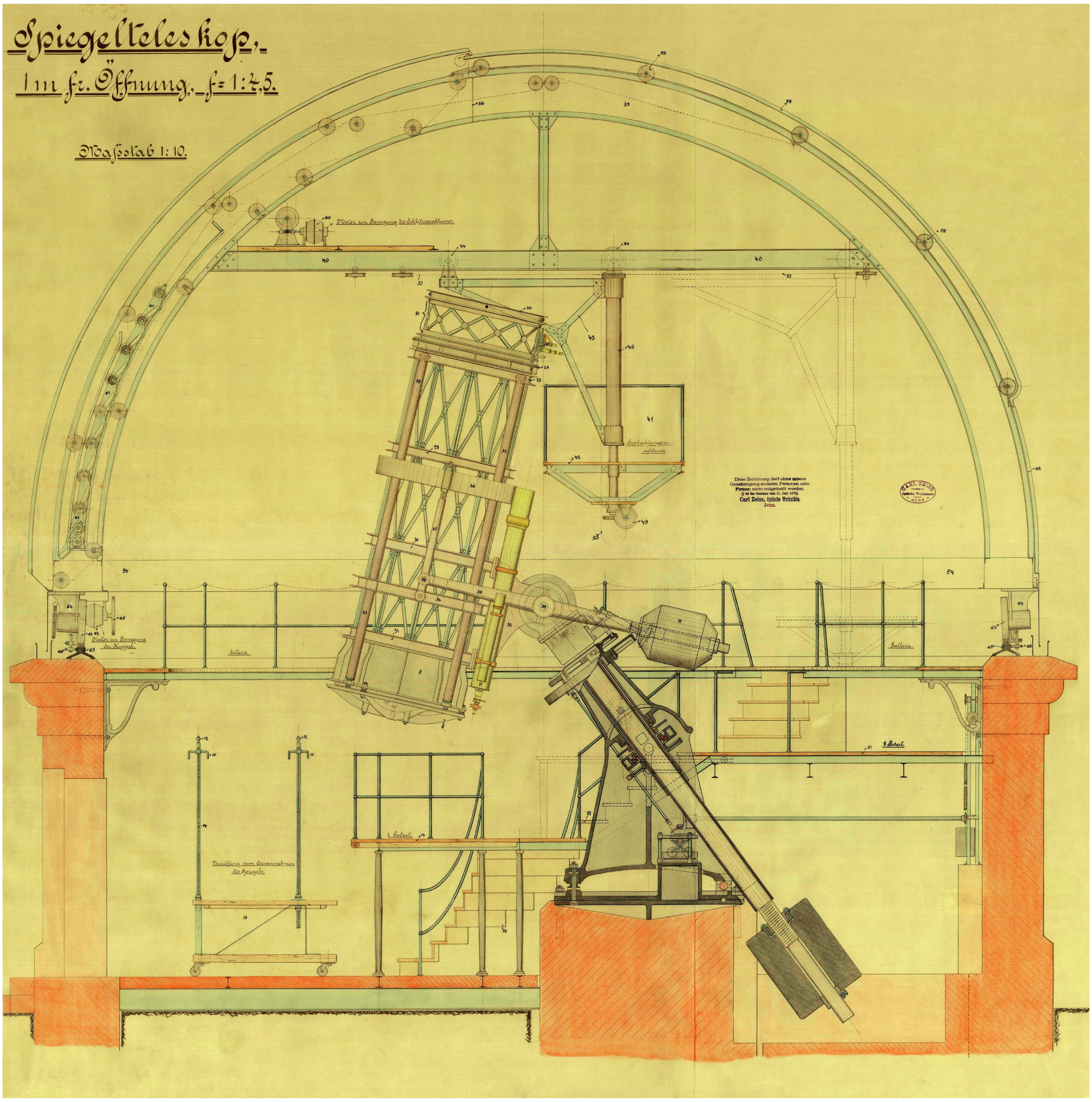

Figure 0.2: *Cross section of the 1 m Reflector of Hamburg Observatory (drawing, around 1906)*

Figure 1.1: *Main building, Hamburg Observatory*

1. Introduction to the Topic of the Symposium

Frank Pieter Hesse (Hamburg, Germany)

Dear Senator,
Dear President,
Dear Prof Wolfschmidt,
Dear Prof Petzet,
Dear speakers and guests from all parts of the world,[1]

I would like to welcome you all to our international symposium on the cultural heritage of astronomy. I am pleased to see that so many speakers have accepted the university's invitation to inform us and each other about our astronomical heritage. As head of the monument conservation department in Hamburg I welcome you here in Bergedorf. For one hundred years the observatory has been in this part of Hamburg; before it had been situated on the outer edge of the historic centre, in the so-called Wallanlagen. But we are not just focussing on this observatory, which is celebrating its 175$^{\text{th}}$ anniversary as a state institute, thus being Hamburg's oldest university institute. Instead, we also intend to look at other astronomical sites that have played a major role in the development of modern astronomy or – to be more precise – of astrophysics, some of which, we believe, could fulfil the requirements of the World Heritage Convention of UNESCO.

It is no longer a matter of course that the Hamburg Observatory is a university institute. Today's astronomers hardly ever need these kinds of instruments that can be found here in such great numbers and of such historic authenticity. Instead, they work with satellites, radio and x-ray observatories beyond the visible light spectrum, or with data provided by modern observatories in South America or from the orbit. Nonetheless, we consider the Hamburg Observatory so important for the history of modern astronomy that it was placed on the monument list in 1996. In addition, we were able to have it acknowledged as a cultural monument of national importance by the Federal Government Commissioner for Culture and the Media, which of course is advantageous for the funding of conservation and restoration measures. It must be preserved as cultural heritage, preferably with the university, which uses it to this day, continuing to take care of it scientifically. Incidentally, in this respect we have total agreement with the astronomers and scientists who work here. Of course, the university hopes it would benefit from the World Heritage title, which might include better funding for the preservation of the observatory, also from several sponsors.

The matter of this monument's exceptional value – if not even its outstanding universal value – was raised not so long ago by a renowned conservationist, the former head of the conservation department in Hessen and present President of the Deutsche Stiftung Denkmalschutz, Prof. Gottfried Kiesow. This started a lively discussion about potential World Heritage sites in Hamburg – especially here in self-assured Bergedorf, which very quickly saw itself as a World Heritage site. However, such a distinction requires scientific expertise, as demanded in the Operational Guidelines of UNESCO.

In order to find a pathway which will bring us a little closer to this goal, we have been able to organise this conference together with the University of Hamburg, ICOMOS as advisory body of UNESCO and with active support from the borough of Bergedorf and a number of private sponsors. I am especially pleased to be able to welcome Prof. Michael Petzet as one of the keynote speakers, until recently President of ICOMOS International and still President of ICOMOS Germany. He will also be taking part in tonight's panel discussion. For every nomination to the World Cultural Heritage List the International Council on Monuments and Sites has to be consulted. This is the organisation whose experts occupy themselves with the heritage of humankind and upon whose advice and evaluation UNESCO tends to rely. So far, however, there is no ICOMOS international committee for astronomy and observatories yet – perhaps this can be set up in the near future.

In matters of World Heritage Hamburg is quite ambitious. Only recently, to the world-famous Chilehaus, which has been on the German tentative list since 1997, the surrounding Kontorhausviertel from the 1920s and the Speicherstadt, erected between 1883 and 1928, were added. The nomination is planned for 2014; the entire German tentative list consists of sites from all federal states to be nominated until 2016. Therefore, additional sites will only have a chance to become World Heritage sites later on. It also needs to be taken into account that the World Heritage Committee is not allowed to declare more than two sites from each signatory state as World Heritage per year. This quota must be divided between the 16 German federal states.

Apart from these national considerations in the effort to place more highly important monuments on the World Heritage List, there is also the global strategy for a more balanced, representative and authentic World Heritage List. This strategy has been pursued by the World Heritage Centre and the World Heritage Committee since 1994 to counterbalance the over-representation of Europe with its many old town centres and churches: *By adopting the Global Strategy, the World Heritage Committee wanted to broaden the definition of World Heritage to better reflect the full spectrum of our world's cultural and natural treasures and to provide a comprehensive framework and operational methodology for implementing the World Heritage Convention.*
This new vision goes beyond the narrow definitions of heritage and strives to recognize and protect sites that are outstanding demonstrations of human coexistence with the land as well as human interactions, cultural coexistence, spirituality and creative expression. Crucial to the Global Strategy are efforts to encourage countries to become States Parties to the Convention, to prepare Tentative Lists and to prepare nominations of properties from categories and regions currently not well-represented on the World Heritage List.

In 1999, the 12$^{\text{th}}$ General Assembly of UNESCO had once again called for a balanced World Heritage List:[2]

The States Parties were invited to check if they already have a substantial number of sites inscribed on the World Heritage List and, if so,

- *to space voluntarily their nominations,*
- *to propose only properties falling into categories still under-represented,*
- *to link each of their nominations with a nomination presented by a State Party whose heritage is under-represented, or*
- *to decide, on a voluntary basis, to suspend the presentation of new nominations.*[3]

To achieve this aim of a representative and balanced World Heritage List, ICOMOS in 2004 published the action plan "Filling the Gaps". This is an analysis and strategic recommendation for filling the regional, temporal, geographical and thematic gaps in the World Heritage List. At present this List proves that there is a considerable imbalance between countries and categories.[4]

Consequently, serial and transnational applications, which the World Heritage Centre encourages, have better chances than individual applications, especially if they also serve to fill thematic gaps in the World Heritage List.

For Hamburg this means that its efforts to have its Jewish cemetery in Altona nominated for World Heritage (a cemetery opened in 1611 and used until 1869, containing richly decorated gravestones of the Sephardic and Ashkenazic Jews) will only be successful if this cemetery can be combined with other similar ones, such as in Amsterdam-Ouderkerk or Curacao.

Most certainly, the same holds true for this observatory. What would have to be considered on its pathway to World Heritage status? At first, let us look at the World Heritage List, which so far includes only a few observatories and these are usually part of a larger World Heritage site. Here are a few examples (date of erection/inscription on WHL):

Royal Observatory of Great Britain in Greenwich (1675/1997 as part of Maritime Greenwich),

Tartu Observatory as part of the Struve Geodetic Arc (1810/2005),

Pulkovo/St. Petersburg (1839/1990 as part of St. Petersburg),

Peking Ancient Observatory (1442 ff / one of over 90 positions on the Chinese tentative list since 1996).

Of particular interest are the activities of UNESCO itself, which are dealing with astronomy and observatories. In March 2004, the World Heritage Centre together with the UNESCO office Venice / regional office for science and culture in Europe (ROSTE) and with ICOMOS organised an expert meeting on the introduction of the category of astronomical heritage and on the methodology for its definition and implementation.[5] The expert meeting proposed the following categories for astronomical heritage:

(i) Properties whose design and/or landscape setting have significance in relation to celestial objects or events;

(ii) Representations of the sky and/or celestial bodies and events;

(iii) Observatories and instruments;

(iv) Properties with a strong connection to the history of astronomy

This was also the start of the initiative "Astronomy and World Heritage" at the UNESCO World Heritage Centre.[6] The objective of this thematic initiative is to link science and culture on the basis of research that aims for the acknowledgement of the cultural and scientific values of astronomical and astronomy-related sites. The three focuses of this programme are the identification, safeguarding and support of these sites.

The programme is meant to give a methodical framework for the associated measures, pave the way for cooperation between the signatory states and the academic communities and to enable the exchange of knowledge. I believe our conference fits perfectly into this initiative. Unfortunately, Anna Sidorenko-Dulom, who looks after this initiative at the World Heritage Centre in Paris, cannot join this conference, but we will read out her presentation.

Ukraine is an example for the way signatory states of the World Heritage Convention refer to this initiative. Since the beginning of this year it has placed three additional observatories on its tentative list (apart from the Mykolayiv Astronomical Observatory), which – as part of a serial trans-national application – is meant to be nominated together with observatories in Germany, England, France, Russia, Ukraine, South Africa, USA and other countries.[7] In its description for the tentative list, the Ukraine is referring to such observatories that participated in the creation of a basic reference coordination system. Incidentally, on the tentative lists of the other states observatories are hardly ever found – perhaps this will change after this conference.

The International Astronomical Year 2009 is one of the important actions initiated in this context by the General Assembly of the UN. We therefore consider our conference as a relevant launch event of this year. The websites of the observatory and the University of Hamburg are already announcing a great number of events for 2009. In connection with this I would like to draw your attention to an exhibition shown here in Hamburg as from 30 October in two different places: "Navigare necesse est" on the history of navigation.

To a certain extent these short remarks on the role of ICOMOS, the strategy of UNESCO and the initiative "Astronomy and World Heritage" are intended to serve as a foil which will allow us to set our conference and possible other resulting activities into context. I am confident we are on the right track with this conference and it is to be expected that this will not be the last of its kind.

Perhaps more than any other category of our built cultural heritage observatories lead us beyond the history of art and architecture and into the history of science and technology. At the same time, they require us to look beyond our national borders. This has been the case for centuries, as astronomy has always been an international and global science. The worldwide connections of Hamburg's observatory are manifold: the sons of its founder, Johann Georg Repsold, expanded their father's workshop for instruments and delivered telescopes – refractors, equatorial telescopes, meridian circles – to Edinburgh in 1830 and to Pulkovo near St. Petersburg in 1836. Up to the First World War the company, which from 1871 called itself Repsold & Söhne, delivered around 70 instruments to Europe and overseas. The already mentioned Mykolayiv Astronomical Observatory also owns an instrument made by Repsold. The groundbreaking Schmidt reflecting telescope, constructed in 1930 by Bernhard Schmidt, was imitated and developed further in the most renowned observatories of the world. There are historic links to Caracas and to Washington; presently, the European Southern Observatory (ESO), Calar Alto and Hubble Space Telescope are closely connected with Hamburg. In fact, Otto Heckmann, who was director of the Hamburg Observatory from 1941 to 1962, was appointed first director of ESO.

The Hamburg type – a park with buildings for the individual instruments – was influenced by the observatory in Nice. In those days the architecture of these observatories used regional or local building traditions or fashions: consequently, for the older observatories of the 19$^{\text{th}}$ century the neo-classical style was predominant. In Hamburg, however, Albert Erbe, the municipal architect of the observatory, was inspired by a moderate neo-baroque style, similar to the many schools and other public buildings he had designed as an alternative to the *Heimatstil* in Hamburg. The pantheistic or cosmic symbolism of the domed structure was inherent in the building task "observatory" itself; therefore the building was to a certain extent sign and purpose at the same time. In the meantime – if we look at the modern buildings on the Paranal in Chile – this has changed a lot. Apart from Peter Müller's well-known work on the architecture and history of observatories, published in 1992, no other comprehensive study or research on the architecture of modern observatories is known. Surely, this would be an interesting and worthwhile task for the architectural historians at our university.

Of course, the style of the architectural shell for these modern telescopes is of lesser interest compared to aspects dealing with the history of science and technology. The majority of our speakers will also be referring to the individual role of their objects within the history of science rather than to the architectural relevance. Nonetheless, for us conservationists the architectural quality plays a not so unimportant role when it comes to evaluating if such a building is worth preserving. Therefore, I am glad that the various presentations will be looking at all important aspects of this cultural heritage; after all, for a successful evaluation of the cultural value an approach as comprehensive as possible will be crucial. This heritage consists not only of the buildings, but first and foremost of the instruments and certainly also of the archives (the collections of photographic plates and data gained by means of these instruments).

Our conference will be focussing on the scientific change from classical astronomy to astrophysics in the second half of the 19$^{\text{th}}$ and in the early 20$^{\text{th}}$ century, and on the observatories built at that time which speeded up this change. It will also be looking at the question of its value as cultural heritage and at the responsibilities for preserving and restoring the buildings as well as their instruments and archives.

If I speak of *our* conference it is because it is a collaboration of several institutions, but primarily of two very assiduous people. To a large extent it was the work of Prof. Gudrun Wolfschmidt, who as coordinator of the main area of research on the history of physics/chemistry/astronomy, general history of science and technology, but also as chairperson of Friends of the Hamburg Observatory (*Förderverein Hamburger Sternwarte e. V.*) has prepared the programme of this conference and made contacts with the relevant colleagues worldwide. For this we would like to thank her sincerely. The fact that we have such a research and work focus at our university is not just very fortunate for our observatory. The other very committed person is Ilka von Bodungen from the Hamburg authorities for culture,

sports and the media. She helped Prof. Wolfschmidt with the organisation of this conference. Our special thanks also go to her. Both of them have done a splendid job. Thank you also to the supporters and sponsors, which are the Buhck-Stiftung, the Körber-Stifting, the Bergedorfer Zeitung and the Senatskanzlei Hamburg. I am certain that thanks to the efforts of the two organisers and to our sponsors we will have a productive and successful conference.
Thank you for your attention.

Figure 1.2: *Main building, Hamburg Observatory, coat of arms*

1.1 German version: Einführung in das Tagungsthema

Sehr geehrte Frau Senatorin,
sehr geehrte Frau Präsidentin,
liebe Frau Prof. Wolfschmidt,
sehr geehrter Prof. Petzet,
sehr geehrte Referenten und Gäste aus allen Teilen der Welt,

ich begrüße Sie alle ganz herzlich zu unserem internationalen Symposium über das kulturelle Erbe auf dem Feld der Astronomie. Ich freue mich, dass so viele Referenten der Einladung der Universität gefolgt sind, um uns und sich gegenseitig über ihr astronomisches Erbe zu berichten. Ich heiße Sie als Leiter des Denkmalschutzamtes Hamburg in der Behörde für Kultur, Sport und Medien herzlich willkommen in Bergedorf. Dieser Stadtteil Hamburgs ist seit hundert Jahren Sitz unserer Sternwarte, die zuvor am Rande der Hamburger Kernstadt in den Wallanlagen lag. Aber nicht nur diesem Observatorium, das in diesem Jahr sein 175-jähriges Bestehen als Staatsinstitut und damit als ältestes Universitätsinstitut der Hansestadt begeht, gilt Ihr und unser Interesse, sondern auch anderen neuzeitlichen astronomischen Stätten, die in der Entwicklung der modernen Astronomie – besser gesagt: der Astrophysik eine wesentliche Rolle gespielt haben und von denen wir glauben, dass einige von ihnen vielleicht die Bedingungen der Welterbekonvention der UNESCO erfüllen.

Der Standort der Hamburger Sternwarte als Universitätsinstitut ist heute nicht mehr selbstverständlich. Heutige Astronomen brauchen kaum noch derartige Instrumente, wie sie hier in hoher historischer Authentizität zu finden sind. Sie arbeiten mit Satelliten, mit Radio- und Röntgenobservatorien jenseits des sichtbaren Lichtspektrums oder mit Daten, die ihnen moderne Sternwarten in Südamerika oder aus der Erdumlaufbahn liefern. Allerdings halten wir die Hamburger Sternwarte für so bedeutend in der Geschichte der modernen Astronomie, dass sie 1996 unter Denkmalschutz gestellt wurde. Darüber hinaus gelang uns die Anerkennung als Kulturdenkmal von nationaler Bedeutung durch den Beauftragten der Bunderegierung für Kultur und Medien, was für die Finanzierung von Erhaltungs- und Restaurierungsmaßnahmen vorteilhaft ist. Als Kulturerbe muss sie Bestand haben, am besten in der tradierten wissenschaftlichen Verantwortung der Universität, die sie bis auf den heutigen Tag betreibt. Übrigens wissen wir uns da einig mit den Astronomen und Wissenschaftlern, die hier arbeiten. Von einer Anerkennung als Weltkulturerbe verspricht sich die Universität natürlich eine hohe Reputation und damit auch bessere finanzielle Möglichkeiten der Erhaltung, sei es auch durch möglichst zahlreiche Sponsoren.

Die Frage des hohen Denkmalwertes – wenn nicht gar des außergewöhnlichen universellen Wertes – the outstanding universal value – wurde vor nicht all zu langer

Zeit von einem anerkannten Denkmalpfleger, dem früheren Landeskonservator des Landes Hessen und heutigen Präsidenten der Deutschen Stiftung Denkmalschutz, Prof. Gottfried Kiesow aufgeworfen. Es begann eine lebendige Diskussion um potentielle Hamburger Welterbestätten – vor allem hier im selbstbewussten Bergedorf, das sich schon bald als Ort auf der Welterbeliste sah. Eine solche Anerkennung freilich bedarf der wissenschaftlichen Expertise, wie sie von den Operational Guidelines des UNESCO-Welterbezentrums verlangt wird.

Um einen Weg einzuschlagen, der uns diesem Ziel etwas näher bringt, haben wir diese Veranstaltung zusammen mit der Universität Hamburg, mit ICOMOS als die UNESCO beratende NGO und mit tatkräftiger Unterstützung des Bezirksamtes Bergedorf und einiger privater Sponsoren organisieren können. Ich freue mich sehr, dass ich hier heute als einen der Keynote speaker Herrn Prof. Michael Petztet, bis vor kurzem Präsident von ICOMOS International, jetzt weiterhin Präsident von ICOMOS Deutschland, begrüßen darf, der auch für die Podiumsdiskussion heute Abend zur Verfügung steht – herzlich willkommen. Kein Weg zur Welterbeliste führt an diesem internationalen Rat für Denkmalpflege vorbei. Hier sitzen die Experten, die sich weltweit mit dem Erbe der Menschheit beschäftigen und auf deren Rat und Urteil die UNESCO sich gern verlässt. Es gibt allerdings bei ICOMOS noch kein internationales wissenschaftliches Komitee zum Thema "Astronomie und Observatorien", das wäre vielleicht noch zu gründen.

Hamburg ist in Sachen Welterbe recht ambitioniert. Erst vor kurzem wurde die Anmeldung des weltberühmten Chilehauses, das seit 1997 auf der deutschen Tentativliste des Welterbezentrums steht, um das umgebende Kontorhausviertel aus den 1920er Jahren und die zwischen 1883 und 1928 errichtete Speicherstadt erweitert. Die Nominierung ist für 2014 vorgesehen, die gesamte deutsche Tentativliste enthält Positionen aus allen Bundesländern bis 2016. Also werden weitere Stätten erst später Aussicht haben, als Kandidaten der Welterbeliste aufgenommen zu werden. Dies auch vor dem Hintergrund, dass das Welterbekomitee je Signatarstaat nicht mehr als zwei Stätten pro Jahr aufnimmt; dieses Kontengent müssen sich unsere 16 deutschen Bundesländer also teilen und über die Konferenz der Kultusminister der Länder abstimmen.

Über diese Hürde hinaus ist bei allen Anstrengungen, weitere hochbedeutsame Denkmäler in Richtung Welterbeliste zu bewegen, die globale Strategie für eine ausgeglichene, repräsentative und glaubwürdige Welterbeliste zu berücksichtigen. Diese Strategie wird seit 1994 vom Welterbezentrum und vom Welterbekomitee der UNESCO verfolgt, um die Überrepräsentation Europas mit seinen zahlreichen alten Stadtkernen und christlichen Sakralbauten abzubauen – wörtliches Zitat Website Welterbezentrum:

By adopting the Global Strategy, the World Heritage Committee wanted to broaden the definition of World Heritage to better reflect the full spectrum of our world's cultural and natural treasures and to provide a comprehensive framework and operational methodology for implementing the World Heritage Convention.
This new vision goes beyond the narrow definitions of heritage and strives to recognize and protect sites that are outstanding demonstrations of human coexistence with the land as well as human interactions, cultural coexistence, spirituality and creative expression. Crucial to the Global Strategy are efforts to encourage countries to become States Parties to the Convention, to prepare Tentative Lists and to prepare nominations of properties from categories and regions currently not well-represented on the World Heritage List.

1999 hatte die 12. Generalversammlung der UNESCO in einer Resolution die Ausgewogenheit der Welterbeliste nochmals angemahnt:[8]

"Die Vertragsstaaten sollen prüfen, ob ihr Erbe bereits auf der Liste gut vertreten ist, und gegebenenfalls das Tempo weiterer Nominierungen verlangsamen, indem sie

- *ihre Nominierungen freiwillig zeitlich staffeln,*
- *nur Denkmäler zur Aufnahme vorschlagen, die zu Kategorien gehören, die auf der Welterbeliste unterdurchschnittlich vertreten sind,*
- *jede Neuanmeldung für die Welterbeliste mit einer Nominierung aus einem Vertragsstaat verknüpfen, dessen Erbe unterdurchschnittlich auf der Liste vertreten ist, oder*
- *freiwillig auf neue Nominierungen verzichten."*[9]

Zur Erreichung dieses Ziels hat ICOMOS 2004 den Aktionsplan "Filling the Gaps" vorgelegt, also eine Analyse und Strategieempfehlung zur Füllung der regionalen, zeitlichen, geografischen und thematischen Leerstellen in der Welterbeliste, die deren großes Ungleichgewicht nach Ländern und Gattungen bestätigt.[10]

Insoweit bestehen für die vom Welterbezentrum gewünschten seriellen und transnationalen Bewerbungen erhöhte Chancen gegenüber Einzelbewerbungen, zumal dann, wenn die thematischen Leerstellen gleichermaßen berücksichtigt werden.

Für Hamburg heißt das, dass seine Bemühungen, auch den 1611 eröffneten und bis 1869 betriebenen jüdischen Friedhof Altona mit seiner reichen sephardischen und ashkenasischen Grabmalkultur für das Welterbe zu nominieren, nur dann erfolgreich sein können, wenn es gelingt, ihn zusammen mit anderen gleichartigen Friedhöfen wie in Amsterdam-Ouderkerk oder Curaçao in das Rennen um einen Platz auf der Welterbeliste schicken.

Gleiches gilt sicher auch für die hier zur Debatte stehende Sternwarte. Was wäre auf dem Weg in das Welterbe zu beachten? Zunächst ein Blick in die Welterbeliste, die bisher nur wenige Observatorien aufweisen kann, zumeist auch nur als Teil einer größeren Welterbestätte: einige Beispiele (Baudatum/WHL-Eintragung):

- Royal Observatory of Great Britain in Greenwich (1675/1997 als Teil von Maritime Greenwich),

- Tartu Observatory as part of the Struve Geodetic Arc (1810/2005),
- Pulkovo/St. Petersburg (1839/1990 als Teil mit St. Petersburg)
- Peking Ancient Observatory(1442ff./ eine von über 90 Positionen der chinesischen Tentativliste seit 1996).

Von besonderem Interesse sind die Aktivitäten der UNESCO selbst, die sich mit dem Thema Astronomie und Observatorien beschäftigen. Im März 2004 organisierte das World Heritage Center zusammen mit dem UNESCO-Büro Venedig/Regionalbüro für Wissenschaft und Kultur in Europa (ROSTE) und ICOMOS ein Expertenmeeting zur Einführung der Kategorie des astronomischen Erbes und zur Methodik seiner Definition und Implementation.[11] Die Sitzung schlug als Kategorien des astronomischen Erbes folgende vor:

(i) Stätten, deren Anlage und/oder landschaftliche Einbindung Bedeutung haben in Bezug auf Himmelsobjekte oder -ereignisse;

(ii) Repräsentationen des Himmels und/oder der Himmelskörper und entsprechender Ereignisse;

(iii) Observatorien und Instrumente;

(iv) Stätten mit starker Verbindung zur Geschichte der Astronomie.

Seitdem besteht beim UNESCO-Weltrerbezentrum die Initiative "Astronomy and World Heritage".[12] Das Ziel dieser thematischen Initiative ist die Verbindung zwischen Wissenschaft und Kultur auf der Grundlage von Forschungen, die auf die Anerkennung der kulturellen und wissenschaftlichen Werte der astronomischen oder astronomiebezogenen Stätten gerichtet sind. Die drei Schwerpunkte dieses Programms sind die Identifizierung, die Sicherung und die Förderung dieser Stätten. Das Programm soll einen methodischen Rahmen für die damit verbundenen Maßnahmen bieten, den Weg für die Zusammenarbeit zwischen den Vertragsstaaten und akademischen Gemeinschaften ebnen und den Austausch des Wissens ermöglichen. Ich denke, dass unsere Tagung hervorragend in den Rahmen dieser Initiative passt. Frau Anna Sidorenko-Dulom, die beim UNESCO-Welterbezentrum in Paris diese Initiative betreut, hätten wir gern hier begrüßt, sie konnte leider nicht zu unserer Zusammenkunft kommen, aber wir können ihren Beitrag hier referieren.

Ein Beispiel, wie sich Signatarstaaten der Welterbekonvention sich auf diese Initiative beziehen, ist die Ukraine. Seit Beginn dieses Jahres hat sie neben dem Mykolayiv Astronomical Observatory gleich drei weitere Observatorien auf ihrer beim Welterbezentrum geführten Tentativliste, die im Rahmen einer seriellen transnationalen Bewerbung zusammen mit Observatorien aus Deutschland, England, Frankreich, Russland, Ukraine, Süd Afrika, USA, u. a. nominiert werden sollen.[13] In ihrer Beschreibung der Tentativliste bezieht sich die Ukraine auf solche Sternwarten, die an der Schaffung des grundsätzlichen Referenz-Koordinatensystems beteiligt waren. Im übrigen sind auf den Tentativlisten der Staaten Observatorien kaum zu finden – vielleicht ändert sich das ja nach dieser Tagung.

Eine der bedeutenden Aktionen, die die Generalversammlung der UN in diesem Zusammenhang initiierte, ist das Internationale Astronomische Jahr 2009. Wir sehen unser Symposium gewissermaßen als eine der bedeutenden Auftaktveranstaltungen zu diesem Jahr. Die Websites der Sternwarte und der Universität Hamburg kündigen bereits eine große Zahl einschlägiger Veranstaltungen für 2009 an. Gern weise ich in diesem Zusammenhang hin auf die ab dem 30. Oktober in Hamburg an zwei Orten gezeigte Ausstellung: "Navigare necesse est" über die Geschichte der Navigation.

Diese Anmerkungen zur Rolle von ICOMOS, zur Strategie der UNESCO und der Initiative "Astronomie und Welterbe" sollen gewissermaßen als Folie dienen, die uns die Einordnung unserer Tagung und möglicher daraus folgender Aktivitäten erlaubt. Ich habe durchaus den Eindruck, wir liegen richtig mit diesem Symposium und es ist zu erwarten, dass es nicht die letzte Zusammenkunft in dieser Sache werden wird.

Mehr als vielleicht alle anderen Gattungen des baulichen Kulturerbes führen uns die Observatorien über die Grenzen der Bau- und Kunstgeschichte hinaus in die Geschichte der Wissenschaft und Technik und zugleich über die Ländergrenzen hinweg. Das war schon in vergangenen Jahrhunderten so, die Astronomie ist eine internationale und globale Wissenschaft. Die Bezüge der Hamburger Sternwarte in alle Welt sind reichhaltig: die Söhne ihres Gründers, Johann Georg Repsold, expandierten die vom Vater aufgebaute astronomischen Instrumentenwerkstatt und lieferten Fernrohre – Refraktoren, Äquatoriale, Meridiankreise – so 1830 nach Edinburgh, 1836 nach Pulkowa bei St. Petersburg. Bis zum Ersten Weltkrieg lieferte die seit 1871 so genannte Fa. Repsold & Söhne rund 70 Instrumente nach Europa und Übersee. Auch das bereits erwähnte Mykolayiv Astronomical Observatory besitzt ein Instrument von Repsold. Der revolutionäre Schmidt-Spiegel, in Hamburg 1930 von Bernhard Schmidt konstruiert, fand Nachahmungen und Weiterentwicklungen in den bedeutendsten Observatorien der Welt. Es gibt historische Bezüge nach Caracas, nach Washington; in der Gegenwart sind die Europäische Südsternwarte ESO, Calar Alto und Hubble Space Telescope mit Hamburg auf das Engste verbunden. Es war Otto Heckmann, 1941 bis 1962 Direktor der Hamburger Sternwarte, der 1962 zum ersten Direktor der ESO ernannt wurde.

Die Hamburger Bauart – eine Parkanlage mit Bauten für die einzelnen Instrumente, hatte schon in Nizza ihr Vorbild. Die Baukunst der Observatorien jener Zeit bediente sich der jeweils der regionalen oder örtlichen Traditionen oder Moden – so war bei den älteren Sternwarten des 19. Jahrhunderts der Klassizismus vorherrschend, in Hamburg bevorzugte Albert Erbe, der städtische Architekt der Sternwarte, mehr die Anleihen beim gemäßigten Neobarock, so wie er es auch bei seinen zahlreichen Schulen und anderen öffentlichen Gebäuden als eine Variante des Hamburger Heimatstils umsetzte. Die pantheische oder kosmische Symbolik des Kuppelbaus lieferte die Bauaufgabe Observatorium selbst und war gewissermaßen Zeichen und Zweck zugleich. Das hat sich inzwischen – betrachtet man die modernen Bauten auf dem Paranal in Chile – sehr geändert. Eine umfassende Studie oder Forschung zur Baukunst der neuzeitlichen Observatorien ist über Peter Müllers bekanntes Werk über Architektur und Geschichte der Sternwarten, erschienen 1992, hinaus nicht bekannt und wäre eine lohnenswerte interessante Aufgabe für die Bauhistoriker an unserer Universität.

Nun ist die Stilistik der baulichen Hüllen der neuzeitlichen Fernrohre gegenüber den jeweiligen wissenschafts- und technikgeschichtlichen Aspekten auch eher von nachgeordnetem Interesse. Auch unsere Referenten werden sich in der Mehrzahl auf die jeweilige Rolle ihrer Objekte in dieser Wissenschaftsgeschichte beziehen als auf ihre baugeschichtliche Stellung, obgleich dieser Bedeutungshorizont gerade für uns als Denkmalpfleger und Erbeverwalter für die Beurteilung der Erhaltungswürdigkeit nicht unbedeutend ist. Ich bin allerdings sehr froh, dass die Reihe der Vorträge auf alle wichtigen Aspekte dieses Kulturerbes eingeht, denn für eine erfolgreiche Evaluierung des kulturellen Wertes wird eine möglichst umfassende Herangehensweise ausschlaggebend sein. Zum Erbe gehören ja nicht nur die Bauten, sondern vor allem die Instrumente und selbstverständlich auch die Archive, konkret der Bestand an Sammlungen von Himmelsfotografien und Daten, die mit Hilfe dieser Instrumente gewonnen wurden.

Unsere Tagung legt ihren Focus auf den wissenschaftlichen Umbruch von der klassischen Astronomie zur Astrophysik in der zweiten Hälfte des 19. und zu Beginn des 20. Jahrhunderts, auf die zu dieser Zeit entstandenen und diesen Umbruch beschleunigenden Observatorien, auf die Frage ihres Wertes als Kulturerbe und die Aufgaben der Erhaltung, Konservierung und Restaurierung der Bauten und Instrumente und Archive.

Wenn ich von unserer Tagung spreche, so deshalb, weil sie ein Gemeinschaftswerk von mehreren Institutionen ist, aber vor allem zweier überaus fleißiger Personen. Es war wesentlich die Arbeit von Frau Prof. Dr. Gudrun Wolfschmidt, die als Koordinatorin des Forschungsschwerpunkts Geschichte der Naturwissenschaften, Mathematik und Technik, aber auch als Vorsitzende des *Fördervereins Hamburger Sternwarte e. V.* diese Tagung inhaltlich vorbereitet und die Kontakte in alle Welt geknüpft hat. Ihr gebührt dafür unser großer Dank. Dass wir an der Universität einen solchen Forschungs- und Arbeitsschwerpunkt besitzen, ist nicht nur für die Sternwarte ein großes Glück. Die andere fleißige Person ist Ilka von Bodungen aus unserer Behörde für Kultur, Sport und Medien, die Frau Wolfschmidt bei der Organisation der Tagung hilfreich zur Seite stand. Auch danke dafür. Sie beide haben das wunderbar organisiert. Dank auch den Unterstützern, und Förderern als da sind die Buhck-Stiftung, die Körber-Stiftung, die Bergedorfer Zeitung und die Senatskanzlei Hamburg. Ich bin sicher, dass wir durch die verdienstvolle Mühe der beiden Organisatorinnen und die Förderer eine ertragreiche Tagung vor uns haben, für deren Verlauf ich Ihnen nun alles Gute wünsche.

Vielen Dank.

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1. This article was translated by Dr. John Ziesemer, ICOMOS Germany.
2. Resolution adopted by the 12th General Assembly of States Parties on Ways and Means to Ensure a Representative World Heritage List. http://whc.unesco.org/archive/12GA99-res.htm.
3. Welterbe-Manual. Handbuch zur Umsetzung der Welterbekonvention in Deutschland. Hrsg. von der Deutschen UNESCO-Kommission, Bonn 2006, darin: Kurt Schlünkes, Die Globale Strategie für eine ausgewogene Welterbeliste.
4. The World Heritage List. Filling the Gaps – an Action Plan for the Future. An ICOMOS study compiled by Jukka Jokilehto, with contributions from Henry Cleere, Susan Denyer and Michael Petzet, München 2005. http://www.international.icomos.org/world_heritage/gaps.pdf.
5. Stanislaw Iwaniszewski: Astronomy in Cultural Landscapes: New Challenges for World Heritage Issues. Paper Presented at the Forum UNESCO University and Heritage, 10th International Seminar "Cultural Landscapes in the 21st Century", Newcastle-upon-Tyne, 11–16 April 2005, Revised: July 2006, S. 3, http://www.ncl.ac.uk/unescolandscapes/files/IWANSZEWSKIStanislaw.pdf.
6. http://whc.unesco.org/en/activities/19.
7. http://whc.unesco.org/en/tentativelists/5267/.
8. Resolution adopted by the 12th General Assembly of States Parties on Ways and Means to Ensure a Representative World Heritage List. http://whc.unesco.org/archive/12GA99-res.htm.
9. Welterbe-Manual. Handbuch zur Umsetzung der Welterbekonvention in Deutschland. Hrsg. von der Deutschen UNESCO-Kommission, Bonn 2006, darin: Kurt Schlünkes, Die Globale Strategie für eine ausgewogene Welterbeliste.
10. The World Heritage List. Filling the Gaps – an Action Plan for the Future. An ICOMOS study compiled by Jukka Jokilehto, with contributions from Henry Cleere, Susan Denyer and Michael Petzet, München 2005. http://www.international.icomos.org/world_heritage/gaps.pdf.
11. Stanislaw Iwaniszewski: Astronomy in Cultural Landscapes: New Challenges for World Heritage Issues. Paper Presented at the Forum UNESCO University and Heritage, 10th International Seminar "Cultural Landscapes in the 21st Century", Newcastle-upon-Tyne, 11–16 April 2005, Revised: July 2006, S. 3, http://www.ncl.ac.uk/unescolandscapes/files/IWANSZEWSKIStanislaw.pdf.
12. http://whc.unesco.org/en/activities/19.
13. http://whc.unesco.org/en/tentativelists/5267/.

Figure 2.1: *Visit of Louis XIV and Colbert to the Académie des Sciences in the Jardin du Roi, title page for Claude Perrault, Mémoires pour servir à l'histoire naturelle des animaux, 1671, engraving by Goyton after Sébastien Le Clerc.*

2. Opening lecture: The Observatory of the Sun King and Classical Astronomy

Michael Petzet (Munich, Germany)

At the start of an international symposium on observatories around 1900, at the turning-point "from classical astronomy to modern astrophysics", it might make sense to look back briefly at the creation of the Paris Observatory, one of the most important classical observatories – a unique testimony to an era dominated by the Sun King Louis XIV. During this era revolutionary innovations also took place in the field of astronomy. The Paris Observatory, a chief work of Claude Perrault,[1] the architect of the Louvre colonnade, appears in the background of an illustration of the Optics in Charles Perrault's Cabinet des Beaux-Arts (fig. 2.2, p. 26).[2]

The foundation of the observatory was the immediate consequence of the foundation of the Académie des Sciences by Colbert in 1666: *"La première chose que M. Colbert fit entendre à ceux qui furent choisis et dans la France et dans les pays estrangers pour composer cette académie, fut ... que pour un observatoire, dont l'astronomie ne pouvoit se passer, ils n'avoient qu'à choisir un lieu qu'ils jugeassent propre pour y bien observer, et qu'aussytost il y seroit construit un édifice qui non-seulement surpasseroit en grandeur; en beauté et en commodité les observatoires d'Angleterre, de Danemark et de la Chine, mais, ce qui estoit tout dire, qui répondroit en quelque sorte à la magnificence du prince qui le faisoit bastir."*[3]

At first there were plans to erect the observatory on Montmartre. However, due to smoke formation above the city there was only limited visibility at this site. Therefore, instead a site was chosen at the exit of Faubourg Saint-Jacques. In a solemn ceremony on 21 June 1667, the day of the solstice, the astronomers and mathematicians of the Academy drew the meridian on a stone and thus defined the exact position of the building: *"Comme ce bâtiment devait être tout savant, et qu'il était principalement destiné aux observations astronomiques, on voulut qu'il fût posé sur une ligne Méridienne et que tous ses angles répondissent à certains Asimuths. Les mathématiciens tirèrent une Méridienne et huit Asimuths avec tout le soin que leur pouvaient inspirer des conjectures si particulières ... Toutes ces observations furent la consécration du lieu."*[4] Together with the most renowned scientists of the time, among them the astronomers and mathematicians Jean Picard, Adrien Auzout and Gilles Personne de Roberval, the physicists Christiaan Huygens and Edme Mariotte, Claude Perrault, the physician and versatile scientist concerned also with architectural designs, was also accepted at the Academy. As early as on 15 January 1667 he had presented to the Academy newly drafted work programmes on anatomy and botany.[5]

The title page of his *Mémoires pour servir à l'histoire naturelle des animaux* of 1671 (fig. 2.1, p. 24)[6] shows a visit of Louis XIV and Colbert to the scholars of the Académie des Sciences in the Jardin du Roi. In addition, the view from the window shows the observatory under construction, "moved" by the illustrator close to this garden. As a member of the Academy familiar with all kinds of scientific experiments, Perrault was considered by Colbert to be ideal for the planning of a building for scientific purposes, also in view of the fact that in 1667 he was commissioned to translate Vitruvius and became member of the Petit Conseil that since April had to deal with the designs for the Louvre façade. The perspective view of the first project of 1667 (fig. 2.3, p. 27),[7] a design by his own hand, is closely related to a perspective view of the Louvre in the Bibliothèque Nationale, drawn at the latest at the beginning of the following year.

The design of the first project cannot be understood without the scientific purpose of the building, which Claude Perrault explained on the margin of one of the plans destroyed in the fire of the Tuileries in 1871: *"Le bastiment de l'Observatoire est construit de telle sorte qu'il peut suppléer tout seul à tous les principaux instrumens d'astronomie dont on se sert pour les observations. La situation donne une ligne méridienne dans l'étage haut, depuis la fenestre du milieu qui regarde le midy jusqu'à celle qui regarde le septentrion, de 17 toises de longeur, la plus juste qui se puisse faire. Les deux pavillons octogones sont coupés de manière qu'un de leurs pans donne le lever du soleil au solstice d'hyver; et l'autre son coucher au mesme solstice ; qu'un autre donne le lever du soleil à l'équinoxe et l'autre le coucher au mesme équinoxe; que deux autres pans donnent l'un le lever du soleil d'esté et l'autre le coucher du mesme soleil."*[8]

The centre of the building is defined by a shaft for a spiral staircase leading down to the underground corri-

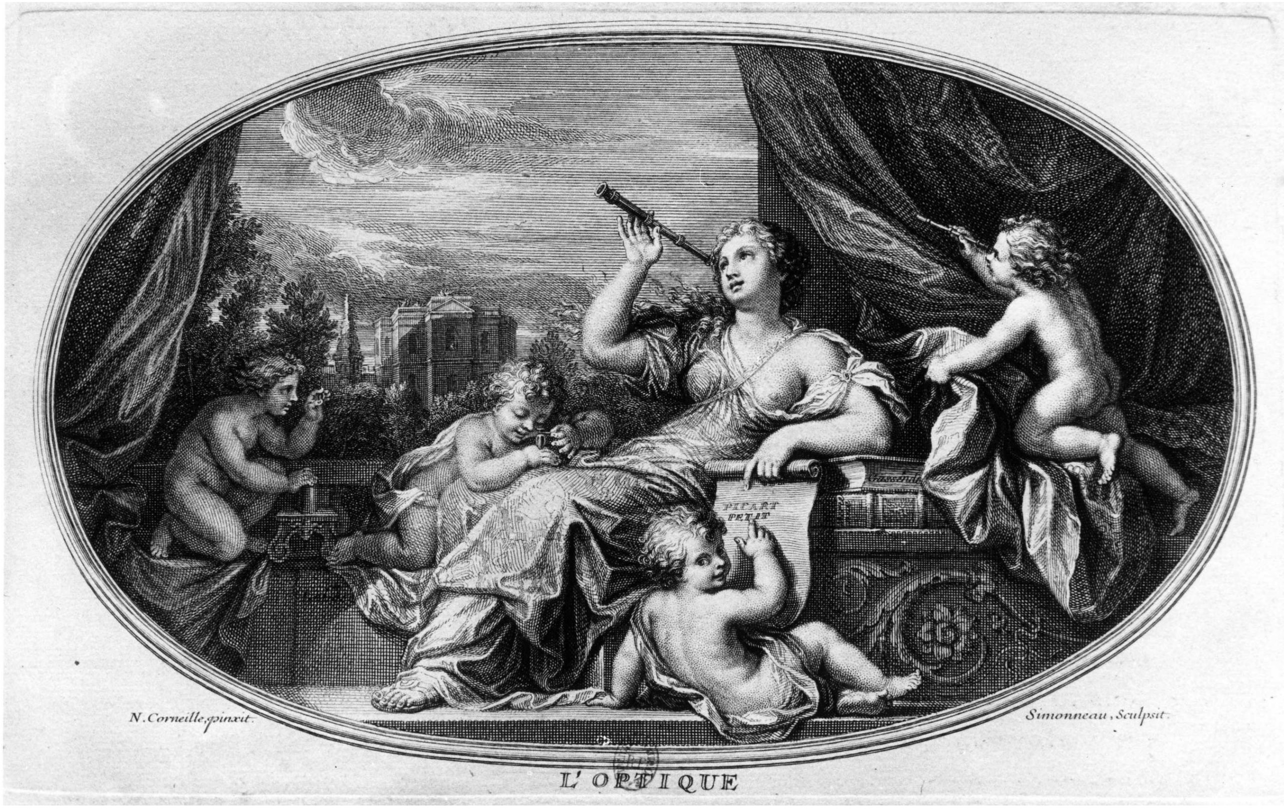


Figure 2.2: *Illustration of the Optics, in Charles Perrault's Cabinet des Beaux-Arts, 1690, in the background the observatory, engraving by Louis Simmoneau after Nicolas Corneille.*

dors. Through circular openings in the vaults this shaft continues up to the roof terrace. Although the old guidebooks were mistaken to believe that this 55-metre shaft enabled one to see the stars in full daylight,[9] Claude Perrault claimed that without the aid of an instrument it could indicate the zenith: *"Le trou ou ouverture qui perce l'Observatoire depuis le fond des carrières jusqu'au dessus de la terrasse donne juste le zénith, sans qu'on ayt besoin pour tout cela de quart de cercle ni d'aucun autre instrument."*[10]

The development of the first design was most likely accompanied by a lively discussion between Perrault and his colleagues at the Academy of Sciences. It is certain that only the famous Uranienburg of Tycho Brahe came into question as a starting point for the planning of the Paris Observatory, since at that time even well-known astronomers had to content themselves with relatively primitive observatories – e. g. Johannes Hevelius in Danzig, who made his observations from a platform erected around 1660 on top of the roofs of three houses – and since the Round Tower in Copenhagen erected in 1642 under Christian IV, a simple seven-storey watch tower of 15 m diameter, can still be considered as exemplary. The observatory on the island of Hven near Copenhagen, which Brahe called Uranienburg after the Muse of Astronomy, had already long disappeared at the time of Perrault. Nonetheless, in his works the astronomer Brahe described the appearance of the building, erected between 1576 (laying of the foundation stone) and 1581, and illustrated them with woodcuts – view of the main building, plan of the ground floor and overall view (fig. 2.4, p. 28).[11] Immediately after Brahe left the island in 1597 the observatory fell into disrepair and was dismantled by the island's inhabitants; only the foundations were excavated in 1901/02.

With laboratories in the cellar, the astronomer's apartment and the library on the ground floor, and guest rooms for King Frederic II and his wife Sophie on the upper storey the Uranienburg had to fulfil similar additional functions as the Paris Observatory. In the modern reconstruction the round room in the axes of coordinates is open right up to the ceiling of the cupola's octagonal tambour that crowns the building. The north tower of Perrault's first project appears like a deliberate quotation of the rectangular porch on the east façade of the Uranienburg with its chamfered corners on the upper storey. Finally, an underground corridor is mentioned which was constructed to connect the Uranienburg with Brahe's "Stjerneborg", an underground observatory installed in 1584 in a hill further south. The Stjerneborg's loosely arranged and circular-shaped observatories of different diameters seem to anticipate the modern observatories of our time.[12]

In connection with this reference to Tycho Brahe's Uranienburg Paris also intended to continue the observations of the *restaurateur de l'astronomie*[13] and for that purpose sent Jean Picard to Copenhagen in 1671. Picard was commissioned to make measurements on the grounds of the destroyed Uranienburg to determine the relation between the meridian there and in Paris.

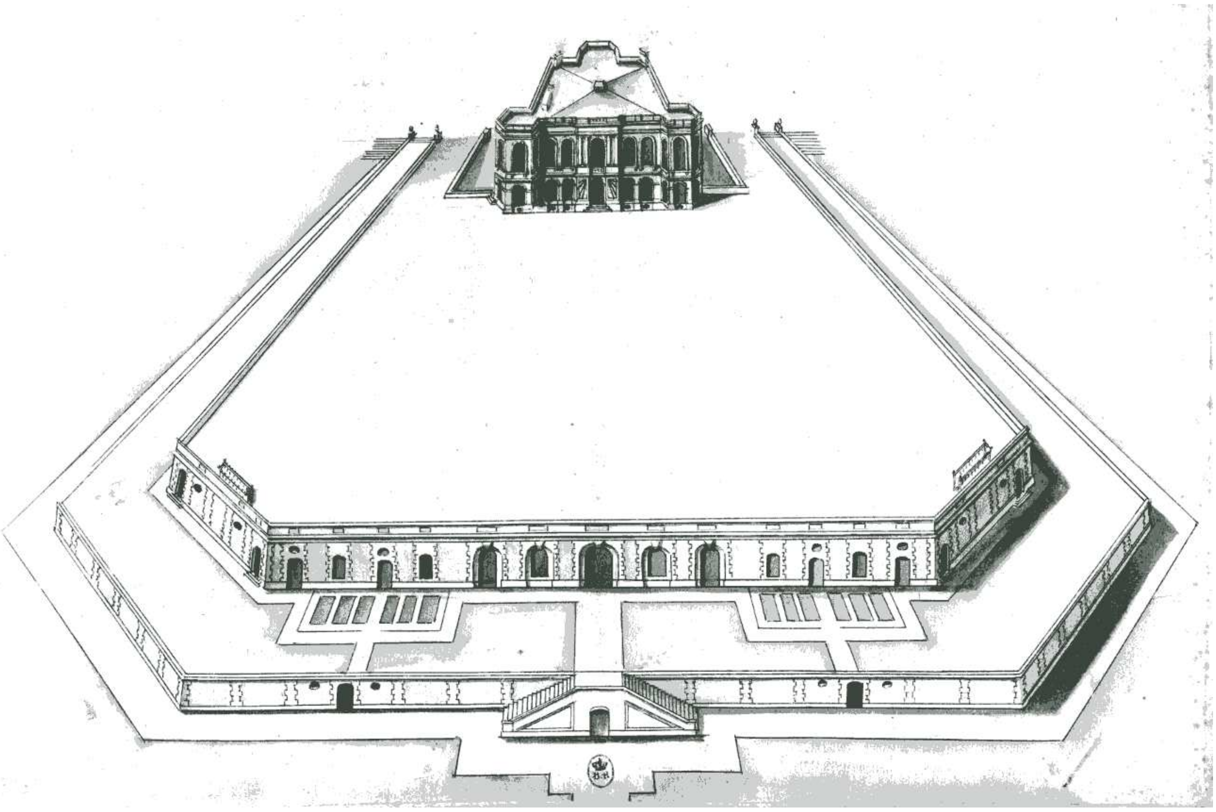


Figure 2.3: *Claude Perrault, first project for the Paris Observatory, perspective view of 1667 with the terrace and the south facade.*

This was a prerequisite for an exact comparison between the new observations of French astronomers and Brahe's old observations. Picard was able to buy Brahe's original manuscript for Paris.[14] However, if on the title page by the engraver Duflos[15] the Paris Observatory is shown between the Uranienburg and the Round Tower in Copenhagen (fig. 2.5, p. 29), this is not so much a reference to the important old tradition of the building's appearance. Instead, this is done to emphasise Louis XIV's observatory as the source of a new tradition.

According to Colbert's above-quoted demand this observatory was to exceed all others *en grandeur, en beauté et en commodité.* In fact, the exterior of the Uranienburg with its domes and conical broach roofs of the various observation stations, decorated by Tycho Brahe's Dutch architects (the court architects of Danish King Frederic II, at first probably Hans von Paschen, later Hans van Stenwinkel) did not have anything of the *noble simplicité*, which Perrault used by avoiding the order of columns and structuring the flat, closed block with rows of round-arched windows, thus giving the building a "Roman" appearance. In a way, he wanted to create a classical observatory without a direct classical model – *en attendant que les somptueux Edifices que S. M. fait construire en France soient en état de servir eux-mesmes de modele à la posterité...*[16] Therefore, Perrault also published Sébastien Le Clerc's engravings of the plans and views of the observatory in his Vitruvius (fig. 2.6 and fig. 2.7, p. 30 and 31).[17]

Already Florent le Comte remarked on the observatory's austere and fortification-like architecture, which in fact was intended by Louis XIV to serve as a model for new architecture: *L'Observatoire basti ... d'une forme qui plait sans le secours des ornements est une modelle d'Architecture militaire*,[18] – the model of an architecture whose austere forms were related to Vauban's fortifications built at the same time, the only difference being that Vauban's star-shaped ground plans took into account the course of the aggressors' bullets and not the course of the stars. The verso of the medal coined on the occasion of the laying of the foundation stone (fig. 2.8 below, p. 32) shows – quite in accordance with this approach – the observatory at the top of two terraces that appear like a steep rock plateau, the south façade being crowned by a gigantic, cannon-like telescope, in addition the motto *SIC ITUR AD ASTRA*. According to the explanation of a contemporary engraving by A. Perelle, who showed the completed observatory with great numbers of scientists at work (fig. 2.9, p. 33),[19] the building with its towers dominating the terrace in the south is evocative of a citadel, – a citadel of the sciences, where for the glory of the Sun King instead of canons the sky is to be conquered with telescopes. In fact, the satellites of Saturn discovered later by Cassini were named "satellites ludovicae" in honour of Louis XIV. Thanks to the sciences the Sun King could conquer the world by conquering the sky, as astronomy found its most important application in geography and navigation.

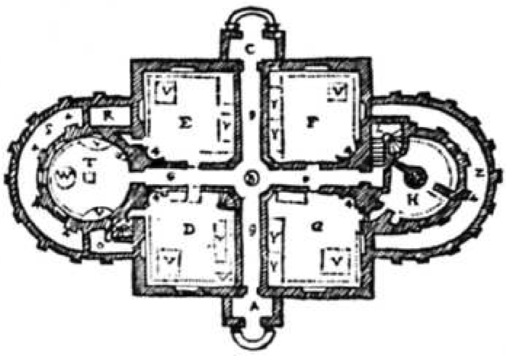
142 ASTRONOMIÆ INSTAURATÆ MECHANICA

ORTHOGRAPHIA PRÆCIPVÆ DOMVS

H 2v

ARCIS VRANIBVRGI IN INSVLA PORTHMI DANICI VENVSIA VULGO HVENNA, ASTRONOMIÆ INSTAVRANDÆ GRATIA CIRCA ANNVM 1580 A TYCHONE BRAHE EXÆDIFICATÆ.

ICHNOGRAPHIA ET EIVS EXPLICATIO.



A Ianua Orientalis. C. Occidentalis. Θ. Tranſitus 4. ad angulos rectos concurrentes, qui tamen poſtea in tres redacti ſunt, ut Cœnaculum hybernum ſive hypocauſtum D ampliaretur, atque in ejus angulo poſt fornacem, parvum quoddam & ſecretum laboratorium ſpagyricum eßet, in quo tamen quinque diſtinctim erant furni, qui promptius ad manus iſthic operi Pyronomico inſerviebant, ne ſemper in majus illud deſcendendum foret. B. Fons aquarium volubilem rotans, qui aquas hinc inde cum lubuit, in ſublime eiaculabatur. D. Cœnaculum illud hybernum. E. F. G. Cameræ pro hoſpitibus. L. Gradus pro aſcenſu in ſuperiorem contignationem. H. Coquina. K. Puteus cementitius 40. ulnas profundus, artificio hydraulico ſerviens & aquas per ſiphones hinc inde occulte per murum tranſeuntes in ſingulas Cameras tam ſuperiores quam inferiores diſtribuens. P. Gradus pro deſcenſu in laboratorium Chymicum. T. Bibliotheca. W. Globus magnus Orichalcicus num. 22. exhibitus. V. Quatuor Menſæ pro Studioſis. 4. Camini tam e laboratorio inferiori aſcendentes, quam in quatuor angulis conclavium. Y. Lecti in iiſdem conclavibus, hinc inde diſpoſiti. Cætera acutus inſpector propriâ intentione facile diſcernet. Intelligenda autem ſunt hæc omnia in eâ quantitate, veluti fundamento majoris domus ſupra depictæ quadrare poterunt: Licet hic coarctationis loci gratiâ in duplo quaſi minori formâ exhibeantur.

EXPLICATIO

Figure 2.4: *East view and ground plan of the Uranienburg In: Tycho Brahe: Astronomiae Instauratae Mechanica, 1598.*

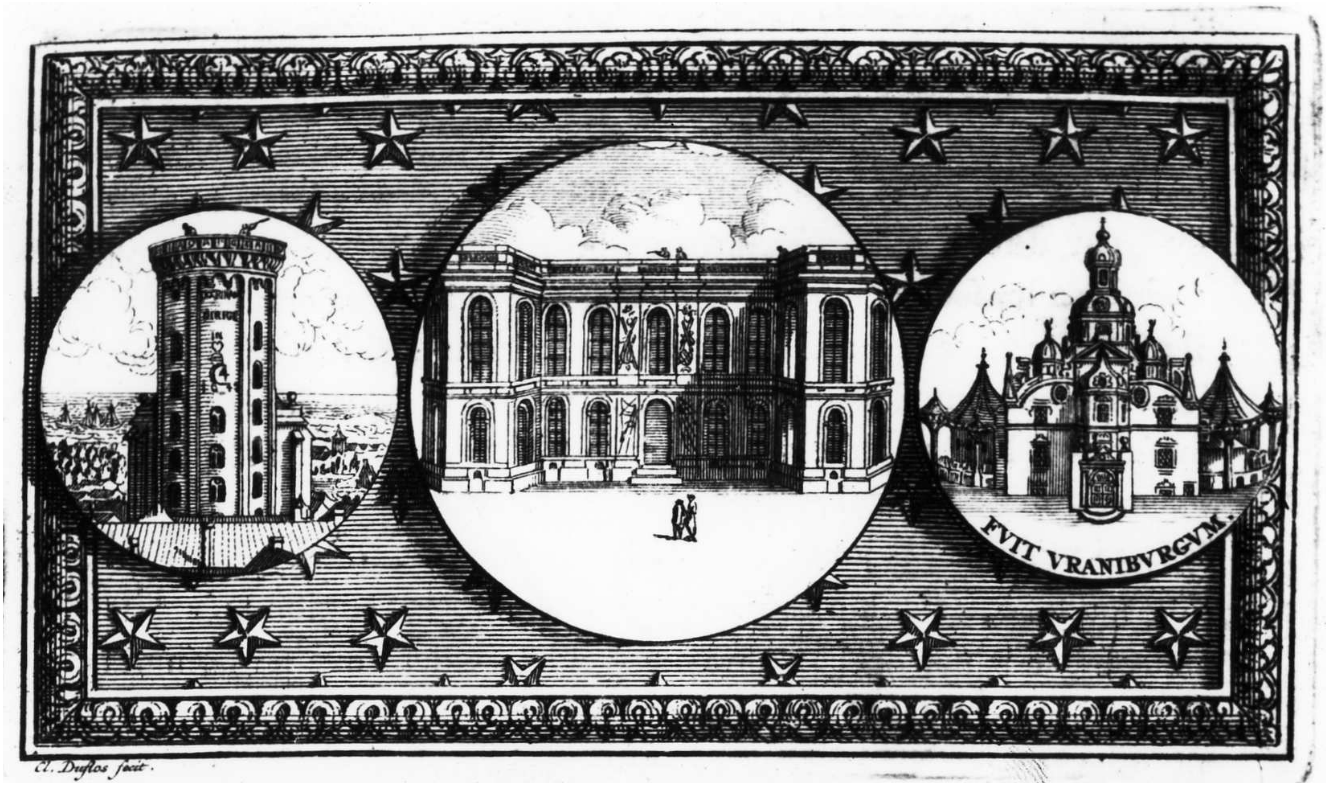


Figure 2.5: *Title page for Giovanni Domenico Cassini: De l'origine et du progrès de l'Astronomie, 1731.*

The walls of the observatory had already been erected up to the height of the first floor when Gian Domenico Cassini (1625–1714) arrived in Paris on 4 April 1669.[20] The astronomer in the service of Pope Clemens IX was the only one among Europe's most renowned astronomers to respond to Colbert's calling (Colbert had also invited Leibniz, Hartsoeker, Tschirnhausen, Hevelius, Viviani and Newton). Cassini, who would have preferred to pull down Perrault's three towers, asked for a spacious hall on the second floor: *"j'aurais voulu que le bâtiment même de l'Observatoire eût été un grand instrument, ce que l'on ne peut pas faire à cause de ces tours qui, d'ailleurs, étant octogones, n'ont que de petits flancs coupés de portes et de fenêtres. C'est pourquoi je proposai d'abord qu'on n'élevât ces tours que jusqu'au second étage, et qu'au-dessus on bâtît une grande salle carrée, avec un corridor découvert tout à l'entour … Mais ceux qui avaient travaillé au dessin de l'Observatoire opinaient de l'exécuter conformément au premier plan qui en avait été proposé* ; et ce fut en vain que je fis mes représentations à cet égard et bien d'autres encore."[21]

It seems Perrault and Cassini, each in his own way, wanted to make this building an outstanding instrument of astronomy. However, contrary to the architect the astronomer wanted the *magnificence* to be completely subordinated to the *commodité*. Besides, Cassini's allegations were almost inevitable, since the foundation of the observatory took place in an era when Picard's and Auzout's new instruments replaced Tycho Brahe's old instruments. These were innovations that Perrault could not yet take into consideration in his first design. Basically, astronomers could not ask for much more than a tall building, from where the whole sky could be seen. The Greenwich observatory erected by Christopher Wren only a few years later, 1675/76, for the first royal astronomer John Flamsteed does have a spacious hall on the upper storey, above the astronomer's apartment, as Cassini had requested; however, in comparison to its Parisian forerunner it is much smaller and simpler.[22] Furthermore, according to its original determination the Paris observatory was not merely intended for the astronomers but for all colleagues at the Academy of Sciences. Therefore, it had to provide space for meetings of the Academy. The underground corridors and the foundations of the terraces were particularly suitable for physical and chemical experiments.

The final layout of the observatory with the hall on the upper storey as an afterthought was developed as a reaction to Cassini's criticism. The observatory's exterior was completed in 1672 with the relief in the pediment and the trophies on the south façade made by the sculptor Francesco Temporiti. Even after Cassini had moved into the observatory in 1671 for several years there were still craftsmen working on the interior. The official date of completion was 1 May 1682 when Louis XIV paid a visit to the observatory. As architect of the observatory Claude Perrault had created a monument that owing to its "simplicité", adequate for the building's use as a scientific instrument, could still be considered a model in the late 18th century: *"Cet édifice dont la masse, l'ensemble et les détails portent ce caractère simple et*

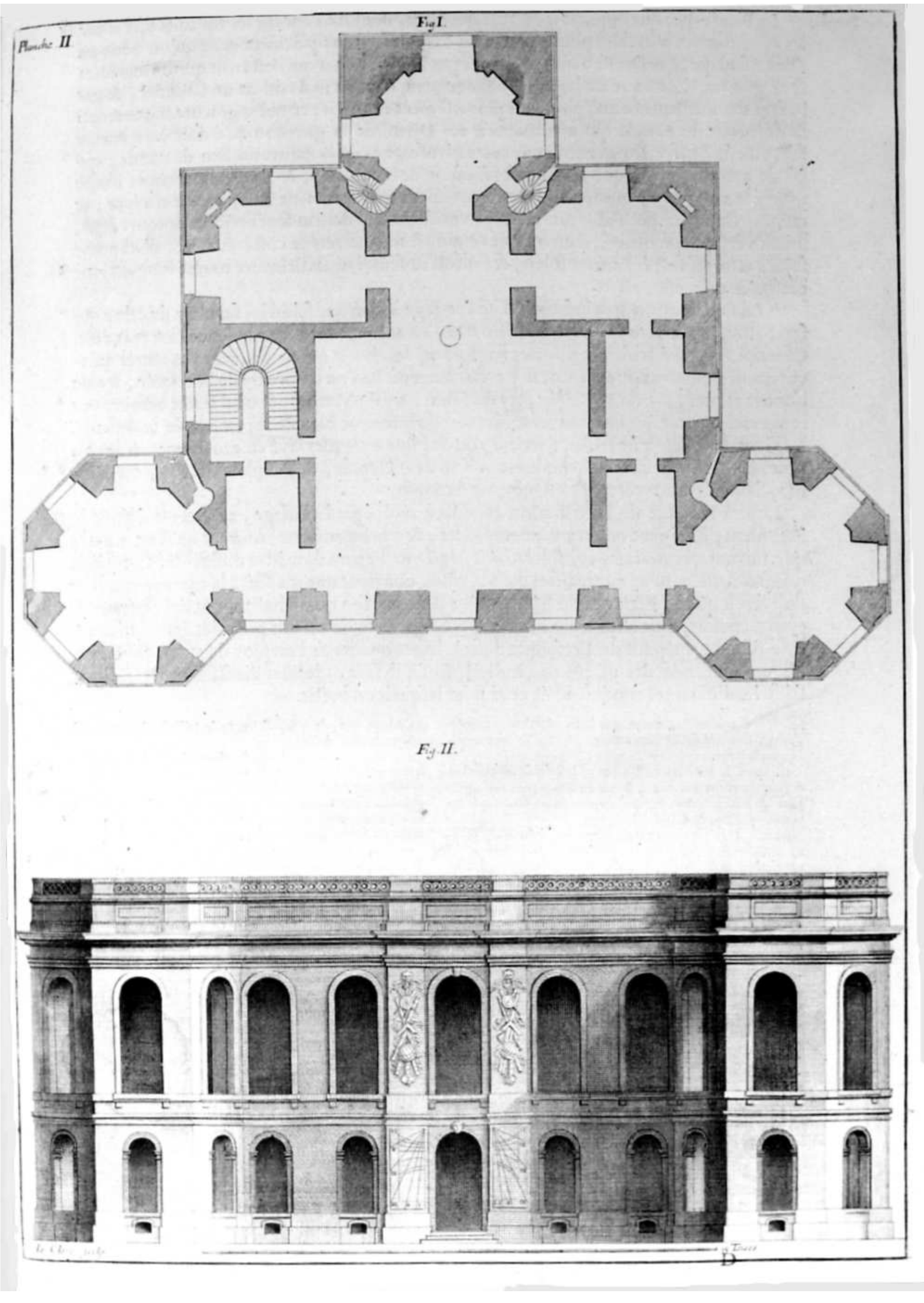


Figure 2.6: *Plate II of Perrault's Vitruvius (1673), ground plan of the second storey and elevation of the observatory's south façade, engraving by Sébastien Le Clerc.*

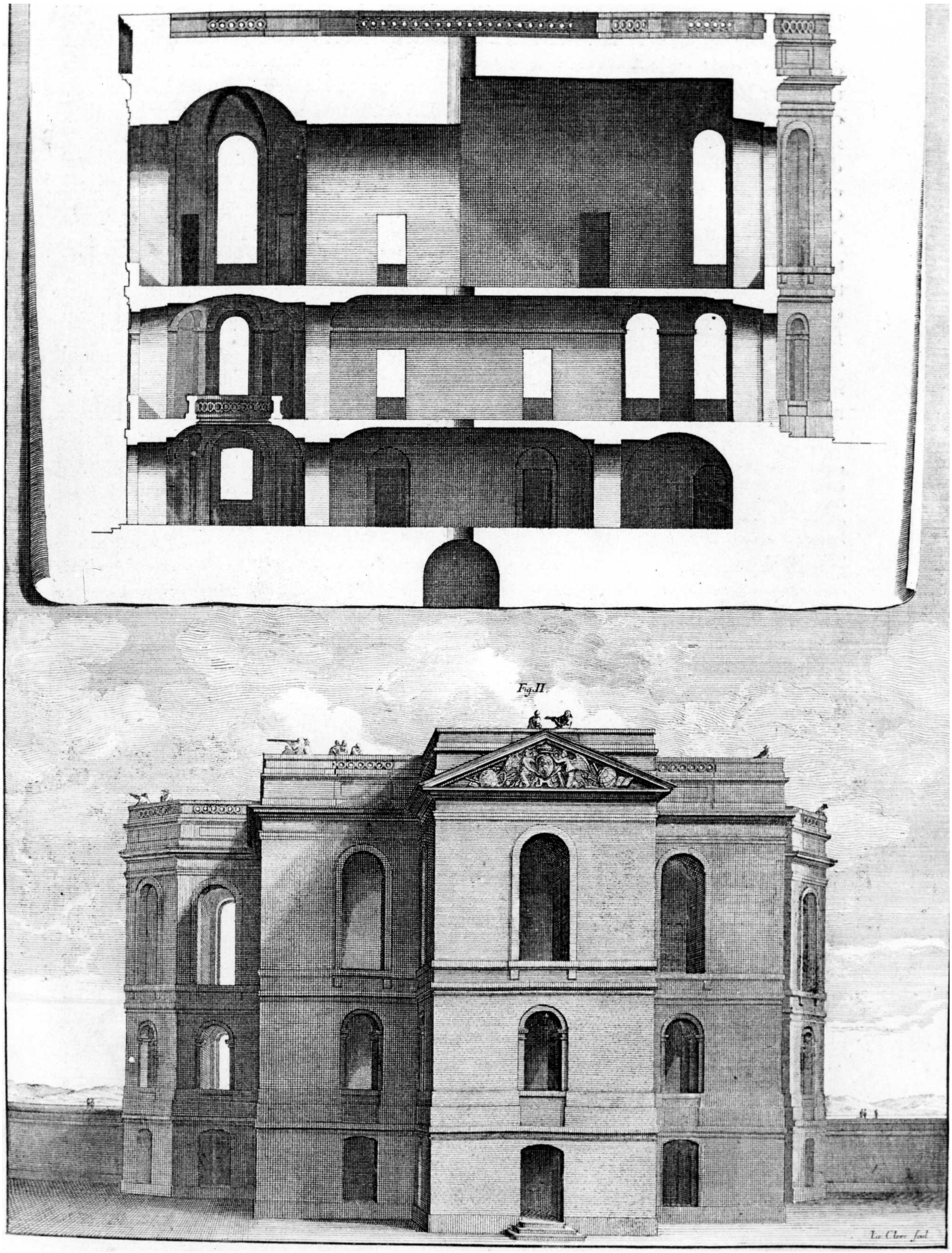


Figure 2.7: *Plate III of Perrault's Vitruvius (1673), longitudinal section and perspective view from the north, engraving by Sébastien Le Clerc.*

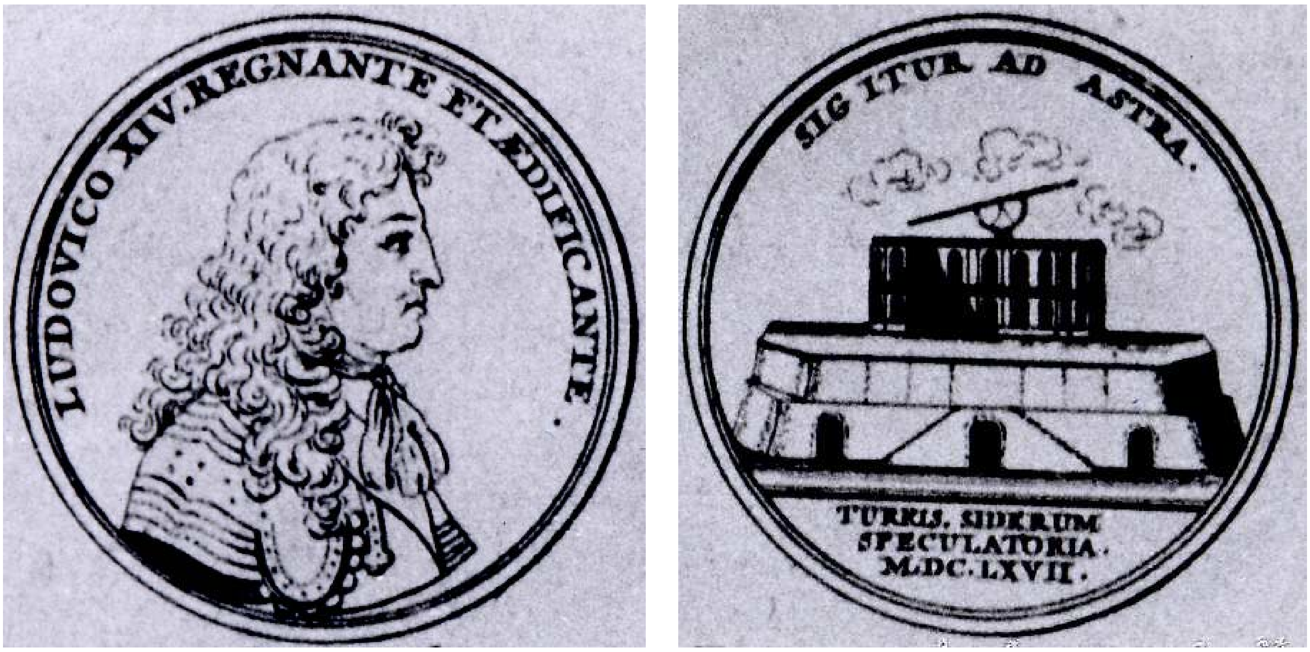


Figure 2.8: *Medal for the laying of the observatory's foundation stone, 1667.*

noble, qui convient à la science et aux usages auxquels il est consacré, est un de ces monuments publics qui caractérisent le mieux le goût et le génie du siècle de Louis XIV."[23]

What this building meant for the Sun King, who was always intent on "grandes choses", is probably summed up best in the *Voyage d'Uranienbourg* by Abbé Jean Picard, Perrault's colleague at the Academy of Sciences: *"On peut dire que l'Astronomie a pour objet ce qu'il y a de plus grand dans l'Univers: aussi a-t-elle eû toûjours l'avantage de trouver accés aupres des plus grands Monarques; & Sa Majesté a bien voulu faire voir le soin particulier qu'Elle prend pour l'avancement de cette noble Science, en faisant bastir un Observatoire, qui parmi les Arcs de triomphe & les trophées demeurera comme une marque éternelle du Regne heureux de Loûïs le Grand."*[24]

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1. Petzet (1967). Petzet 2000, S. 355–397.
2. Perrault, Charles: Le Cabinet des beaux Arts, 1690. – On the history of the Paris Observatory see also Wolf 1902. Débarbat et al. 1984.
3. Perrault, Charles: *Pourquoy et comment l'observatoire a esté basty.* Mémoire of August 1667, after Clément 1861–1873, V, pp. 515–516. – On the foundation of the Académie des Sciences see also Perrault: Mémoires de ma vie, publ. par Bonnefon 1909, p. 42 ff.
4. Histoire de l'Académie des Sciences, vol. I, p. 43.
5. See in detail Picon, Antoine: Claude Perrault, 1613–1680, ou la curiosité d'un classique, 1988, pp. 44–52.
6. Title page for Claude Perrault: Mémoires pour servir à l'histoire naturelle des animaux, Paris 1671–1676, engraving by Goyton, signed *S. Le Clerc in. et f.* and *Goyton ex.*
7. BN, Estampes, Va. 304 I, no. 69 (red no. 1730), perspective view of the first project with the terrace and the south façade of the observatory: pen drawing, 305 × 393 mm, at the top title written by Claude Perrault: *Eleuation perspectiue de l'obseruatoire.*
8. Description on the margin of the lost "plan principal". Clément 1861–1873 (see note 3), vol. V, p. 516.
9. Brice, Germain: Description nouvelle de Paris, 1684, p. 101: *"On dit qu'il a esté fait exprès pour voir les Astres en plein jour, cependant personne ne les a vû jusqu'à présent, quoique l'on y eut souvent regardé."*
10. Description on the margin of the lost "plan principal" (see note 8).
11. The oldest illustration with east elevation of the main building, plan of the ground floor and overall view can be found in a woodcut that Tycho Brahe sent to his benefactor, Landgrave Wilhelm IV of Hessen (illustration in Dreyer: Tychonis Brahe Dani Opera Omnia, vol. VI. Hauniae 1919, pp. 348–349). This was followed by similar woodcuts in Brahe's *Epistolarum Astronomicarum Liber Primus* of 1596 (Dreyer 1919, vol. V, pp. 138, 142). An exact reconstruction with ground plans, elevations and sections, taking into consideration Brahe's information and the excavation results was attempted by Christensen and Becket: Tycho Brahe's Uraniborg and Stjerneborg on the island of Hveen. London, Copenhagen 1921.
12. Ground plan and view of the Stjerneborg in Brahe's *Epistolae astronomicae* (1596) and in *Astronomiae instauratae mechanica* (1598); Dreyer 1919, vol. VI, pp. 293 f; vol. V, p. 146.
13. Cassini: De l'origine et du progrès de l'Astronomie, 1731, p. 29.
14. Picard: Voyage d'Uranienbourg, 1731, p. 61ff.
15. Title page for Cassini: De l'origine et du progrès de l'Astronomie, 1731 (see footnote 13), signed *Cl Duflos fecit.*
16. Perrault, Claude: Les dix Livres d'Architecture de Vitruve, 1684, preface.

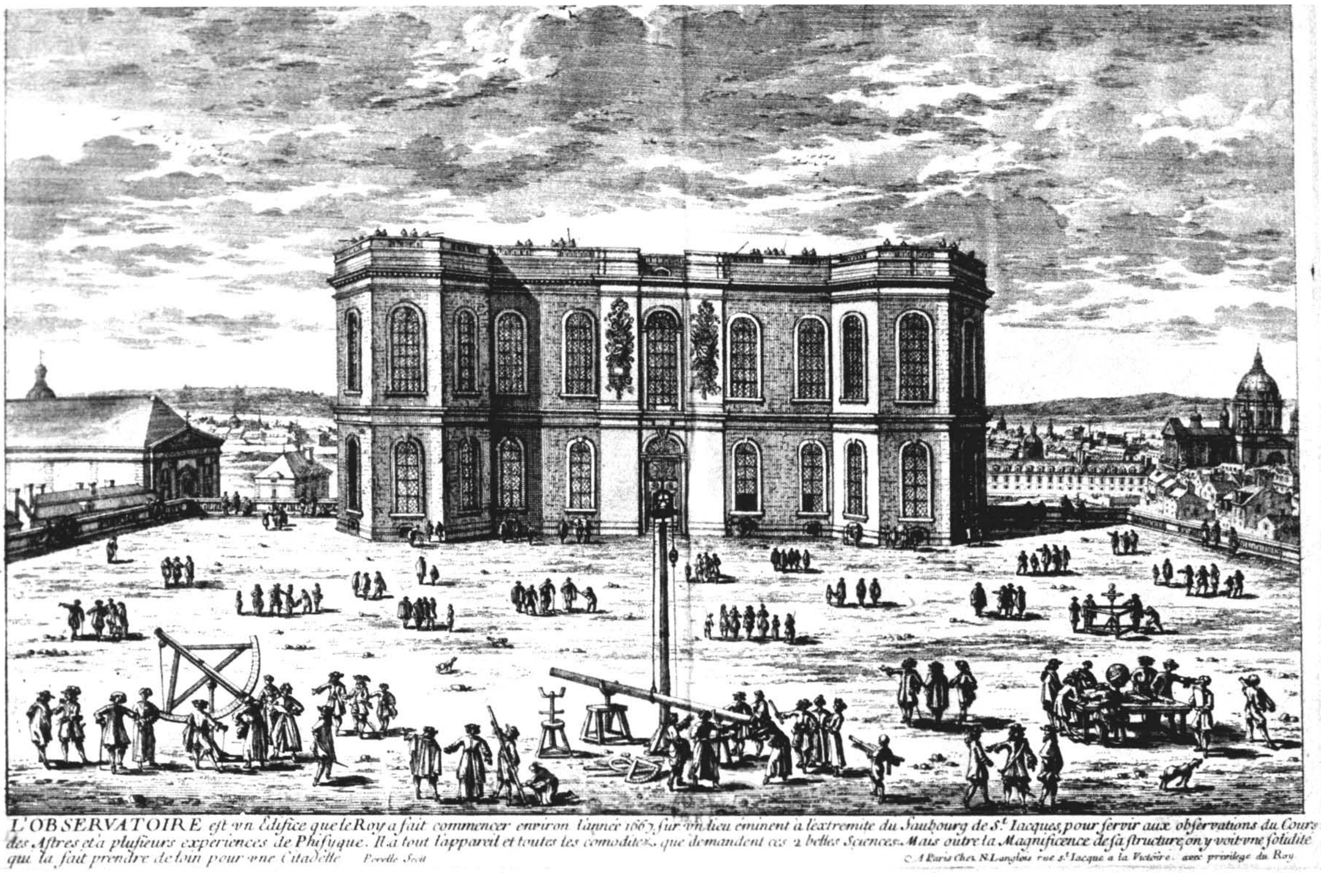

Figure 2.9: *View of the observatory from the south, engraving by Adam Perelle.*

17. Perrault, Claude: Les dix Livres d'Architecture de Vitruve, Paris 1673, plates II and III, signed *Le Clerc sculp.* (pp. 10–13); Perrault, Vitruve, 1684, plates II and III (pp. 13 and 15).
18. Comte, Florent le: Cabinet des Singularités d'Architecture, Peinture etc., 1699.
19. View of the observatory from the south, signed *Perelle fecit.*
20. For Cassini's life and work see Wolf: Observatoire, 1902 (see footnote 2); Brazza 1941, pp. 35–64; Débarbat et al. 1984 (see footnote 2), p. 9 ff.
21. Cassini, Jean-Dominique: Mémoires pour servir à l'histoire des sciences et à celle de l'Observatoire de Paris. Paris 1810, p. 293, quoted after Clément V, p. 516.
22. On the Greenwich observatory see Sekler: Wren and his place in European architecture, 1954, p. 147.
23. Thiéry: Guide des amateurs et des étrangers voyageurs à Paris, vol. II. Paris 1787, p. 265.
24. Picard: Voyage d'Uranienbourg, 1731 (see footnote 14), p. 65.

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Figure 3.1: *Uluġ Begs (1394–1449) sextant of 40 m radius, Samarkand Observatory, Uzbekistan (©UNESCO)*

3. UNESCO Thematic Initiative “Astronomy and World Heritage”

Anna Sidorenko-Dulom (UNESCO World Heritage Centre, Paris, France)

3.1 Introduction

The Convention concerning the protection of cultural and natural World Heritage of 1972 provides a unique opportunity to preserve exceptional properties worldwide and to raise awareness about scientific concepts linked to these properties.

The mission of UNESCO regarding World Heritage consists of assisting the States Parties to this Convention to safeguard sites inscribed on the World Heritage List, to support activities led by States Parties in the preservation of World Heritage, and to encourage international cooperation in heritage conservation.

The World Heritage Committee adopted in 1994 the Global Strategy whose objective is to establish a representative and balanced World Heritage List, to fully reflect the cultural and natural diversity of heritage of outstanding universal value.

Considering that properties related to science are among the most under-represented on the World Heritage List and recognizing the absence of an integrated thematic approach for sites which have a symbolic or direct connection to astronomy, the UNESCO World Heritage Centre, in close consultation with States Parties and Advisory Bodies, has elaborated the Thematic Initiative “Astronomy and World Heritage”.

3.2 Astronomy and World Heritage

Created by an international multidisciplinary expert group[1] within the framework of the Global Strategy, as a pilot activity for the identification of the sites connected with astronomy, as well as recognized by an expert working group on scientific heritage,[2] the Thematic Initiative on Astronomy and World Heritage, aims to establish a link between Science and Culture towards recognition of the specific values of properties connected with astronomical observations dispersed throughout all the geographical regions of the world, not only scientific but also as a testimony of traditional community knowledge.

3.3 Why “Astronomy” and “World Heritage”

The cosmos have captivated the imagination of civilizations throughout the ages. The efforts of those cultures to understand or interpret what they see in the sky are often reflected in their architecture, petroglyphs, and other cultural representations.

Properties relating to astronomy stand as a tribute to the complexity and diversity of ways in which people rationalized the cosmos and framed their actions in accordance with that understanding. This includes, but is by no means restricted to, the development of modern scientific astronomy. This close and perpetual interaction between astronomical knowledge and its role within human culture is a vital element of the outstanding universal value of these properties.

Understanding the role of these properties connected with astronomy, as well as promoting them through public awareness-raising campaigns, are crucial and vital steps in our common efforts to safeguard them for future generations.

3.4 Implementation Strategy

The proposal of the Thematic Initiative on “Astronomy and World Heritage” was finalized during the first meeting of the representatives of the scientific community of twelve States Parties, ICOMOS and NASA (Venice, Italy, March 2004), and presented during the 29th session of the World Heritage Committee (Durban, South-Africa, July 2005).

The World Heritage Committee in July 2005 requested the Director of the World Heritage Centre to explore further this Thematic Initiative as a means to promote, in particular, nominations which recognize and celebrate achievements in science. The World Heritage Centre launched an appeal to States Parties to contribute to the implementation of this Initiative. Numerous National Focal Points in charge of its implementation were designated world-wide and participated to the elaboration of the first proposal of the integrated implementation strategy of the Initiative.

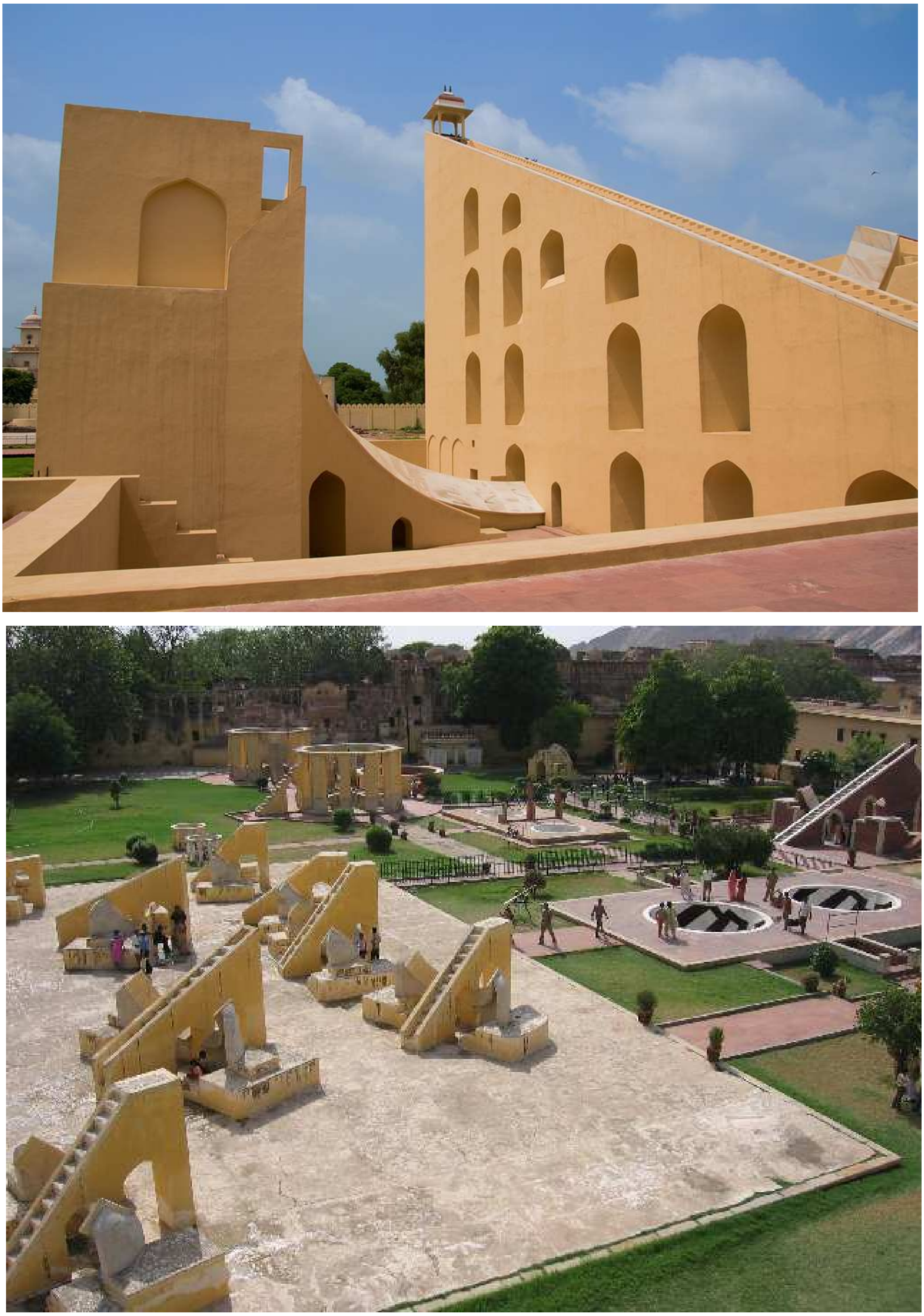

Figure 3.2: *Jaipur Observatory (Jantar Mantar), India, built under Maharaja Sawai Jai Singh (1688–1744)*

At its 32nd session (Quebec City, 2008) the World Heritage Committee examined this integrated implementation strategy, as well as information document on Thematic Studies, including the Heritage of Astronomy.

This implementation strategy of the Initiative could be applied through the following three broad phases:

- Phase I aims at (a) acquiring an in-depth knowledge of the outstanding properties connected with astronomy in all geographic regions through their identification, study and inclusion of the most representative of these properties on the national tentative lists; (b) creating networks of cooperation between scientific communities, governmental bodies and site managers; (c) developing pilot-project on serial transnational nominations.
- Phase II aims at (a) promoting the most outstanding of these properties which recognize and celebrate achievements in science through their inscription on the World Heritage List; (b) promoting international cooperation in order to safeguard and promote these properties; (c) providing a platform for capacity building; (d) raising public-awareness.
- Phase III aims at (a) fine-tuning the results of the research and capacity building activities; (b) ensuring the sustainability of results; (c) monitoring the ongoing development of pilot projects.

The Executive Board of the International Astronomical Union (IAU) unanimously adopted the proposal to establish an official partnership with UNESCO within the framework of this World Heritage Initiative in order to facilitate the identification and nomination process of astronomical properties. The Memorandum of Understanding between UNESCO and IAU within the framework of this Initiative will be signed on 30 October 2008. The International Astronomical Union created in 1919, will provide through its bodies composed by 9.000 experts from 70 countries, the scientific expertise in the field of Astronomy required for the implementation of this Thematic Initiative worldwide.

The establishment of tripartite collaboration between UNESCO, ICOMOS and IAU in order to provide the necessary expertise to the State Parties for the identification and nomination of properties connected with astronomy on the World Heritage List is in process. The Thematic study on the Heritage of Astronomy associated to the UNESCO thematic initiative "Astronomy and World Heritage" would be developed in the context of the recent interest in the review of the relationship between heritage of sciences, traditional community knowledge and the World Heritage Convention.

3.5 The Database

In order to facilitate the collaboration between different national and international experts, the World Heritage Centre created, thanks to financial support of the Royal Astronomical Society of the United Kingdom, the structure of the first visual and documentary Data Base of sites related to astronomy on the Web site of the World Heritage Centre.[3]

This data base could be used as a tool for the inventory, research, management and pooling of information as well as provides a network to share knowledge for all international, national cultural and scientific institutions, as well as NGO's, involved in the development and implementation of the Initiative.

A public web page was also created in order to increase the visibility of the cultural World Heritage sites which have a link to astronomical observations.[4]

3.6 Conclusion

The UNESCO Thematic Initiative "Astronomy and World Heritage" offers States Parties a possibility to evaluate and recognize the importance of this specific heritage, in terms of enrichment of the history of humanity, the promotion of cultural diversity and the development of international exchanges.

Amongst the cultural activities of UNESCO, the Thematic Initiative on Astronomy and World Heritage is to date the only cultural activity created in accordance with the Resolution of the 33rd session of the UNESCO General Conference, in support of the 2009 – *International Year of Astronomy* which provides an opportunity to raise public awareness, especially with young people about scientific heritage and to enhance the links between science, education, culture and communication.

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1. 2003 – First presentation of the pilot project "Archaeoastronomical sites and observatories" (UNESCO World Heritage Centre); 2004 – First International Expert Meeting on elaboration of the Implementation Strategy of the Thematic Initiative "Astronomy and World Heritage" (UNESCO Venice Office).
2. 2008 – Expert Workshop "World Heritage: Science and Technology" (London, UK).
3. `http://whc.unesco.org/pg.cfm?cid=281\&id\_group=21`.
4. `http://whc.unesco.org/pg.cfm?cid=281\&id\_group=21\&s=home`; `http://whc.unesco.org/en/activities/19/`.

Figure 4.1: *The famed rust-less iron pillar installed in Delhi in about 1233 CE was originally erected as a gnomon in Udaigiri, central India, located on tropic of Cancer. The gnomon, built about 400 CE was designed to cast shadow in the direction of the passage to temples, on summer solstice day. (Photo courtesy R. Balasubramaniam)*

4. Astronomical Heritage: Towards a Global Perspective and Action

Rajesh Kochhar, International Astronomical Union (IAU)

This international symposium is taking place in the 400th year of the chance invention of telescope. The accidental discovery in 1608 of a combination of lenses by the Dutch optician Hans Lippershey may belong to the realm of romance of history. But the next year when Galileo made the world's first designer telescope and turned it skywards, he initiated a revolution the impact of which has gone beyond astronomy and science.

Homo Sapiens is an astronomical species. Ever since humans learnt to walk upright they have looked at the sky and wondered. The sky has remained the same but its meaning as well as significance has continually changed. To begin with, the sky was a divinity to be feared and appeased. It then became a phenomenon to be observed and utilized. And finally now it has been reduced to be an object of study and a laboratory for testing our scientific theories. In the course of time as the human intellect gradually gained sophistication, humankind also reworked its equation with nature. From estimating angles to measuring distances our understanding of the skies has indeed deepened, literally and figuratively.

Astronomy today is at the cutting edge of intellectual enquiry and, at its most glamorous, a child of high technology. But it is more than a branch of modern science. It is a symbol of the collectivity and continuity of humankind's cultural heritage. This mixture of science and culture is astronomy's strength as well as dilemma. Strength, because support for astronomy transcends all boundaries; dilemma, because this support transcends science also.

As is well known it is very difficult to define things. It has been said that definition should emerge from actual practice. This is largely true. But there are times when concepts need to be defined properly so that future actions can be given a direction. When we were in school we were told in the English class that the word history has no plural. Now I realize that we were wrongly taught. I am inclined to go to the other extreme and assert that there is no history only histories. That is why today the trend is to use the term heritage as in the title for this symposium. Heritage can be seen as the sum total of histories. And yet for the sake of developing a global perspective and planning combined action we must try to develop a universal history.

Elsewhere I have used the term Cultural Copernicanism. Just as Copernican principle in cosmology tells that the universe does not have a preferred location or direction, Cultural Copernicanism would imply that no cultural or geographical area or ethnic or social group can be deemed to constitute a benchmark for judging and evaluating others. Within this framework how do we deal with the past? Past should not be pitted against the present. It must be conceded that modern astronomy is the terminus of an evolutional track. Astronomy (as well as science in general) should be seen as a multi-stage civilizational cumulus where each stage builds on the knowledge gained in the previous stages and in turn leads to the next. In various stages there are invariably deed ends which should be handled with sensitivity. In this context it would be useful to keep in mind a wise statement by Henry David Thoreau: *"A man is wise with the wisdom of his time only, and ignorant with its ignorance."*

History is an exercise in reconstructing the past that is carried out in the present with an eye on the future. Thus paradoxical as it may seem history is an instrument that converts the past into a bridge between the present and the future. More specifically, history of astronomy is an enquiry into how human perception of their cosmic environment has evolved with time. It is relatively an easy matter to discuss the history of modern astronomy as western astronomy. But if we wish to advance the cause of astronomy, if we wish to see world-wide development of astronomy, we must place post-Galilean developments in a wider spatial and temporal context. Some relevant details of the activities planned by the International Astronomical Union and the United Nations in commemoration of International Year of Astronomy 2009 will be provided.

Figure 5.1: *Astronomy park Hamburg Observatory (Hamburg Observatory)*

5. Cultural Heritage of Observatories and Instruments – From Classical Astronomy to Modern Astrophysics

Gudrun Wolfschmidt (Hamburg, Germany)

Abstract

Until the middle of the 19th century positional astronomy with meridian circles played the dominant role. Pulkovo Observatory, St. Petersburg, was the leading institution for this kind of research. The design of this observatory was a model for the construction of observatories in the 19th century. In addition, in Hamburg Observatory and in some other observatories near the coast, time keeping and teaching of navigation were important tasks for astronomers.

Around 1860 astronomy underwent a revolution. Astronomers began to investigate the properties of celestial bodies with physical and chemical methods. In the context of "classical astronomy", only the direction of star light was studied. In the 1860s quantity and quality of radiation were studied for the first time. This was the beginning of modern "astrophysics", a notion coined in 1865 by the Leipzig astronomer Karl Friedrich Zöllner (1834–1882).

It is remarkable that many amateurs started this new astrophysics in private observatories but not in the established observatories like Greenwich, Paris or Pulkovo. In Germany this development started in Bothkamp Observatory near Kiel, with Hermann Carl Vogel (1841–1907), strongly influenced by Zöllner. An important enterprise was the foundation of the Astrophysical Observatory in Potsdam, near Berlin, in 1874 as the first observatory in the world dedicated to astrophysics – a foundation that inspired others. Important innovations and discoveries were made in Potsdam.

The new field of astrophysics caused, and was caused by, new instrumentation: spectrographs, instruments for astrophotography, photometers and solar physics instruments. In particular, the glass mirror reflecting telescope was recognised as a more important instrument than a large refractor; for the new observatory in Hamburg-Bergedorf a 1-m-reflector, the fourth largest in the world, made by Zeiss of Jena, was acquired in 1911.

Another change was made in the architecture, the idea of a park observatory came up, as in the case of Nice Observatory, Hamburg-Bergedorf and in America. Finally the Schmidt telescope was the most important and influential invention in the Hamburg Observatory.

In the last quarter of the 19th century only a few centres of astrophysics existed in the world. Besides Potsdam one should mention Göttingen, Heidelberg, Bonn and Hamburg in Germany, then observatories in Hungary, Italy, England and France and late, around 1900, also in the United States and India.

The change from classical astronomy to modern astrophysics can be seen very well in the case of the Hamburg Observatory around 1900 – concerning the choice of instruments, the architecture and the idea of the astronomy park; all this is an important cultural heritage connected with observatories of this time.

5.1 Navigation, Timekeeping and Astronomy

In some observatories near the coast, time keeping and teaching of navigation were important tasks for astronomers. Famous examples are Greenwich Observatory, the Naval Observatory in Washington D. C. and Real Observatorio Astronómico de la Armada in San Fernando, founded in 1753 in Cádiz.[1]

Already in the 18th century two private observatories in Hamburg were dedicated to the close connection between astronomy and navigation, for example the *Baumhaus* near the old inner port of Hamburg, founded by Johann Georg Büsch (1728–1800) in 1790.[2] The balcony was used for observing the stars and for teaching navigation.

Also in the 19th century in Hamburg Observatory astronomical research was combined with a school for navigation. The observatory was founded by Johann Georg Repsold (1771–1830) in 1802, the new building was erected by the architect Hinrich Anton Christian Koch (1758–1840) in 1825 near Millerntor (cf. fig. 36.1, p. 316).[3] It had two domes, an unusual case, but it was dedicated to astronomy and navigation respectively. In 1833 the institution was taken over by the State of Hamburg. In the context of navigation – time keeping and chronometer testing played an important role in the time of George Rümker (1832–1900), director in Hamburg Observatory from 1857/67 to 1900. Chronometer makers started their firms in England and France, but also in Hamburg and Altona.[4]

Time keeping played always an important role for navigation; accurate time was needed for the exact determination of longitude. Time was determined by observing meridian transits of stars in the observatories:

"Lord Commissioners of the Admiralty hereby give notice, that a time-ball will henceforth be dropped, every

day, from the top of a pole on the Eastern turret of the Royal Observatory at Greenwich, at the moment of one o'clock PM mean solar time. By observing the first instance of its downwards movement, all vessels in the adjacent reaches of the river (Thames) as well as in most of the docks, will thereby have the opportunity of regulating and rating their chronometers. The ball will be hoisted half-way up the pole, at five minutes before One o'clock, as a preparatory signal, and close up at two minutes before One."

By command of their Lordships,
John Barrow (1764–1848) (1833)

Figure 5.2: *Astronomy and Navigation: Observatory Baumhaus near Baumwall in Hamburg (1790) (model in HamburgMuseum) (Photo: Gudrun Wolfschmidt)*

The most famous time ball was erected in Greenwich Observatory in 1833,[5] made of wood and painted leather, later in 1919 replaced by an aluminium one. The time-ball was dropped at one o'clock for setting the chronometers on the ships – a public time signal, not only for ships in London's river and docks. It drops at 1 pm because the astronomers were busy to determine the time with the help of the midday sun.

Around 160 time-balls existed, about 60 are still existing,[6] many in English speaking countries, e. g. Portsmouth (1829), Royal Observatory at the Cape of Good Hope (1836), Washington, D. C. (1845), Liverpool (1845), Nelson Monument on Calton Hill in Edinburgh (1852), San Francisco (1852), Sydney (1858) in Australia, St. Helena and Mauritius Island, Karachi in India, Lyttelton in New Zealand (1876), New York (1877),[7] Canada, Amsterdam (1881) and Hong Kong (1885). With the introduction of the radio time signals (in Britain from 1924) time balls disappeared step by step. In Germany time-balls existed besides that in Hamburg (1876, made by Carl Bamberg of Berlin, in use until 1934) the first in the Imperial Navy Observatory (Kaiserliches Marineobservatorium) in Wilhelmshaven (1874), then in Cuxhaven (1875), Bremerhaven, Bremen, Kiel (on the roof of the observatory), Swinemünde (now Swínoujście, Poland), and Danzig-Neufahrwasser (1894, now Gdansk, Poland).[8]

Figure 5.3: *Astronomy and Navigation: Observatorio Astronómico de la Armada in San Fernando, founded in 1753 in Cádiz, built in 1798*

5.2 Positional Astronomy with Meridian Circles – Pulkovo as a Model Observatory for the 19th Century

Around 1800 surveying and mapping started for the earth as well as for the sky. Coordinates of the stars in the sky were measured carefully. In this context also the *Struve Arc* should be mentioned, a chain of survey triangulations stretching from Hammersfest in Norway to the Black Sea, through ten countries and over 2,820 km in the northern hemisphere; it is accepted as UNESCO world heritage.

The Royal Observatory Greenwich is also the source of the Prime Meridian, longitude 0°0′0″. In 1884, his Prime Meridian for the world was adopted during the *International Meridian Conference* in Washington D. C. by 25 countries.

The determination of stellar coordinates is besides time keeping and navigation another important task of classical astronomy. Many examples of meridian circles are still to be seen in several observatories in France (Nice and others, Strasbourg) but also in Lisbon, Rio de Janeiro or la Plata. This positional astronomy with meridian circles played the dominant role in research in Hamburg Observatory until the beginning of the 20^{th} century.[9]

Pulkovo Observatory, St. Petersburg, was the leading institution for this kind of research. Characteristic is facade with three domes, the middle one the prominent one, and in addition there are the slits for the meridian circle observations. The design of this observatory was a model for the construction of observatories in the 19^{th} century. Examples can be found e. g. in Astrophysical Observatory Potsdam, Yerkes Observatry and Potsdam-Babelsberg.

Figure 5.4: *Greenwich time ball (1833) (Photo: Gudrun Wolfschmidt)*

5.3 The Rise of Astrophysics

Simon Newcomb (1835–1909) wrote in 1888:

“that the age of great discoveries in any branch of science had passed by, yet so far as astronomy is concerned, it must be confessed that we do appear to be fast reaching the limits of our knowledge.”[10]

But he was wrong. In the second half of the 19^{th} century a new, revolutionary branch of astronomy began to be practised – the New Astronomy – as Newcomb later called it, in contrast to classical positional astronomy and celestial mechanics. The main point of research had crossed over from classical positional astronomy to the new astrophysics.[11]

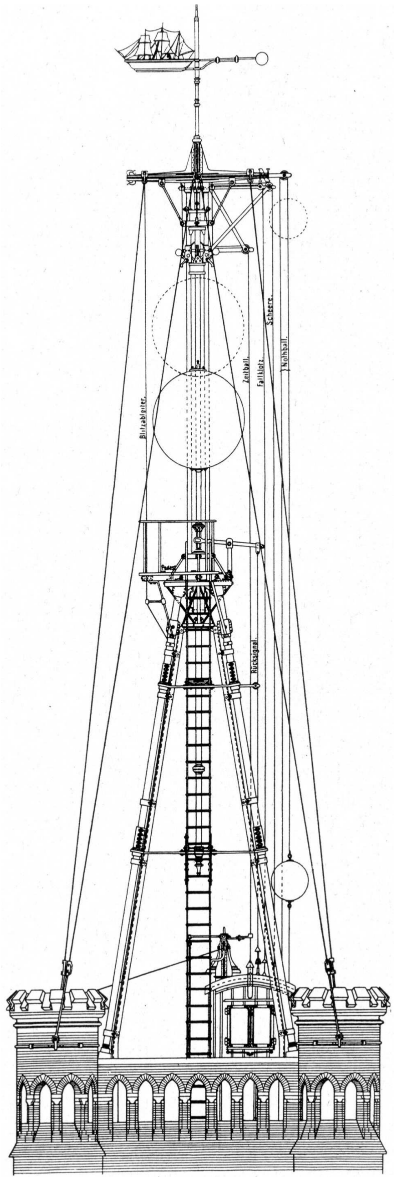

Figure 5.5: *Hamburg time ball, Carl Bamberg of Berlin (1876) used until 1934 (Photo: Gudrun Wolfschmidt)*

Around 1860 astronomers began to investigate the properties of celestial bodies with physical and chemical methods: In 1859 Gustav Robert Kirchhoff (1824–1887) and Robert Wilhelm Bunsen (1811–1899) were able to determine that certain terrestrial elements are also found on the Sun. To that end they decomposed solar light into the colours of the rainbow with a prism and measured the dark lines in the spectrum. William Huggins became a pioneer of astrophysics:

„I soon became a little dissatisfied with the routine character of ordinary astronomical work, and in a vague way sougt about in my mind for the possibility of research upon the heavens in a new direction or by new methods. It was just this time, when a vague longing after new methods of observation for attacking many of the problems of the heavenly bodies filled my mind, that the news reached me of Kichhoff's great discovery of the

Figure 5.6: *Meridian circle and transit, Observatório Nacional, Rio de Janeiro (Photo: Gudrun Wolfschmidt)*

Figure 5.7: *Meridian circle of Hamburg-Bergedorf observatory, A. Repsold & Söhne, Hamburg, 1909 (Photo right: Gudrun Wolfschmidt, Photo left: Hamburg Observatory)*

true nature and chemical composition of the sun from its interpretation of the Fraunhofer lines. This news was to me like the coming upon a spring of water in a dry and thirsty land. Here at last presented itself the very order of work for which in an indefinite way I was looking – namely, to extend novel methods of research upon the sun to the other heavenly bodies.“[12]

5.3.1 Change in Instrumentation – Spectrographs and Photometers

Huggins described the change in his Observatory Tulse Hill near London in 1862:

"Then [1862] *it was that an astronomical observatory began, for the first time, to take on the appearance of a laboratory: Primary batteries, giving forth noxious gases, ... a large induction coil ... several Leyden jars; shelves with Bunsen burners, vacuum tubes, and bottles of chemicals ... lined its walls. ...*

In February 1863 the strictly astronomical character of the Observatory was further encroached upon by the erection, in one corner, of a small photographic tent, furnished with baths and other appliances for the wet collodion process."[13]

Figure 5.8: *Pulkovo Observatory, St. Petersburg (1839) (Photo: Yang-Hyun Choi)*

The next new field besides spectroscopy was photometry, measuring the brightness of stars. In the context of "classical astronomy", only the direction of star light was studied. In the 1860s quantity and quality of radiation were studied for the first time. This was the beginning of modern "astrophysics", a notion coined in 1865 by the Leipzig astronomer Karl Friedrich Zöllner (1834–1882).[14] Photometers (see the influential Zöllner photometer, which existed in many observatories around the world, fig. 16.9, p. 159) were improved since the 1860s – visual, photographic and photoelectric photometry – in order to measure precisely the brightness of the celestial objects; especially important and instructive for astronomers are stars with variable brightnesses.

Solar physics played a role in the beginning of Potsdam observatory because it was even founded as a solar watch station, but later it became important in the 1920s with the erection of the Einstein tower.[15]

5.3.2 Change in Instrumentation – Instruments for Astrophotography

Especially since the 1880s the new technique of photography helped to study and archive faint stars and nebulae. In 1887 with the *Astrophotographic Congress* in Paris the standard astrograph was introduced by the the brothers Paul Pierre and Prosper Mathieu Henry. Portrait lenses like the Willard lens were used by Edward Emerson Barnard (1857–1923) at Lick Observatory or by Max Wolf in Heidelberg observatory to photograph the Milky Way. But also reflectors like the Waltz reflector in Heidelberg are used.

In Hamburg Observatory the Lippert Astrograph, a standard astrograph with UV-Triplet L (focal ratio 1:10, long focal length 34 cm/3,4 m), Carl Zeiss, Jena, 1911 (in use until 1957), was used in combination with an objective lens prism. In addition in Hamburg existed a double astrograph (Triplet K and Petzval, focal ratio 1:5, short focal length 30 cm/1,5 m) with an object lens prism, made by Carl Zeiss of Jena in 1914 (in use until 1972). The Lippert astrograph was used for an international project initiated by Jacobus C. Kapteyn (1851–1922) in 1906, revised from 1918 to 1924, concerning stellar statistics in order to decode the structure of the Milky Way; for this project stellar data like brighness, colours, spectraltypes, proper motion and so on, should be collected in 206 selected aereas over the whole sky. Many observatories in the world cooperated: Potsdam, Hamburg-Bergedorf, Berlin-Babelsberg, Bonn and abroad Groningen, Netherlands as well as five american observatories, Harvard, Lick, Mt. Wilson, Yale and Yerkes. The result in Hamburg was the so-called *Bergedorfer Spektraldurchmusterung* of the northern sky, published in 1935 to 1953 by Arnold Schwassmann (1870–1964) and Pieter Johannes van Rhijn (1886–1960). In 1926 with the Bolivia expedition of the Astrophysical Observatory Potsdam this project was continued with observing the southern sky, using the objective prism of the Lippert astrograph.

In a similar way like the Henry brothers the *Astronomische Gesellschaft* (AG) started in 1924 an international cooperation with an AG astrograph, made by Zeiss of Jena; the same astrographs were used in Bonn and St. Petersburg. After photographing the whole sky with 180,000 stars, as result the AGK 2 catalogue was published (1952). After WW II a new catalogue was compiled (AGK 3, 1964).[16]

5.3.3 The Importance of Reflectors

The new field of astrophysics caused, and was caused by, new instrumentation: spectrographs,[17] objective prisms, cameras, astrographs, Schmidt telescope, photometers[18] and solar physics instruments.

Refractors, although satisfactory and perhaps even superior for visual observations, brought only two (or three) wavelengths to the same focus, and were thus less suitable than the new glass-mirror reflecting telescopes for spectroscopy and photography. These silvered-glass mirrors had better light gathering than the old speculum-metal mirrors, and were generally of better optical quality. The glass-mirror reflecting telescopes of John Browning (1835–1925) in England were especially well-known at the time.

As early as in the 1870s, Konkoly recognized the importance of the reflector for astrophysical research, when he ordered a 10″ Newtonian from Browning, London. Konkoly often used his reflector (see fig. 16.4, p. 154) photographically, combined with an objective prism for obtaining many spectra at the same time. An original Fraunhofer objective prism was donated to Konkoly by Sigmund Merz of Munich.

Léon Foucault's glass-mirror reflecting telescope in Marseille is one of the early successful reflectors (see fig. 14.3, p. 141). But most professional astronomers at

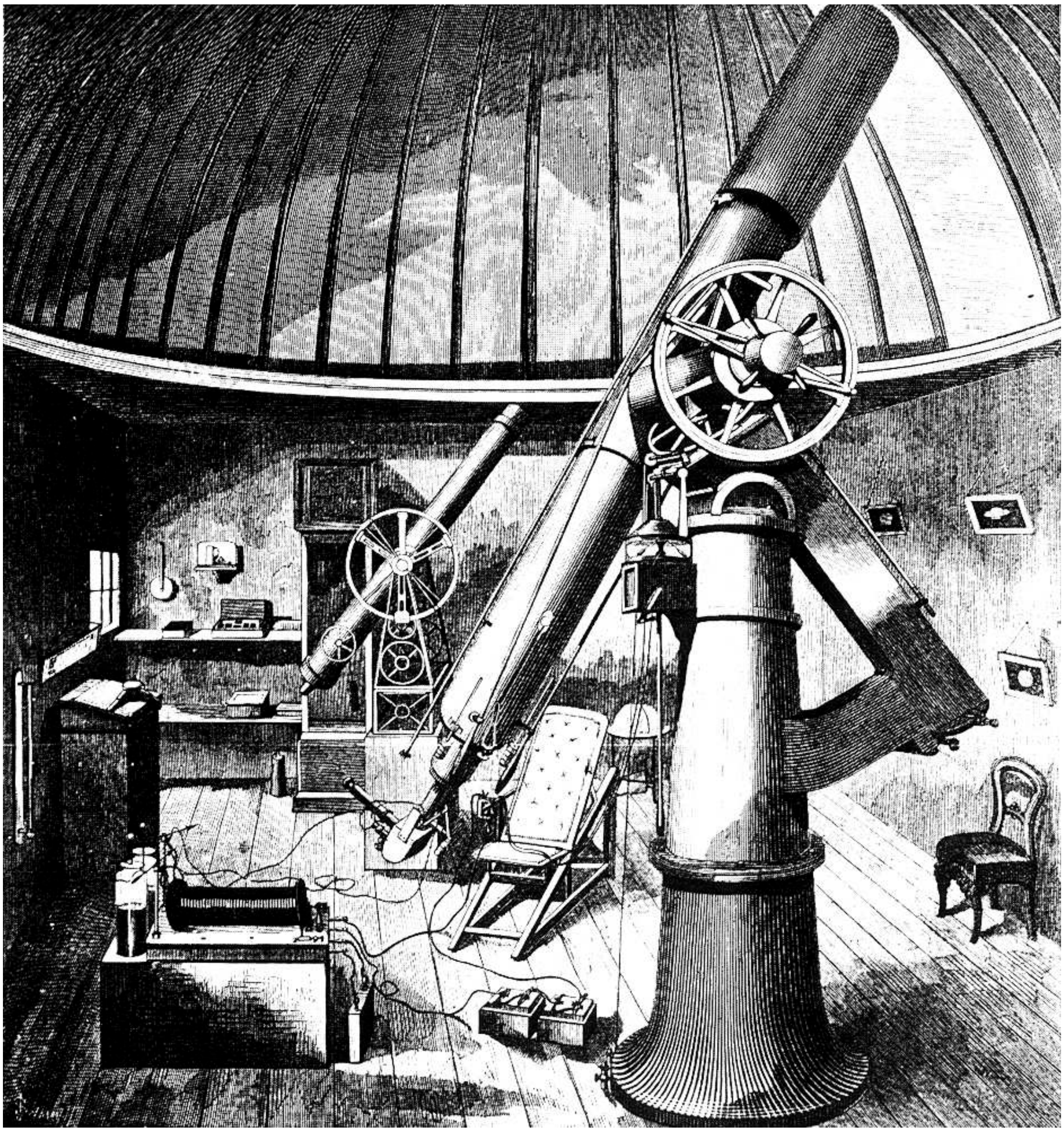

Figure 5.9: *Observatory Tulse Hill near London, Sir William (1824–1910) and Lady Margaret Lindsay Huggins' (1848–1915), 8″ refractor and prism spectroscope, 1860/68 (Huggins 1899, p. 4.)*

that time regarded the reflector as an typical instrument for amateurs and did not pay attention that the reflecting telescope is extremely usefull for the new field of astrophysics because it has no chromatic aberration. Thus can be used much better than a refractor for astrophotography[19] and for spectroscopy where one wants to use the instrument in the whole spectral region. Parallel to Foucault in Germany started the glass-mirror reflecting telescope with the invention of a wet silvering method by the chemist Justus von Liebig[20] (1803–1873) in 1835. After the English chemist pointed out the importance of this method in 1843, Liebig described his method in more detail in the 1850s; then Carl August von Steinheil developed the first small reflecting telescopes up to 40 cm. Also Foucault made his first experiments in the 1850s but succeeded to get really large diameters up to 80 cm diameter for Marseille Observatory.

Around 1900 the company Carl Zeiss of Jena, having just opened an astronomical department in 1897,[21] recognized the possibilities of reflecting telescopes and produced two prototypes of 70 cm for Max Wolf in Heidelberg (1904) and of 40 cm for Innsbruck (1905). The next one was already the 1 m reflecting telescope for Hamburg (1911). The success of this instrument, even the fourth largest in the world, was the breakthrough of the reflecting telescope in Europe. Now the glass mirror reflecting telescope was recognised as a more important instrument than a large refractor. The Hamburg 1-m-reflector was also used in combination with a three prism spectrograph. Since the 1920s Zeiss produced further large reflectors for Potsdam-Babelsberg (1.25 cm, 1924), Merate, Milano (1 m, 1926), and Uccle Observatory, Bruxelles (1 m, 1932).

In the USA the importance of large reflectors was recognised since the beginning of 20$^{\text{th}}$ century, important examples are the glass reflectors of Mt. Wilson Observatory, founded in 1904: $60'' = 1.5$ m reflector (1908) and the Hooker telescope, $100'' = 2.5$ m (1917).

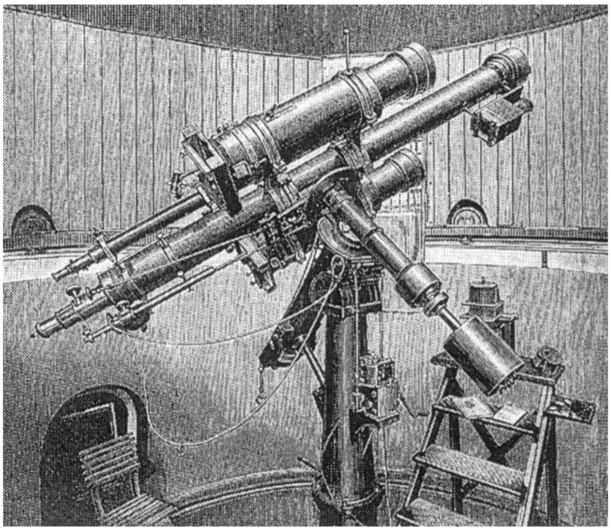

Figure 5.10: *Astrophotography: portrait objectives of Max Wolf, Heidelberg*

As a further important example I show Nicolaus [Miklós] von Thege Konkoly (1842–1916) with his O'Gyalla Observatory in Hungary (fig. 16.3, p. 153), founded in 1871 (in 1899 transformed into a national observatory),[22] when Konkoly became director of the Hungarian Meteorological and Geomagnetic Observatory in Budapest in 1890, and his friend Eugen von Gothard (1857–1909), who founded his private observatory in Szombathely-Herény in 1881 (it existed until 1895, today it is the astronomical observatory of the Eötvös University in Budapest). In addition in Hungary existed the Jesuit Observatory in Kalocsa, founded in 1878; here Karl Braun and in the 1880s Gyula Fényi were active in the field of solar physics.

In Germany the development started in Bothkamp near Kiel, a private observatory, founded by Friedrich Gustav chamberlain (Kammerherr) von Bülow in 1869,[23] where Hermann Carl Vogel (1841–1907) was active, who was strongly influenced by Zöllner in their time together in Leipzig.

5.4 Amateurs as Pioneers of Astrophysics, 1860–1874

n the prehistory of astrophysics (1840 to 1860) amateurs played the dominant role. The field of research was mainly observation and analysis of sunspots and solar-terrestrial relationship; an example id the Kew Observatory where Warren Da la Rue took daily photographs of the Sun with his photoheliograph from 1858 to 1873.

Already in the next two decades, in the phase of beginning professionalization since the 1860s, many new discoveries were made, new instruments were developed – and astrophysics quickly advanced, especially in the field of solar physics, although the classical astronomers didn't take any notice. The simple analysis of light from remote cosmic objects provides us not only with information on the chemical composition but also on temperature, pressure, and density on stellar atmospheres. For example the structure of the solar atmosphere could be explained: There are three layers: Photosphere, Chromosphere and Corona, connected with spectrum of sunspots, H_α, Ca H and K lines and the green Coronium line. By analysing the spectrum of the prominences one can tell the composition but also the velocities. Independently from each other, Joseph Norman Lockyer (1836–1920) and Pierre Jules César Janssens (1824–1907) discovered helium in the Sun, an element not known on earth at that time – discovered in 1895 on earth by William Ramsey.

As a whole at least seven pioneers of astrophysics existed in the beginning: Zöllner, Huggins, Lockyer, Secchi, Vogel, Konkoly and Jules Janssen (1824–1907) in Meudon near Paris. It is remarkable that many amateurs started this new astrophysics in private observatories but not in the established observatories like Greenwich, Paris or Pulkovo.

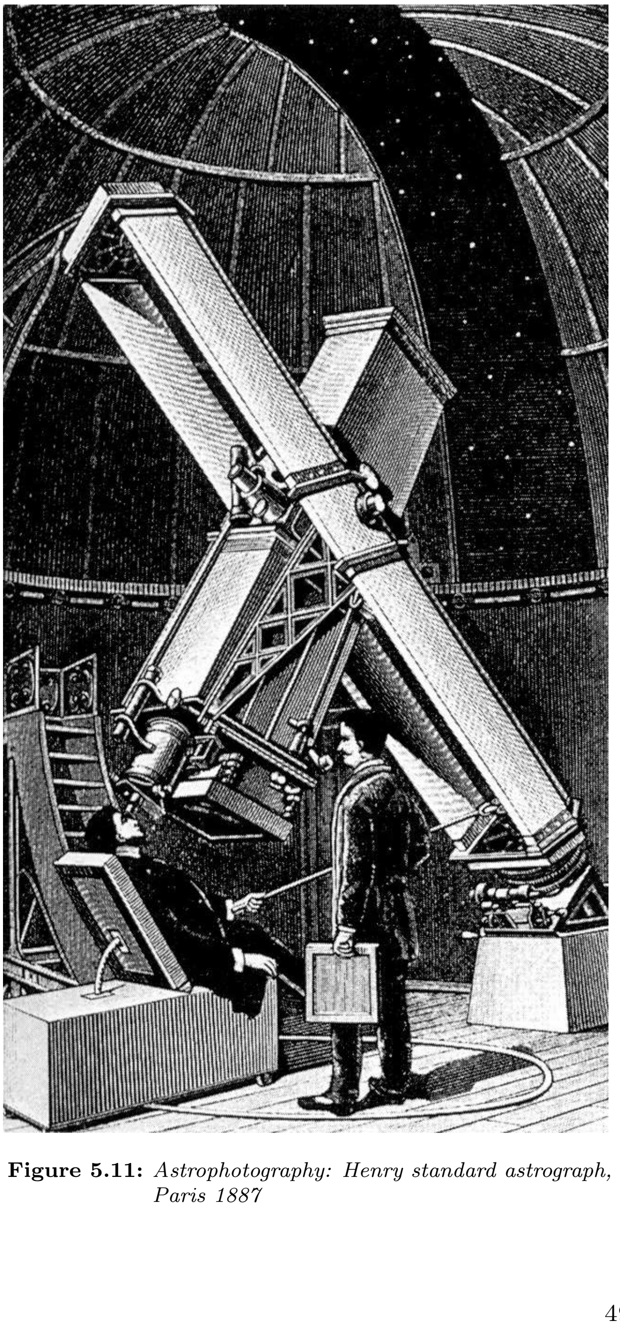

Figure 5.11: *Astrophotography: Henry standard astrograph, Paris 1887*

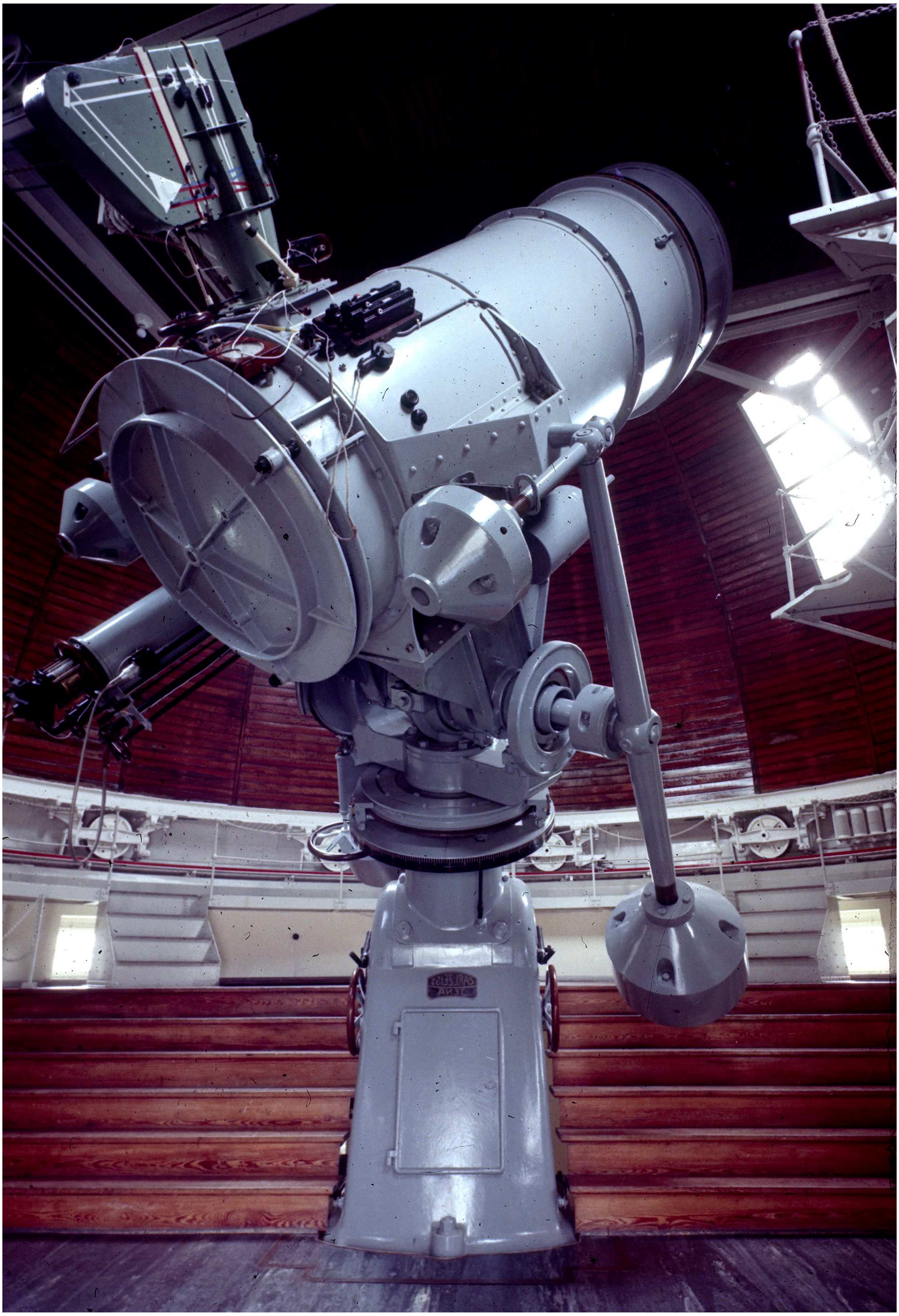

Figure 5.12: *1m-reflector Hamburg, Zeiss of Jena (1911), with three prism spectrograph, load relieving mounting by Franz Meyer (1868–1933) (Hamburg Observatory)*

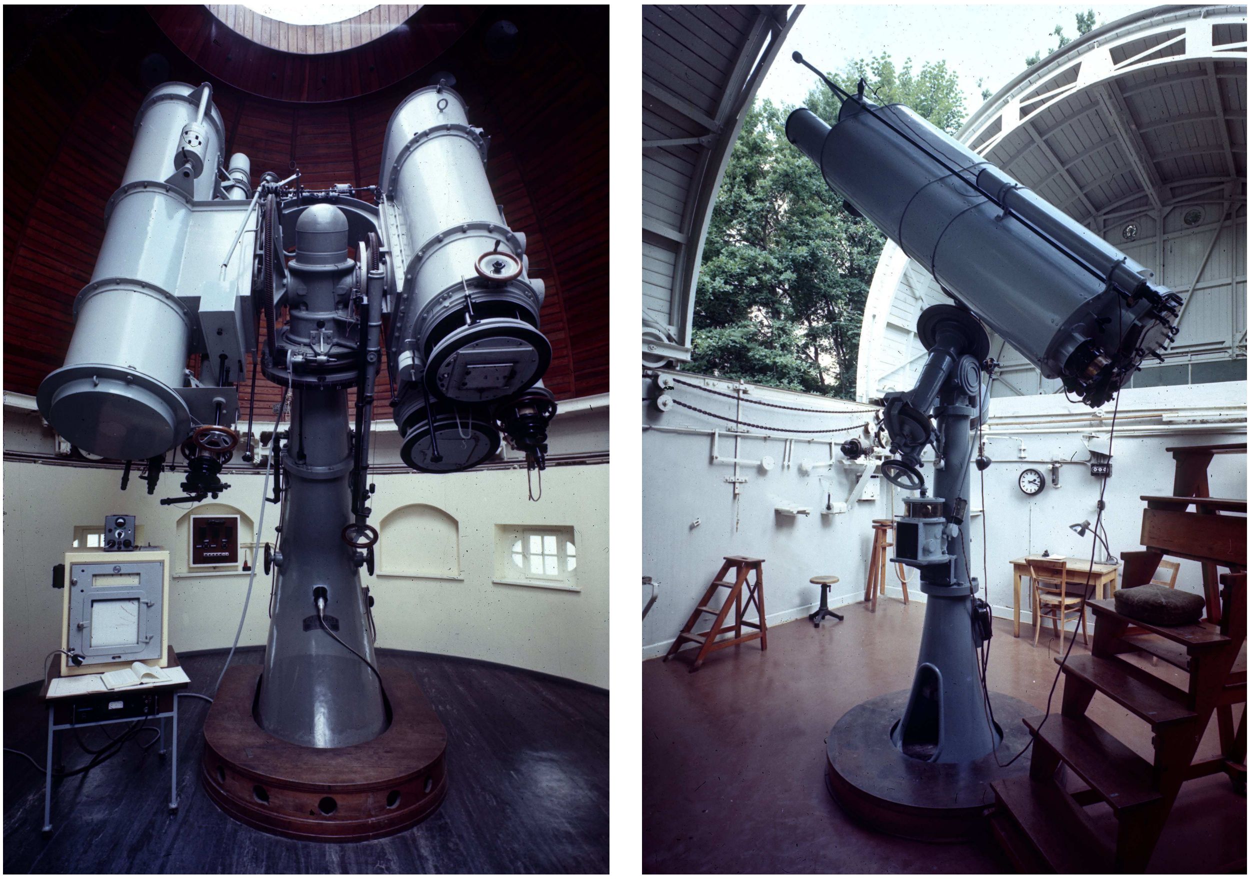

Figure 5.13: *Astrographs of Hamburg Observatory. Left: Lippert Astrograph and Double Astrograph with an object lens prism, Carl Zeiss of Jena, 1911/1914; Right: AG-Zonen-Astrograph, Carl Zeiss Jena, 1924 (Hamburger Sternwarte)*

5.5 Institutionalisation of Astrophysics, 1874–1914 – Potsdam, the First Institute of Astrophysics in the World

Institutionalisation of astrophysics started around 1874 with the founding of the Astrophysical Observatory in Potsdam, near Berlin.

This was an important enterprise; Hermann Carl Vogel was appointed as first director in 1882 (since 1874 observator). Potsdam was the first state financed astrophysical observatory in the world dedicated to especially to astrophysics – a foundation that inspired others. It kept the leading role in that field until around the turn from 19th to 20th century.

The building of the Astrophysical Observatory Potsdam was erected by Paul Spieker (1826–1896) from 1876 to 1879. But Pulkovo Observatory still served as a model for the design of an observatory with three domes on the top of the main building and for the choice of instruments; for example a large refractor was added in 1899 but no reflector, important for astrophysics, was ordered. Important innovations and discoveries were made in Potsdam like the first photographic measurement of radial velocities of stars or the discoveryy of the first spectroscopic binary by Hermann Carl Vogel or the discovery of interstellar gas in 1904 by Johannes Hartmann (1865–1936). Julius Scheiner (1858–1913) succeeded to photograph the spectrum of the Andromeda nebula M 31, and recognised the Andromeda nebula as a stellar system outside of our Milky Way.

5.6 Centres of Astrophysics

5.6.1 Centres of Astrophysics in Germany

In the last quarter of the 19th century only a few centres of astrophysics existed in the world, besides Potsdam one should mention Göttingen, Heidelberg, Bonn, Bamberg and Hamburg in Germany.

- Hermann Carl Vogel and the other Potsdam astrophysicists are already discussed.
- Max Wolf in Heidelberg, since 1896 professor of astrophysical astronomy, is important in the field of photography and spectroscopy.
- Johannes Hartmann (1865–1936) was active as observer, especially in the field of stellar spectroscopy, in the Astrophysical Observatory in Potsdam in 1896, then in 1902 he got a professorship in Berlin. After he acted as professor and director in Göttingen from 1909 to 1921, he became

Figure 5.14: *Glass reflectors, Mt. Wilson (1904): 60″ = 1.5 m reflector and Hooker telescope, 100″ = 2.5 m (Mt. Wilson Observatory)*

director of the Argentine National Observatory in La Plata due to the better observation conditions. Finally he returned to Göttingen in 1934.

- Friedrich Wilhelm August Argelander (1799–1875) and Eduard Schönfeld (1828–1891) in Bonn (1845) were active in the field of photometry and variable stars, later Friedrich Küstner in spectroscopy.
- In the Dr. Remeis Observatory in Bamberg photographic sky patrol, photometry and variable stars and played the important role.[24]
- In Hamburg astronomers were especially interested in solar physics: several solar eclipse expeditions were undertaken (Spain 1860, Algeria 1905, 1923 Mexico, 1927 Jokkmokk, 1929 Philippines). A horizontal solar telescope was erected by Bernhard Schmidt in Hamburg; it was used for the solar eclipses.

But 80% of the German observatories were still dominated by classical astronomy around 1900 which was an important tradition in Germany.

5.6.2 Centres of Astrophysics in Europe

Soon observatories in England, France, Italy, Hungary and Russia started astrophysics. In the 1870s and 1880s the first astrophysical departments were founded: the solar observatory Meudon near Paris (1876), the establishment of an astrophysical department in Greenwich in the 1870s, an astrophysical department in Pulkovo Observatory (1882), and the Solar Physics Observatory South Kensington near London in 1885.

In this epoch of institutionalisation also the first professorships for astrophysics or physical astronomy were extablished. The first professor for physical astronomy was Zöllner in Leipzig University in 1866 (only until 1882), then Pickering in Harvard in 1876, Lockyer in South Kensington/London in 1888, Hale in 1892/95, Julius Scheiner in Berlin in 1894, Max Wolf in Heidelberg in 1896 (in 1902 chair for astrophysics), Rudolf Spitaler in Prague in 1897, Frank Newall in Cambridge in 1909, Karl Schwarzschild and Paul Guthnick in Berlin in 1916.

- Italy:
  Angelo Secchi, Osservatorio del Collegio Romano, Giovan Battista Donati (1826–1873), and other members of the important Società degli Spettro-

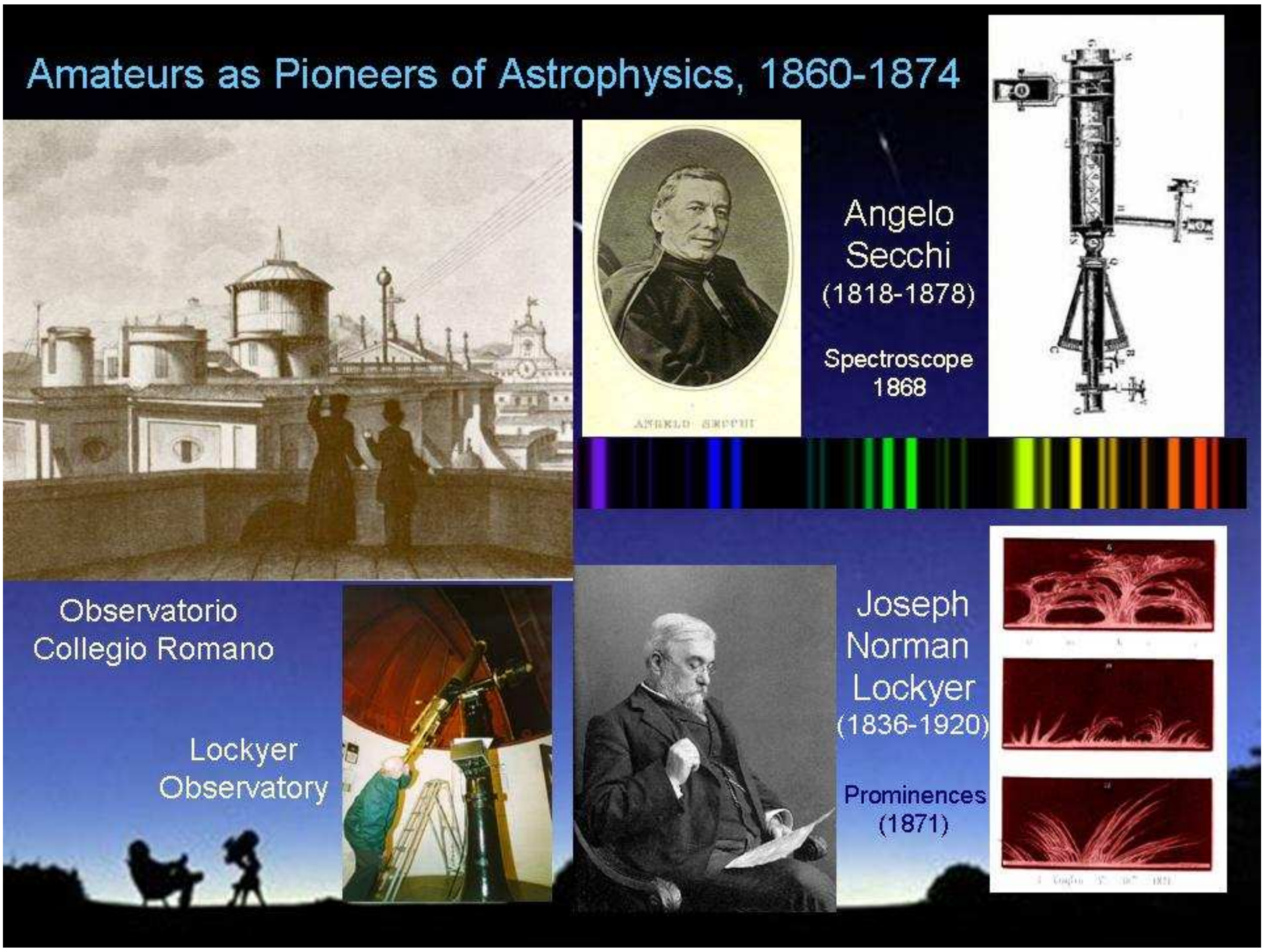

Figure 5.15: *Spectroscopists: Angelo Secchi (1818–1878) in Rome, Joseph Norman Lockyer (1836–1920) in England*

scopisti Italiani in the 1870s should be mentioned. In 1896 George E. Hale wrote to Tacchini: *"No one appreciates more fully than I do how much of us who are engaged in solar investigations owe to the spectroscopic workers of Italy. The volumes of the Memorie which you so kindly presented to me stand in a case near my table and are used almost every day. I have good reason to know how much I am indebted to Tacchini, Secchi, Respighi, Lorenzoni and Riccò, not to mention the other members of the Society."* [25]

- England:
  After the start of astrophysics by Huggins and Warren De la Rue (Kew Observatory with the photoheliograph) in 1873 in Greenwich an astrophysical department was established: Edward Walter Maunder (1851–1928) became photographical and spectroscopical assistant. Lockyer was director of the Solar Physics Observatory in South Kensington near London in 1885. In 1912 Lockyer's observatory was moved to Salcombe Hill, near Sidmouth in Devon. The Solar Physics Observatory (SPO) was moved around 1910 from South Kensington to Cambridge.

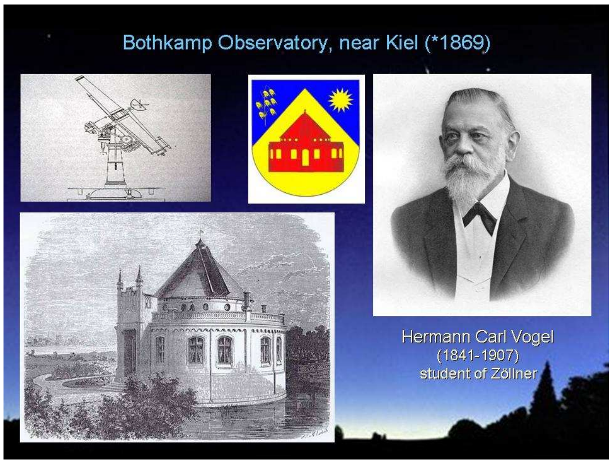

Figure 5.16: *Bothkamp Observatory (1869), Friedrich Gustav chamberlain (Kammerherr) von Bülow*

- France
  Meudon was established in 1876 with Pierre Jules Janssen, since 1865 Professor of physics, and later around with Henri Deslandres, since 1908 director in Meudon.
- Russia:
  The Swedish astrophysicist Bengt Hasselberg was active in Pulkovo: For example Otto Wilhelm

Struve, an astronomer well known for precision meaurements in the field of classical astronomy in Pulkovo Observatory, who was not completely refusing astrophysics:

„As yet, astrophysical investigations are far from the standard of scientific accuracy possessed by classical astronomy, which, with its solid mathematical base and constant progress in both observation and theory, rightfully occupies the premier place among experimental sciences. God forbid that astronomy should be carried away by a fascination with novelty and diverge from this essential basis, which has been sanctified for centuries, and even millennia.“[26]

After Zöllner refuted the calling in 1868 the Swedish astrophysicist Bengt Hasselberg did not get an appointment before end of the 1870s in Pulkovo. He carried out photographical work. In 1882 an astrophysical department was erected with a special building in 1886. Around 1890 Aristarchos A. Belopolsky started as a second astrophysicist in Pulkovo with spectroscopy.

5.6.3 Centres of Astrophysics in America

Since the 1890s the rise of astrophysics started in the USA:
„In spite of this list of illustrious scientists [Huggins, Lockyer, Janssen, Zöllner, H.C. Vogel, Secchi], astrophysics has been a particulary American development. 'American money and technology, applied at fine observing sites in the favorable climate of California, enabled the United states to overtake Germany and Great Britain, and become the world leader of observational astronomy.'“[27]

- Also in the United States astrophysics started in private observatories, Lewis Morrison Rutherfurd in New York and Henry Draper in Hastings am Hudson, New York, and Charles Augustus Young (1834–1908) in Halsted Observatory in Princeton, New Jersey.
- The most important and influential is without doubt the Harvard College Observatory with its director Edward Charles Pickering's (1846–1919), 1869/1877 to 1919, and his female astronomers.
- Lick Observatory, Mt. Hamilton, was erected in 1888.
- Chicago, Yerkes and Mt. Wilson:
  In the 1890s George Ellery Hale started as amateur astronomer in Chicago (Kenwood Observatory), in 1892 he was an unpaid associate professor of Astral Physics, 1895 paid professor, University of Chicago. As a solar physicist he established observatories with excellent instrmentation with the help of important sponsors: Yerkes in 1897 and Mt. Wilson in 1904.[28]
  Yerkes had still the design of Pulkovo, Lick and Mt. Wilson were modern observatories with a group of buildings on the top of a mountain.

5.7 Change in Observatory Architecture: Astronomy Park and Mountain Observatories

An important change was made in the architecture of observatories, the idea of a park observatory came up – no longer Pulkovo served as a model.[29]

Figure 5.19: *Large 80 cm Hamburg Schmidt telescope, Zeiss, Jena, Heidenreich & Harbeck, Hamburg, 1954 (Hamburg Observatory)*

In Strasbourg Observatory (1876/1880) the first step was made in the direction of modern observatory architecture with two domes separated from main building, but this still with the main dome like the cross shaped observatories around 1800.[30] Also in other observatories this separation in pavillions started, I would like to mention Bamberg (1889) and Marseille.

Best examples for park observatories can be found in Nice (1879/1888), Bruxelles Observatory (1883/1890)[31] and Heidelberg-Königstuhl (1896), but especially in the USA like the US Naval Observatory in Washington D. C. (new site in 1893, see fig. 23.1, p. 216). Now several domes in a park are separated completely from each

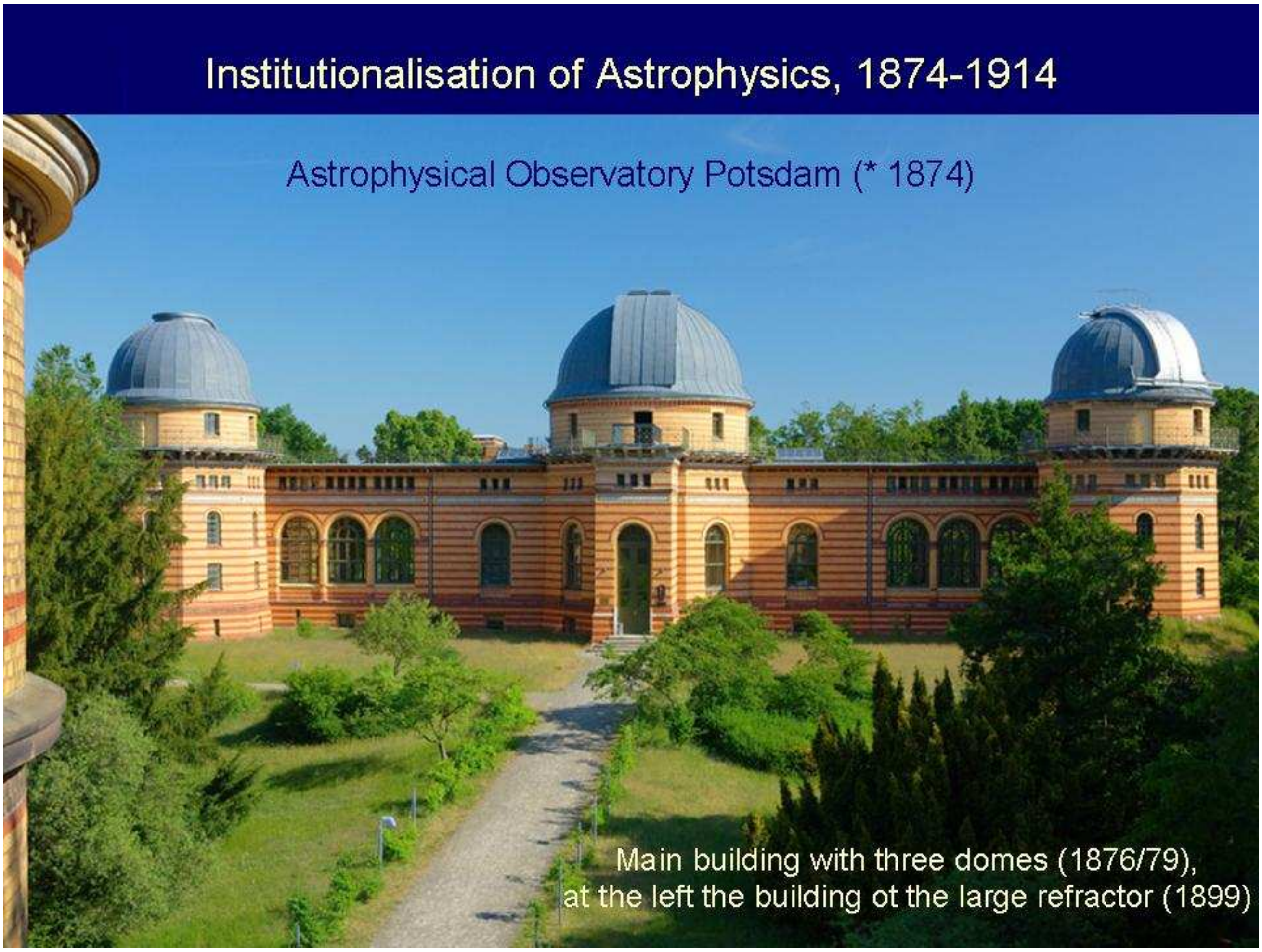

Figure 5.17: *Astrophysical Observatory Potsdam (1874), building 1876–1879, large refractor 1899*

other and especially from the heated offices and dormitories.

Nice[32] (1879/1888) shows an additional interesting feature because it is situated on the hill *Mont Gros* like the Pic du Midi Observatory (1878) in the French Alpes, founded nearly at the same time as an observatory for solar physics, but it is really on a high mountain, the others are on more or less high hills near cities.

Similar examples of observatories on hills are Blackford Hill Observatory in Edinburgh (1888/1896) and Observatory of Barcelona on Monte Tibidabo (1902) and the already mentioned Landes-Sternwarte Heidelberg-Königstuhl (1896). Also La Plata Observatory (1883), Argentina, showing links to both kinds of research, classical astronomy and navigation as well as astrophysics, has the layout of the buildings in a park, in addition it is situated on the top of a hill.

Further very good examples for real mountain observatories can be found in the USA, carefully chosen for the quality of astronomical seeing. Here the famous American observatories[33] should be mentioned like Lick on Mt. Hamilton (1875–1888), Mt. Wilson (1904) and Mt. Palomar (1948). These sites have much better weather conditions for astronomical observation than the old observatories in middle Europe near the cities.

Hamburg Observatory was built at its present location in Hamburg-Bergedorf between 1906 and 1912 on a small hill *Gojenberg* at the border of the city.[34]

The buildings mirror the architecture of that time, and the instruments form an important historical record of astronomical research. In Hamburg the idea of an astronomy park observatory is realised with a strict separation of observatory domes on one side and the main building with the library and administration, the office buildings and the workshop on the other side (fig. 5.1, p. 42).

In this way Hamburg can be seen as a model observatory for the beginning of astrophysics because of the site (astronomy park, hill at the outskirts of the city) but also because of the instrumentation, especially the choice of a modern reflector, well suitable for astrophysics, besides the instruments for classical astronomy like the meridian circle and the refractor.

Finally the Schmidt telescope, an important and influential invention for astrophotography, was made in Hamburg Observatory;[35] now one can find Schmidt telescopes all over the world.

In addition Hamburg served as a model for Mérida Observatory in Venezuela with the whole instrumen-

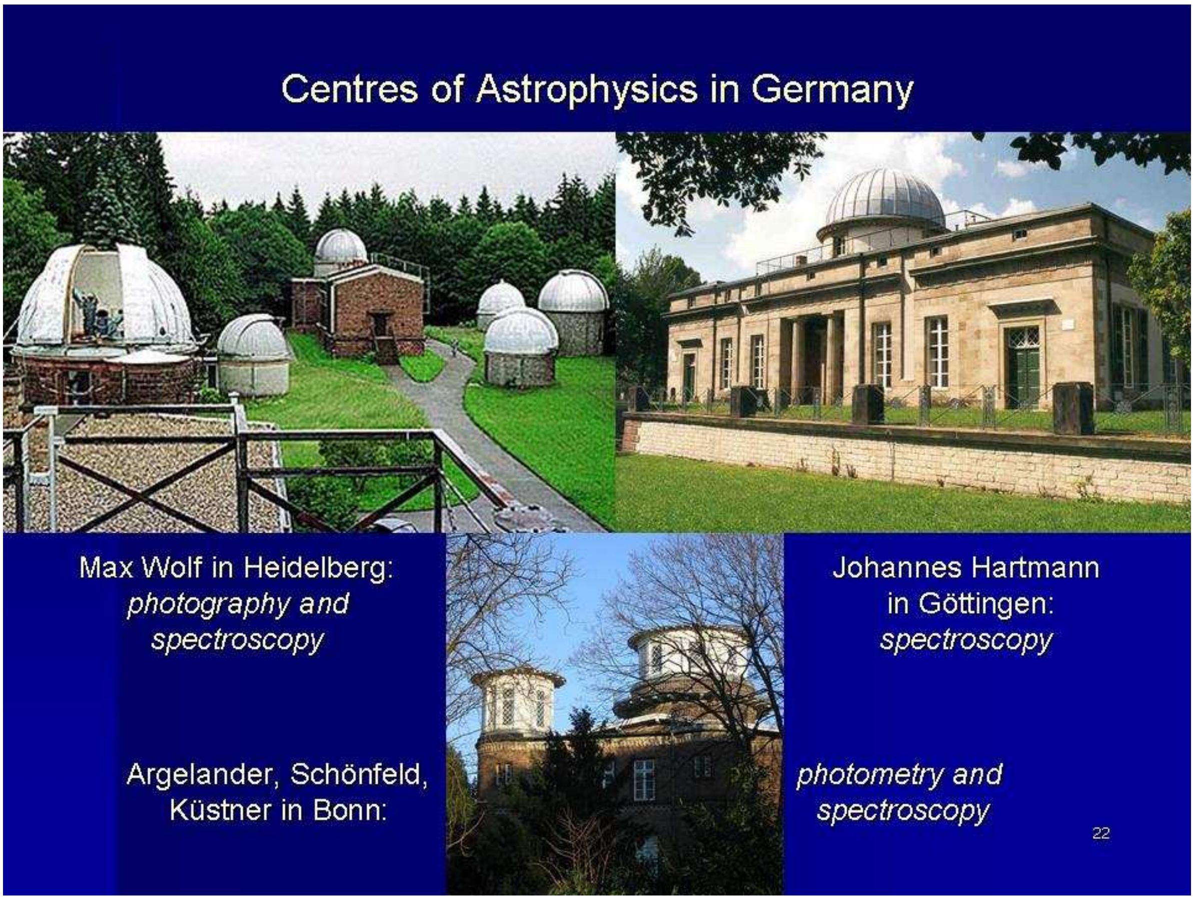

Figure 5.18: *Centres of Astrophysics in Germany: Max Wolf in Heidelberg, Karl Schwarzschild and Johannes Hartmann in Göttingen, Argelander, Schönfeld and Küstner in Bonn*

tation, meridian circles, refractors, reflecting telescope, but also a Schmidt telescope (see fig. 8.1, p. 84).

5.8 Conclusion

The development of architecture of observatories had reached around 1800 a specific shape, it was a building with a dome, sometimes in the shape of a cross. With Pulkovo Observatory, well known in the astronomical world for its achievements, a new standard was created, a building with three domes and with the slits for the important meridian circle observation visible. It served as a model for observatories through the 19th century where positional astronomy, combined with a time service for time and navigation, played an important role.

At the turn from the 19^{th} to the 20^{th} century astrophysics as a new field of astronomy started to play the dominant role. This new kind of research caused new instrumental equipment (reflecting telescopes, spectrographs, instruments for astrophotography, photometers and solar physics equipment), but also a new architectural layout where the new functions are visible.

Hamburg Observatory together with this group of observatories presented in this symposium shows very well this important step in the development of observatory architecture, this transition around 1900, the change from classical astronomy to modern astrophysics concerning the choice of instruments, the modern architectural structure and the idea of the astronomy park; all this is an important cultural heritage connected with observatories of this time.

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1. The magnificent building on the Isla de León, constructed according to the plans of the Marqués de Ureña, Gaspar de Molina y Saldívar (1741–1806), in 1798, exists until the present time. His architectural ideas are described in his book *Reflexiones sobre la arquitectura, ornato, y música del templo* (Madrid 1785). González 1992, González 1995. Lafuente, Sellés 1988.
2. Wolfschmidt 2007.
3. Koch 2001.
4. The clock room in Hamburg Observatory has clocks and chronometers made by Kessels (1830s), Tiede (1879), Kittel (1889, 1912), Bröcking (1902, 1910), Riefler (1911, 1917), cf. `http://www.hs.uni-hamburg.de/DE/Ins/Bib/Uhren/index.html`.
5. Dyson 1983. Littlewood, Butler 1998. Forbes, Meadows, Howse 1975.
6. Also time guns were used to announce noon, e. g. in Edinburgh Castle (1861) and in Royal Observatory Blackford Hill (1896), `http://www.1oclockgun.com/history\_balls.html`.

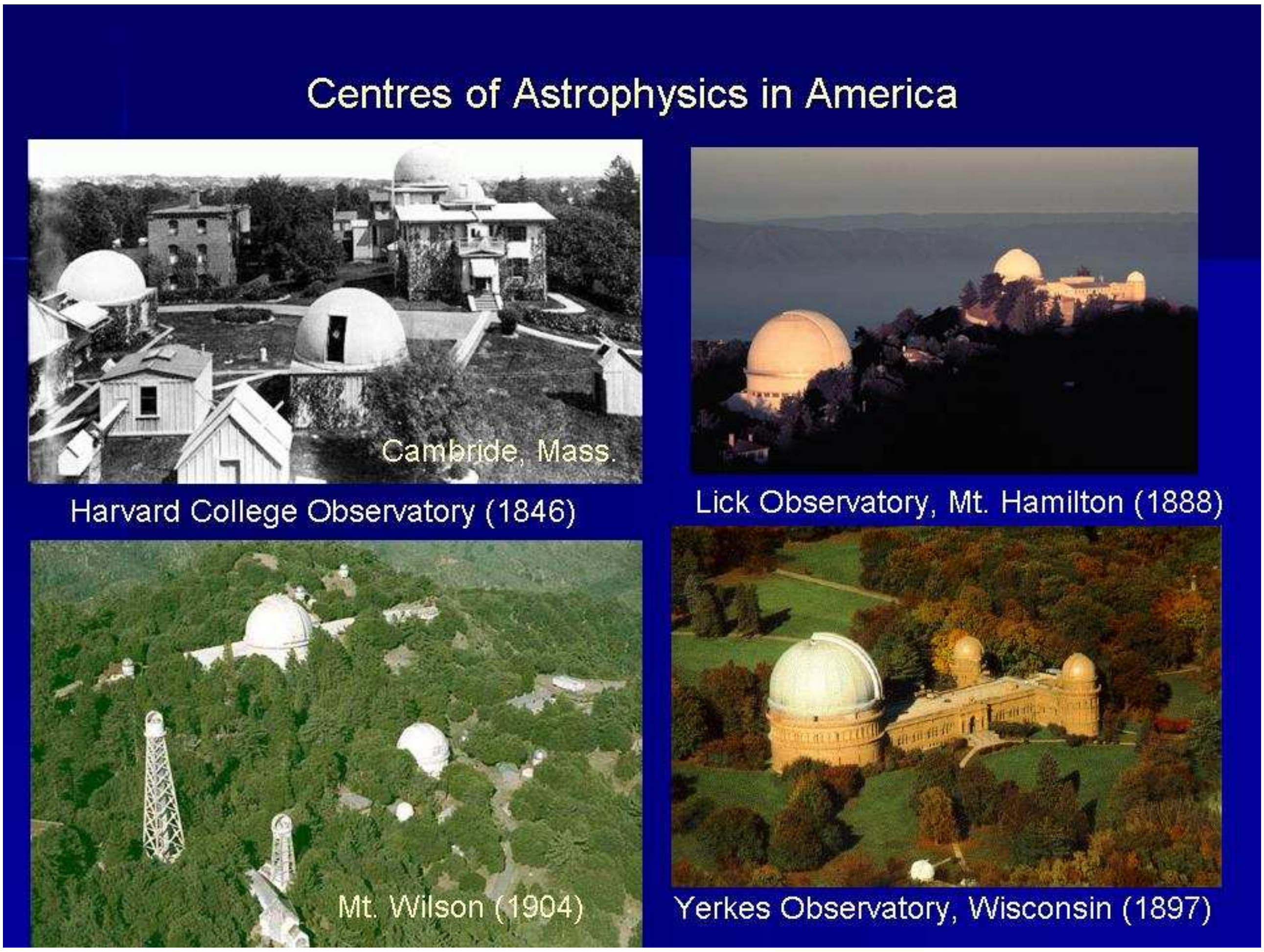

Figure 5.20: *Centres of astrophysics in the USA: Harvard College Observatory (1846), Lick Observatory, Mt. Hamilton (1888), Yerkes Observatory, Wisconsin (1897), Mt. Wilson (1904)*

7. The Naval Observatory in Washington D. C. telegraphed a daily signal to the time ball on the roof of the Western Union Telegraph Building in New York.
8. In 1903 in Hamburg a telegraphical time signal was started. A switchboard for transmitting the time signal "Alster 10,000" by telephone (1907) was used.
9. 19 cm-meridian circle, (focal length 2,3 m), A. Repsold & Söhne, Hamburg, 1909.
10. Newcomb (1888), p. 14–20, p. 65–73.
11. Wolfschmidt: Genese der Astrophysik, 1997.
12. Huggins, William: Nineteenth Century Review (1897), June.
13. Huggins, William: An Atlas of Representative Stellar Spectra, 1899, here p. 8–9.
14. Zöllner: Photometrische Untersuchungen, 1865.
15. Wolfschmidt 2005c.
16. With the modern zone astrograph, made by Zeiss of Oberkochen, 1973, this astrometric work was continued in Hamburg, see p. 281.
17. Hearnshaw 2009.
18. Hearnshaw 1996.
19. A refractor like an astrograph has to be corrected for astrophotography in the blue or visual region.
20. Vaupel 1989.
21. The Zeiss firm in Jena was already founded by Carl Zeiss (1816–1888) in 1846, but in 1888, when Ernst Abbe (1840–1905) became director, the company was structured in a new way step by step in four departments: 1888 "Photo" *Photographische Abteilung* – photography, 1893 "Meß" *Abteilung Optische Meßinstrumente* – optical instruments like microscopes, 1893 "Tele" *Abteilung Erdfernrohre*, terrestrial telescopes, and finally in 1897 "Astro" *Astronomische Abteilung* – astronomy, cf. Wolfschmidt 1993.
22. Wolfschmidt 2001, p. 39–58.
23. Lühning 2008.
24. Müller, Gustav und Ernst Hartwig: Geschichte und Literatur des Lichtwechsels, 1918, 1920, 1922.
25. `http://www.sait.it/StoriaSAIT.html`.
26. Struve, Otto Wilhelm von: Letter to the Academy of Sciences in St. Petersburg in 1886, quoted after: Gingerich 1984, 4A, p. 61.
27. Krisciunas 1988, S. 122. Osterbrock 1984, S. 2.
28. Osterbrock 1993.
29. Concerning the architecture of observatories see: Müller 1978, Müller 1992.
30. Wolfschmidt 2005a, Wolfschmidt 2005b.
31. The Uccle Observatory in Bruxelles (*Observatoire royal de Belgique*, *Koninklijke Sterrenwacht*) was built by the Art nouveau architect Octave van Rysselberghe (1855–1929) from 1883 to 1890.
32. Le Guet Tully 2008.
33. Wolfschmidt 2002.

34. The whole ensemble was put under monument protection in 1996 due to its significance in cultural history.
35. Dufner 2002. Wolfschmidt 2009a.

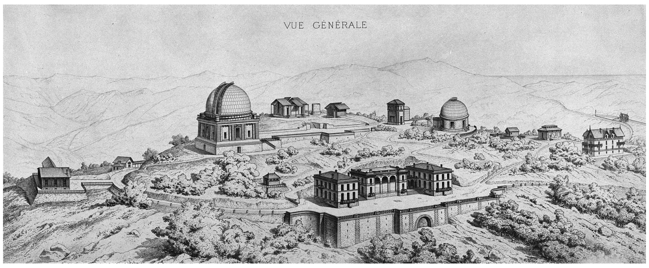

Figure 5.21: *Nice Observatory on Mont Gros (1888) with the large dome by Gustave Eiffel (Garnier, Charles: Monographie de l'Observatoire de Nice, 1892).*

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Figure 5.22: *La Plata Observatory, Argentina (1886) (La Plata Observatory)*

Figure 6.1: *Above: The Nicholas Central Astronomical Observatory (Pulkovo Observatory) (the view before WWII)*
Below: The restored Pulkovo Observatory (the view after WWII) (Pulkovo Observatory, St. Petersburg)

6. The Pulkovo Observatory on the Centuries' Borderline

Viktor K. Abalakin (St. Petersburg, Russia)

Figure 6.2: *Friedrich Georg Wilhelm (Vasily Yakovlevich) Struve (1793–1864), director 1834 to 1862 (Courtesy of Pulkovo Observatory, St. Petersburg)*

Abstract

The present paper deals with development of astrophysical researches at the Pulkovo Observatory (now: the Central (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences) at adjacent time periods separated by the threshold between the XIXth and the XX$^{\text{th}}$ centuries.

The Pulkovo Observatory, had been inaugurated in 1839. Its traditional field of research work was Astrometry. The confirmation of the light absorption phenomenon in the interstellar space by Friedrich Georg Wilhelm Struve had marked the turn of the Observatory's research programs toward Astrophysics.

New tendencies in the development of the contemporaneous astronomy in Russia had been pointed out by Otto Struve in his paper "About the Place of Astrophysics in Astronomy" presented in 1866 to the Saint-Petersburg Academy of Sciences.

The wide-scale astrophysical studies were performed at Pulkovo Observatory around 1900 during the directorship of Theodore Bredikhin, Oscar Backlund and Aristarchos Belopolsky.

The Nicholas Central Astronomical Observatory at Pulkovo, now the Central (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences, had been co-founded by Friedrich Georg Wilhelm Struve (1793–1864) [Fig. 6.2] together with the All-Russian Emperor Nicholas the First [Fig. 6.3] and inaugurated in 1839. The Observatory had been erected on the Pulkovo Heights (the Pulkovo Hill) near Saint-Petersburg in accordance with the design of Alexander Pavlovich Brüllow, [Fig. 6.3] the well-known architect of the Russian Empire. [Fig. 6.4: Plan of the Observatory]

From the very beginning, the traditional field of research work of the Observatory was Astrometry – *i. e.* determination of precise coordinates of stars from the observations and derivation of absolute star catalogues for the epochs of 1845.0, 1865.0 and 1885.0 (the later catalogues were derived for epochs of 1905.0 and 1930.0); they contained positions of 374 through 558 bright, so-called fundamental, stars. It is due to these extraordinarily precise Pulkovo catalogues that Benjamin Gould had called the Pulkovo Observatory the "astronomical capital of the world".

They served for decades as a reliable basis for further compilation by Simon Newcomb, August Auwers and Lewis Boss of the fundamental catalogues which contained data on stellar positions and proper motions and incorporated the astronomical, celestial, frame of reference as frozen on a definite date (an epoch), *i. e.* for the begin of the Besselian annus fictus as designated above by using the symbol '.0'.

From the first days of Observatory's existence the considerable attention had been paid by Wilhelm and Otto Wilhelm Struve to establishing an astronomical library which later was called by Simon Newcomb to be the "main instrument of the Pulkovo Observatory". Extensive catalogues of books and manuscripts (among them the famous manuscripts of Johannes Kepler!) of the Pulkovo Library were compiled by Wilhelm Struve and by Eduard Lindemann ("Librorum in Bibliotheca

Speculae Pulcovensis contentorum Catalogus Systematicus". Tomus primus, 1845, tomus secundus, 1880).

Figure 6.3: *Above: Czar Nicholas the First (1796–1855) Below: Alexander P. (Aleksandr Pavlovich) Brüllow (1798–1877) (Courtesy of Pulkovo Observatory, St. Petersburg)*

It should be noted that on the time span from 1816 to 1855 geodesists of Russia, Sweden and Norway (*"trium gentium geometrae"* as sculptured on the obelisk marking the Southern terminal of the meridian arc) under permanent guidance of Wilhelm Struve had performed the immense work on astro-geodetical measurements of length of the meridian arc extending from Hammerfest (Fuglenaes) in Norway to Ismail (Staro-Nekrassowka) in Russia and being 25°20′ long. This meridian arc had been later named the "Russo-Scandinavian Arc", or the "Struve Arc"; the measurements of it had served as a basis for establishing the Earth's size and shape. They were in full detail described by Wilhelm Struve himself in his book "Arc du meridien de 25°20′, entre le Danube et mer Glaciale". The Pulkovo meridian passes through the center of the Round Hall of the Observatory which is marked by the post on the floor symbolizing the origin of the geographic system of reference of Russia [Fig. 6.5].

The assumption about existence of the light absorption in the interstellar space was made in 1840 by Wilhelm Struve, the first Director of the Observatory. The confirmation of his supposition in 1847 to be true which had been obtained by Wilhelm Struve from his profound analysis of the apparent distribution of stars and given in his well-known work *"Les Études d'Astronomie Stellair"* may be considered as the first result of an outstanding astrophysical significance obtained at the Observatory. It was of the decisive importance for solution of the Olbers' photometric paradox (1826) having a major impact onto Cosmology and Philosophy.

The steady development of the astrophysical research in the astronomical world community has been reflected in the communication read by Otto Struve (1819–1905) [Fig. 6.9], the second Director of Pulkovo Observatory, in 1866 in a session of the Petersburg Academy of Sciences, and entitled "About the Place of Astrophysics in Astronomy". The very first astrophysical (rather geophysical) observations at the Observatory were made by Otto Struve in 1868 who observed together with August Wagner the main lines in the spectra of the Aurorae Borealis.

Problems related to the Astrophysics were included into the plans of the Nicholas Central Astronomical Observatory's research works at the time of the directorship of Otto Struve, so that he ordered in 1862 the Schwerd photometer which was obtained in 1865[1] shortly before the end of navigation, being installed only in 1866 in the tower specially erected for it because of the bitter frosts in the winter of 1865/1866 [Fig. 6.8]. This event had been noted by himself in his annual "Report" about Observatory's activities covering the time-span from June 1865 to May 1866. Otto Struve had written: *"Due to the acquirement of the photometer the Observatory is now equipped with one of the main instruments for performing the astrophysical research"*, adding, however, also the following remark:

"This will still more split up our forces and distract the astronomers to such themes which, although belonging essentially to the Stellar Astronomy, do not bear any

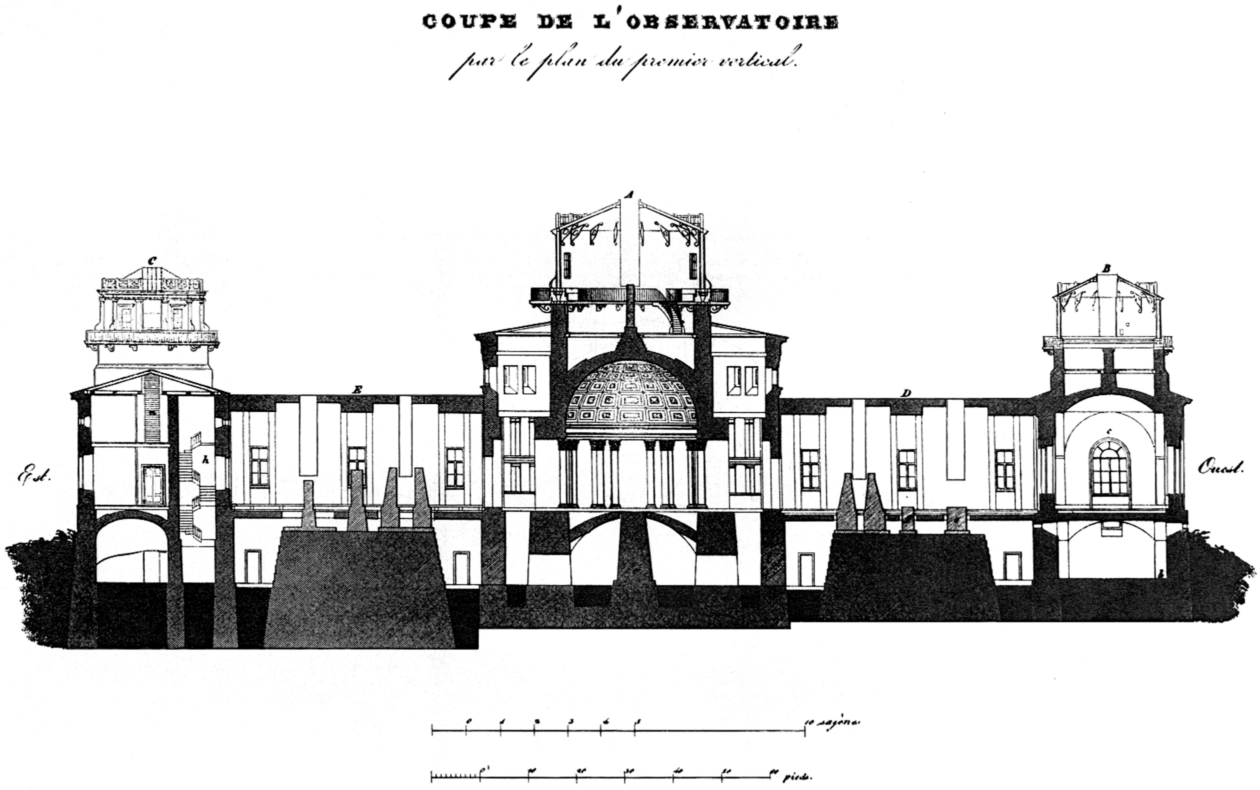

Figure 6.4: *The sectional view of the Nicholas Central Astronomical Observatory (Pulkovo Observatory) in the First Vertical Plane (Pulkovo Observatory, St. Petersburg)*

similarity to our main works because of the kind of their performance and of the state of their development."

But from the other side, Struve agreed with the extraordinary importance of the astrophysical data concerned with the properties of celestial objects and, therefore, he asked Giovanni Donati who was the director of the Physical Observatory in Florence to take his personal care and supervision over manufacturing the spectroscope for the Pulkovo Observatory which had finally arrived in Pulkovo in 1865.[2] Moreover, due to the increasing value of the Astrophysics in the astronomical world community Otto Struve had acquired the spectral device from Georg Merz and the photometer of Karl Friedrich Zöllner. The Observatory obtained from London the three instruments for the observations of the passage of Venus across the Sun's disk: the photoheliograph, the portable heliometer and the portable refractor. In his annual "Report" for 1867 to 1868 Struve wrote:

"The permanent increase of the importance of the Astrophysics has prompted me in the past year to increase the amount of instruments related to these subjects, i. e. to order the spectral device from Georg Merz and the Zöllner photometer."

After these instruments arrived at the Observatory the observations with the Zöllner photometer started already in 1868 and continued up to 1886, the first observer being Per G. Rosén [Fig. 6.7] who made photometric measurements for stars of various stellar magnitudes. Eduard Lindemann (1842–1897) [Fig. 6.6] had begun to work with the Zöllner photometer in 1873 and observed the same star groups as Per Rosén did and by 1874 he made already ca. 400 determinations which allowed to find out the luminosity ratios for stars from the 3^{rd} to the 9^{th} stellar magnitudes. Eduard Lindemann measured the stellar magnitudes until 1884.

His main results were published in the monographs *„Helligkeitsmessungen der Bessel'schen Plejadensterne"'* (1884) and *„Photometrische Bestimmung der Grössenclassen der Bonner Durchmusterung"'* (1889). Otto Struve noted in his "Reports" that the weather in Pulkovo considerably hindered these observations, and in his letter addressed to Leopold Berkiewicz (1828–1897), director of the Astronomical Observatory of the New-Russia University in Odessa, and dated April 21, 1873, he proposed to perform there astrophysical and photometric investigations. These works were continued at the Odessa Astronomical Observatory by its director Alexander Kononowicz (1850–1910), the successor of Professor Berkiewicz, who published several monographs on photometry ["Фотометрические исследования планет Марса Юпитера Сатурна" (Photometric investigations of planets Mars, Jupiter and Saturn), "Определение альбедо белого картона" (Determination of the albedo of the white cardboard)].

Figure 6.5: *The Round Hall of Pulkovo Observatory (Courtesy of Pulkovo Observatory, St. Petersburg)*

In the same letter addressed to Berkiewicz Otto Struve had pointed out the meteors – the "shooting" stars – as the worthwhile objects to be observed in Odessa. This subject was earlier mentioned by Otto Struve in his letter to Giovanni Schiaparelli, the Director of the Osservatorio astronomico di Brera:[3]

The additional volume of the "Supplements aux Observations de Pulkova" was published in 1888. It contained the results of photometric measurements of the brightness of stars from the 3rd to the 9th stellar magnitude which are included into the famous "Bonner Durchmusterung" catalogue.

The astrophysics was rather slowly entering the scientific research domain of the Pulkovo Observatory because of several causes:

- Firstly, at the very beginning of the existence of the Observatory only astrometric and astronomical-geodetical problems had been posed to be solved although the astrophysical research work was already performed at many European observatories. Perhaps, it was caused by the meteorological conditions in Pulkovo which were rather unfavorable for astrophysical observations, in general.
- Secondly, Observatory was technically backward as compared with observatories in Europe and the United States of America.
- Thirdly, the scientific staff of the Observatory was extremely small: there were only five astronomers (Georg Fuss, Friedrich Peters, Georg Sabler, Otto Struve, including the Director Wilhelm Struve) to use five big instruments. In spite of the fact that later, from 1857 on, two positions of adjoint-astronomers and two positions of calculators were added to it, the greater part of the work time was spent on the treatment of current observations including those made earlier by Wilhelm Struve himself.
- And fourthly, there were still no experts in the Astrophysics at that time at the Observatory.

It was in 1868 that Otto Struve addressed the Committee (a sort of the Board of Directors) of the Observatory with a request to introduce a position of the Senior Astronomer into the Observatory staff for Professor of Astrophysics Karl Friedrich Zöllner from Leipzig but the Imperial Academy of Sciences did not approve this application. Otto Struve repeatedly submitted the analogous request in 1881 but with no result again. It was only in

1883 that the astrophysicist position had been approved by the Committee, and it was given to Bengt (or: Klas Bernhard) Hasselberg (1848–1922) [Fig. 6.15] who began his astrophysical activities at Pulkovo Observatory in 1876 establishing there the so called physical cabinet. By the way, it was the same Bengt Hasselberg who had written later on 1901 in Stockholm an introduction (in Latin) to the reprint in a black-and-white facsimile of the 1598 edition of Tycho Brahe's famous treatise *Astronomiae instauratae mechanica.* The treatise had been composed and dedicated "... to the Holy Roman Emperor, Rudolf II" by Tycho Brahe after he left his Uraniborg on the island of Hven and found his refuge by Heinrich Rantzau who allowed Tycho to stay at his estate in Wandsbek near Hamburg.

Figure 6.6: *Eduard E. (Eduard Yevguen'yevich) Lindemann (1842–1897) (Pulkovo Observatory, St. Petersburg)*

It was Hugo Gyldén (1841–1896) [Fig. 6.11], an outstanding expert in Celestial Mechanics, who worked in 1862 to 1865 at the Observatory on a physical theory related to the problems concerning the refraction of light in the terrestrial atmosphere and published in Saint-Petersburg as *Untersuchungen über die Constitution der Atmosphäre und die Strahlenbrechung in derselben* (1866) and *Über eine allgemeine Refractionsformel* (1868). His theory had been implemented by Alexander I. Gromadzki in his famous *Tabulae refractionum in usum speculae Pulcovensis congestae* (*Tables de Refraction de l'Observatoire de Poulkovo*) computed by himself und published in 1870. These "Tables" were re-published four times since then and are being used until the present time to correct the astrometric and geodetical observations of stars for refraction.

In his annual "Report" for 1877–1878 Otto Wilhelm Struve wrote about necessity to establish an astrophysical laboratory. He believed, however, that for the time being it were not rational to engage only in astrophysical researches because of "a rather great unsteadiness" of theoretical foundations for such investigations but he added that "the assistance in strengthening of foundations of the Astrophysics appears to be very desirable. We are guided by this reason in the choice of new instruments for the Laboratory".

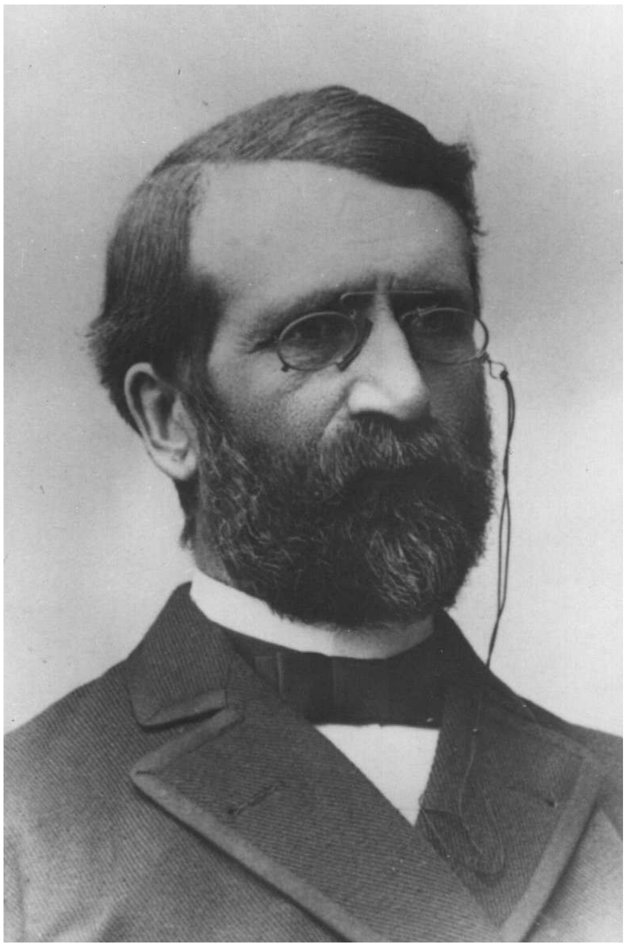

Figure 6.7: *Per Gustaf Rosén (1838–1914) (Pulkovo Observatory, St. Petersburg)*

The Astrophysical laboratory [Fig. 6.10] was built in 1886 due to active assistance and participation of the architect Alexander F. Vidov after the finances for the construction were received in 1885. The Laboratory itself occupied the majority of rooms in the ground floor of the building [Fig. 6.10]. The heliostat was mounted in the greater hall [Fig. 6.10, V]. The Sun light coming in from two southern windows could be directed to any part of the hall as well as to the hall where two big spectral devices were installed. One of them was intended to investigate the absorption spectra, whereas

Figure 6.8: *Pulkovo Observatory. The view in a winter (Courtesy of Pulkovo Observatory, St. Petersburg)*

the other one served for photometric and spectrophotographic measurements; besides those two devices there were other spectral devices, smaller in size, located in the same hall.

There were two photographic rooms in the Laboratory building [Fig. 6.10, II (the dark room) and III (the preparatory room)] in addition to the hall, the room for astrophotographic measurements and for preparation of the devices for work [Fig. 6.10, IV]. The Laboratory floor was solidly built and covered with asphalt in order to avoid vibrations. In the same building there were also the working office of the astrophysicist [Fig. 6.10, VI], the living quarters for astrophysicists and adjoint-astronomers and for the engineer and attendants [Fig. 6.10, IX] as well. The Alfred-Nobel-steam-engine and the Siemens-Halske electric generators were placed in the annex adjacent to the Laboratory. The electric batteries were situated in the separate room [Fig. 6.10, VII] in the Laboratory building.

The astrospectroscopic investigations at the Observatory were initiated by Bengt Hasselberg under supervision and by direct participation of Otto Struve. Hasselberg had spent much effort to establish the Laboratory and to equip it. In accordance with his instructions the Observatory's mechanician Wilhelm Herbst had manufactured a heliostat. Many new devices were acquired in addition to the available ones (the exposure meter, the vessel for water distillation, devices for the photochemical work, the Geißler air pump, the Weinhold device for mercury distillation, the voltmeter of Hofmann, the gasmeter). Moreover, the spectroscope for laboratory works was ordered and the Vogel astrospectrograph for the telescope was manufactured.

There were two topics in the primordial working plan of the Astrophysical laboratory concerned with the study of the exposure time influence upon the photographic image formation and with investigation of spectra of chemical compounds showing a similarity with those of the comets. The photographing of sun spots was initiated with the photoheliograph in order to study their formation process. The first-class prismatic spectroscope arrived in 1881 from Paris which was ordered earlier and considered to be the best in Russia at the time. Another spectroscope of medium size was presented to the Pulkovo Observatory by Saint-Petersburg Institute of Technology.

By that time, many scientific papers dealing with Astrophysics appeared in the world astronomical literature but Otto Struve believed the conclusions drawn from the astrophysical studies to remain "entirely shaky" unless a strict theory of light would be developed, and the phenomena observed on celestial objects would be confirmed by terrestrial experiments made in laboratories.

Bengt Hasselberg shared these views of Otto Struve. In his article "Астрофизическая Лаборатория" (The Astrophysical Laboratory) included into the volume "К пятидесятилетию Николаевской главной астрономической обсерватории. Описание 30-дюймового рефрактора и Астрофизической Лаборатории" (To the Fiftieth Anniversary of the Nicholas Central Astronomical Observatory. Description of the Astrophysical Laboratory) published in 1889 he had written:

"To the most gratifying successes of astronomical research in our century belongs doubtlessly quick and consecutive development of physical studies of celestial bodies ... The easiness of plucking seemingly ripe fruits has generated in this branch of Astronomy numerous amateurs who often are careless with respect to scientific prudence and strictness that are desirable and necessary where the foundations of a new science are being laid. Many erroneus and unsufficiently sound opinions have appeared due to this fact which are difficult to be eliminated. It is, therefore, very important to include the astrophysical investigations into the scope of major astronomical observatories and to create new scientific institutions for developing this new field of the science. The useful influence of these observatories is noticeable already now, the first place among which being occupied by the Königliches Astronomisches Observatorium in Potsdam."

Hasselberg investigated, in the first place, the absorption spectra of chemical elements and compounds aiming at determining the wave lengths of lines in various spectra. By comparison of the laboratory study results with observations of cometary spectra B. Hasselberg had discovered in comets some hydrocarbon compounds which were investigated by himself under laboratory conditions. Hasselberg had published his results in 1880 in the *"Mémoires de l'Observatoire du Poulkova"*. It was the first publication in the world which was dealing with the nature of comets. For expansion of his investigations onto the violet part of the spectrum Hasselberg made use of the so called "wet" colloidal photographic plates which he manufactured at first himself with his own hands. While investigating the spectrum of the Comet Wild he discovered the sodium lines which disappeared as the comet proceeded off the Sun, and while having studied the spectrum of luminescence of the mixture of hydrocarbons and sodium he had found this spectrum to be similar to that of this comet.

Hasselberg had performed a great work related to the analysis of the measurements of spectral lines of nitrogen (1,700 lines) and hydrogen (500 lines) on astrophotographs and continued to photograph the Sun aiming at the study of the nature of sun spots. The measurements of the astroplates was done at that time by Michael N. Morin.

In the autumn of the year 1886 Hasselberg moved to the new laboratory which was now completely equipped, and there, in 1887 and 1888, by use of the great spectrograph he investigated the absorption spectrum of the gaseous iodine, having measured the wave lengths of 3,500 lines; his results were published in the "Mémoires" of the Saint-Petersburg Academy of Sciences again. But in spite of his first success in the research B. Hasselberg has left Russia for Sweden in May 1889 after he was elected a member of the Academy of Sciences of Sweden.

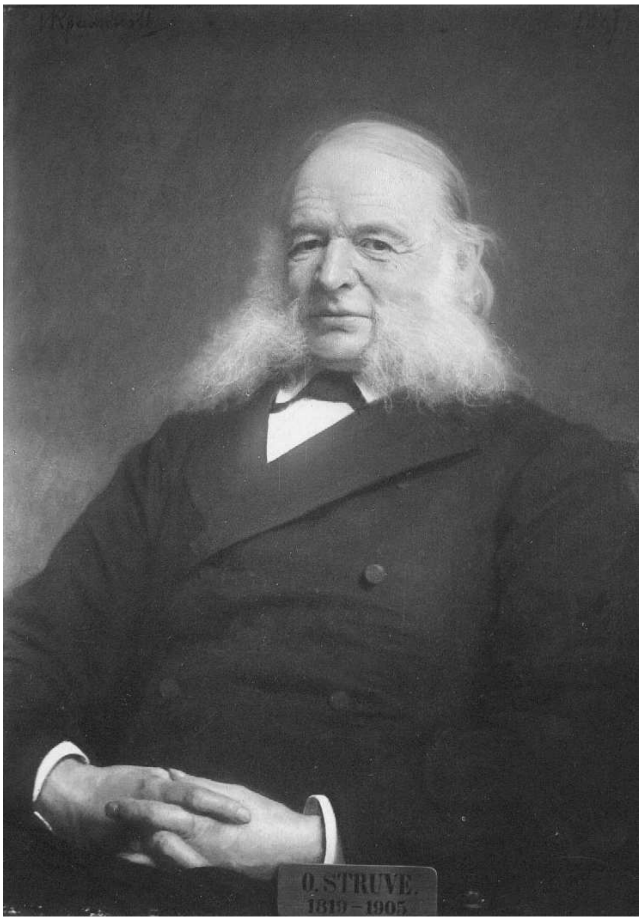

Figure 6.9: *Otto Wilhelm (Otton Vasil'yevich) Struve (1819–1905), director 1862 to 1889 (Courtesy of Pulkovo Observatory, St. Petersburg)*

The better conditions for development of astrophysical research were created in 1890 when Theodore A. Bredikhin (1831–1904) [Fig. 6.17], the former Director of Moscow Observatory, was appointed as Director of Pulkovo Observatory. He was well-known for his profound studies of comets and for his theory of forms of cometary tails. Bredikhin especially promoted astrospectroscopic studies.

He had appointed Aristarchos A. Belopolsky (1854–1934) [Fig. 6.17] who moved from Moscow to Pulkovo somewhat earlier as the Senior Astrophysicist. Belopolsky renovated the Astrophysical laboratory, designed and constructed more modern spectroscopic equipment and spectrographs which had been mounted on great

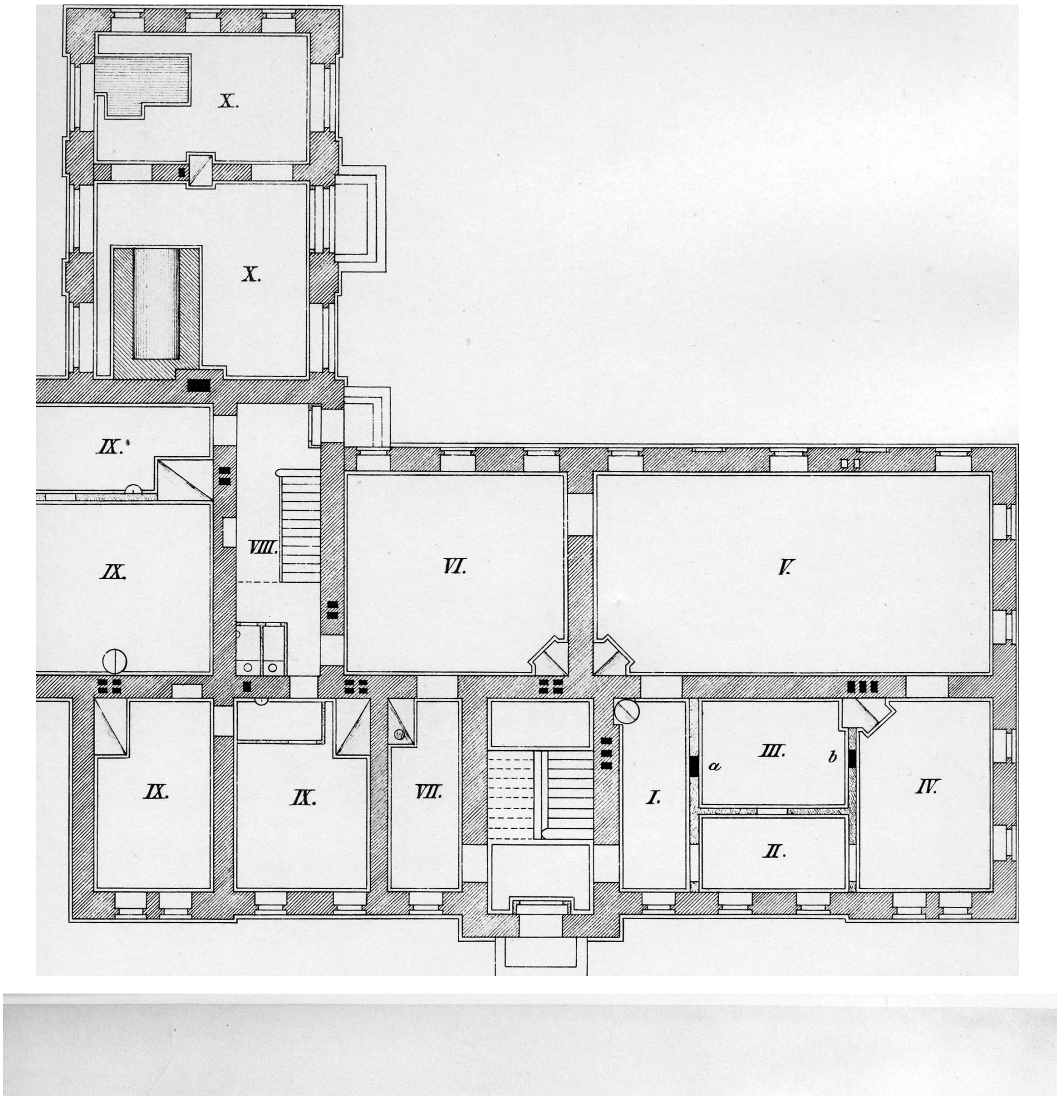

Figure 6.10: *Above: The Plan of the Ground Floor of the Astrophysical Laboratory Below: The Astrophysical Laboratory, architect Alexander F. Vidov (1886) (Pulkovo Observatory, St. Petersburg)*

telescopes of the Pulkovo Observatory (the 30-inch Clark refractor [Fig. 6.14], the biggest telescope of the Observatory, was equipped beforehand with the Toepfer spectrograph and was used by Belopolsky exclusively for the astrophysical work; this refractor had been placed in the dome [Fig. 6.18] which was specially designed and built for it by the military builder, General Paucker).

Belopolsky had explored the rotation of Jupiter making use of numerous observations made by various observers and established the fact that Jupiter doesn't rotate like a solid, *i. e.* that it is performing the differentiated *zonal* rotation: the rotation period of the equatorial zone is different from those for higher jovigraphic latitutes. He had applied the same method to his study of the Sun's rotation using measurements of the motions of the faculae on numerous photoheliograms obtained by Hasselberg in 1881 to 1888 and had come to the analogous results: the periods of the Sun's zone rotation increased as the heliographic latitudes increased. Belopolsky had returned to the detailed studies of the Sun' rotation later on in 1905 making use of the spectroscopy.

It may be noted that the systematic photoheliographic observations of the Sun made by Hasselberg and Belopolsky in 1881 to 1895 could be considered as establishing the regular Solar observation service in the Pulkovo Observatory. Of a certain astrophysical interest were also the observations of the particular phenomena such as passage of solar spot groups through the Sun's disk central meridian and of terrestrial magnetic storms made simultaneously at the Pulkovo Astronomical Observatory and the Pavlovsk Magnetic Observatory as having been arranged in 1892.

The introduction of the astrophotography as of one of the powerful methods for astrophysical researches at the Pulkovo Observatory is inseparably linked to the name of Professor Sergius K. Kostinsky (1867–1936) [Fig. 6.12]. Kostinsky had graduated from the Moscow University in 1890 and worked at the Pulkovo Observatory since 1894. The main direction of his activities was concerned with applying of the astrophotography to Astrometry. In 1895 Kostinsky spent several weeks at the Imperial Astrophysical Observatory Potsdam with Julius Scheiner who was a well-known expert in astrophotography and astrospectroscopy, going afterwards to Groningen University where he got acquainted with the techniques developed by Jacobus Kapteyn. So, it was Kostinsky who had laid at the Observatory the foundations of a new branch of the astronomical science – of the photographic astrometry.

The collection of photographs of the starry skies had been created in the framework of the international astronomical undertaking known as the *Carte du Ciel* by use of the normal astrograph (the "photographic" objective lens of 330 mm (13-inches) and of the focal length of 345 cm (135.8-inches), the plate dimensions being 16 cm by 16 cm, the scale $19''.81$ per 1 mm; the "visual" objective lens of 250 mm (9.8-inches) and of the focal length of 350 cm (137.8-inches)). The optics of this telescope was manufactured by Henry Brothers in Paris while the mechanical parts of it were made by Repsolds in Hamburg. This collection was accumulated by Professor Kostinsky and contained snapshots of regions of the sky which were included also into the Kapteyn's plan, launched in 1906 for a major study of the distribution of stars in the Galaxy, using the counts of stars in different directions. This enormous project had involved measuring the apparent magnitude, spectral type, radial velocity, and proper motion of stars in 206 areas (the Kapteyn areas) and was presenting the first coordinated statistical analysis in Astronomy in the framework of the international cooperation of over forty various observatories. Kostinsky also was successful in his determinations of stellar parallaxes the results of which were published in 1905 as *"Untersuchungen auf dem Gebiete der Sternparallaxen mit Hilfe der Photographie"*.

Figure 6.11: *Right: Hugo Gyldén (1841–1896) (Courtesy of Pulkovo Observatory, St. Petersburg)*

The photographs collected by Kostinsky had constituted the basis of the famous "Pulkovo Glass Library" which contained the astroplates exposed at the Observatory from1893 to 1940 (nowadays there are ca. 900 astroplates which survived the WW II period).

Their comparison with the astroplates exposed at the Pulkovo Observatory at later epochs served as a basis for compilation of the catalogue containing the proper motions of 18,000 stars which are located in the Kapteyn Selected Areas. Kostinsky had determined the proper motions of many nebulosities as well. He had photographed the major planets Saturn (in 1906–1920) and

Figure 6.12: *Left: Sergius K. (Serguey Konstantinovich) Kostinsky (1867–1936) Right: Jöns Oskar (Oskar Andreyevich) Backlund (1846–1916) (Pulkovo Observatory, St. Petersburg)*

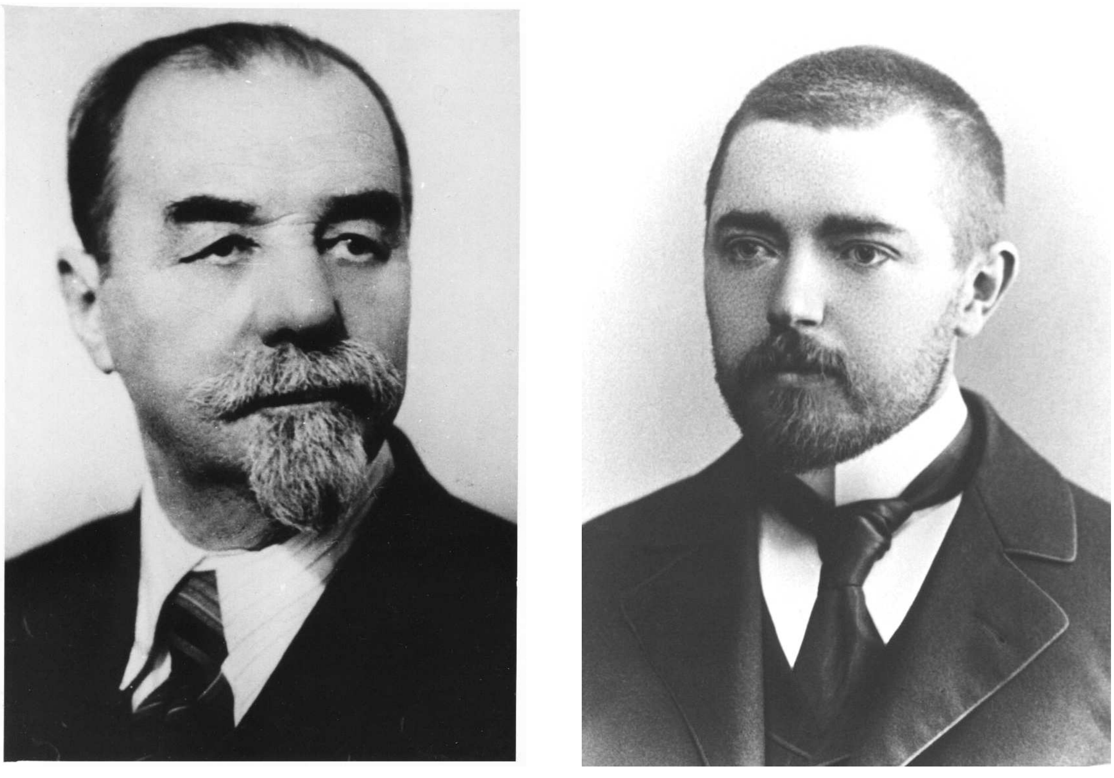

Figure 6.13: *Left: Gabriel A. (Gavriil Andrianovich) Tikhov (1875–1960) Right: Alexis P. (Alexey Pavlovich) Hanski (1870–1908) (Pulkovo Observatory, St. Petersburg)*

Neptune (in 1899–1920) with their satellites, particularly Triton, the satellite of Neptune, which is especially hard to observe.

These photographic observations, made by Kostinsky, have played an important rôle in constructing precise theories of motion for these objects of the Solar System by use of the Celestial Mechanics methods. This was done, in particular, by Hermann Struve (1854–1920), the elder son of Otto Struve.

Kostinsky made outstanding contributions to the study of accuracy of the astrophotographic methods and into their perfection. In particular, in 1906 he discovered the phenomenon of "interaction" (the repulsion) of two adjacent photographic images of components of close binaries (which has been called the "Kostinsky effect"). Later there was found the effect of attraction of close images.

Kostinsky's interests were spread over many fields of the Positional Astronomy: he successfully investigated also the problem of variability of geographic latitudes and derived the formula for computation of the terrestrial pole coordinates which has been named after him (the "Kostinsky formula").

The further promotion of Astrophysics in Pulkovo Observatory is closely related with Jons Oscar Backlund (1846–1916) [Fig. 6.12] who was appointed the Director of the Observatory in 1895.

Oscar Backlund was famous for his thorough studies of the motion of the periodic comet Encke which is known nowadays as the Encke-Backlund comet. Backlund continued to support the astrophysical research at Pulkovo Observatory in every possible way and in 1912 established the Simeiz branch of the Observatory where the astrophysical studies played the major rôle. The grounds and pavilions of the Simeiz Observatory were presented to Pulkovo Observatory together with the first-class telescopes (the Zeiss Astrograph with two photographic cameras, the Rheinfelder & Hertel refractor) and other astronomical instruments and accessories by brothers Nikolaus and Iwan Maltsevs in 1908. By the way, the astronomers of the Simeiz Observatory have celebrated the centenary of it this year.

By this time, Belopolsky succeeded in precise determinations of radial velocities of stars at Pulkovo Observatory discovering many spectroscopic binaries. Moreover, he began to spectroscopically determine the axial rotation velocities for major planets (Jupiter, Venus, Saturn and Mars) and the rotation velocities of the Saturn's rings obtaining in 1895 the results which confirmed the theoretical investigations of Sophie (Sonja) Kowalewskaya concerning the meteoroid structure of the Saturn's ring. A decisive rôle in the final solution of this problem had been played by photometric studies of the Saturn's rings performed in 1906 by Gabriel A. Tikhov (1875–1960) [Fig. 6.13]. It should be noted, however, that in his letter of January 1901 to Otto Struve Giovanni Schiaparelli had expressed some doubts about correctness of Belopolsky's results concerning the rotation of Venus.[4] As a matter of fact, Belopolsky couldn't make any definite conclusion because of extremely slow rotation of Venus, except that he pointed out that its rotation period should exceed 34 hours.

Figure 6.15: *Bengt Hasselberg [Klas Bernhard] (1848–1922) (Pulkovo Observatory, St. Petersburg)*

In 1899–1901 Belopolsky had constructed an original special device to prove the validity of the Doppler-Fizeau principle. It was similar to a watermill with two wheels to which the mirrors were attached. Belopolsky had found the perceptible shift of spectral lines making use of spectroscopic measurements of the velocity of motion of images formed by multiple reflections from the rotating mirrors.

Belopolsky determined the radial velocities of comets, too, observing, in particular, the spectra of comets in 1911 and in 1914 as well. He observed the spectrum of the Sun and of the formations on its surface succeeding in 1915 as the first in the world in determination of the sunspot temperatures. His achievements in astrophysical research were marked by his election in 1902 to the Editorial Board of the *Astrophysical Journal*.

G. Tikhov determined the colours of various stars from his observations made with the short-focus wide-aperture astrograph, especially of those belonging to the stellar clusters. This astrograph was equipped with the Zeiss objective lens of 170 mm (6.7-inches) in diameter and of the focal length of 80 cm (31.5-inches) and had been acquired by Bredikhin for his own money and later was named after him. Tikhov used the so-called *longitudinal spectrograph* method for this end and based his

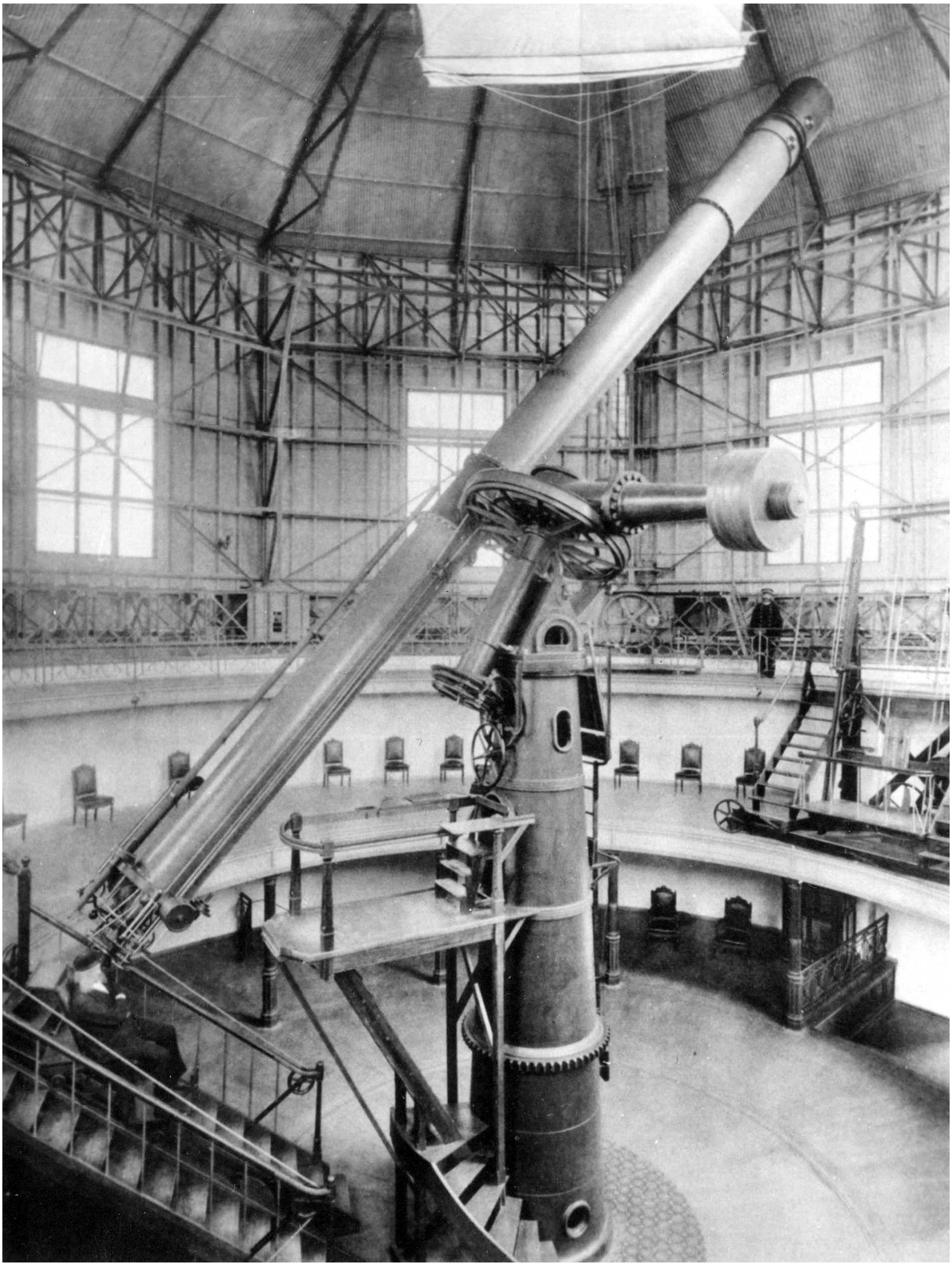

Figure 6.14: *The 30-inch refractor (76 cm), the optics by Alvan Clark & Sons of Cambridgeport, Massachusetts, the mounting and the tube by A. Repsold & Söhne (1883) (Pulkovo Observatory, St. Petersburg)*

determinations on the difference in the appearance of extrafocal images of stars photographed by use of the objective lens with a considerable chromatic aberration. In 1908–1912 he discovered the selection effect in the light absorption by the interstellar medium, now known as the Tikhov-Nordmann effect. It was also discovered independently by Charles Nordmann in France. [It was the same Charles Nordmann himself, a French graduate student, who had undertaken the *first* radio astronomical experiments trying to detect radio waves from ... the Sun as early as 1900. He set up a long wire antenna on a glacier on Mont Blanc at about 3,100 m (about 10,000 ft). But he failed because the radio bursts occur most often during Solar activity maxima, and unfortunately the Sun was at the Solar activity minimum that year. (*Vid.*: Comptes Rendus Acad. Sci. **134** (1902), p. 273.)]. Tikhov observed also the spectra of stars and comets.

Figure 6.16: *Inna Nikolayevna Lehmann-Balanovskaya (1881–1945) (Pulkovo Observatory, St. Petersburg)*

Almost at the same time period Alexis P. Hanski (1870–1908) [Fig. 6.13] had obtained excellent photographs of the solar granulation and of the solar corona at the Simeiz Station of the Pulkovo Observatory and also investigated the meteor spectra. Earlier, during 1897–1905, he had climbed the Mont Blanc mountain 9 times for observations of the solar corona without the eclipses of the Sun and to determine the accurate value of the solar constant.

At the Pulkovo Observatory Dr. Inna N. Lehmann (1881–1945) [Fig. 6.16] (who was a student of Karl Schwarzschild during her learning stays at Göttingen and Potsdam before WW I) discovered variability of the radial velocities of some stars, particularly, of the star δ Cephei, thus confirming the pulsation hypothesis proposed by Nicholas A. Umov, a Russian physicist from the Moscow University, and of the star α Geminorum which is caused by changes of the orbital elements of this eclipsing binary. Later Mrs. Lehmann-Balanowsky had worked on continuation of the *Yerkes Actinometry* and determined to a high accuracy the photographic magnitudes of 2,135 stars listed in the *Bonner Durchmusterung*, thus contributing to compilation of the Pulkovo astrophotographic photometric catalogue. It should be noted that later, in 1937, Dr. Lehmann-Balanowsky had been arrested the Soviet secret police NKWD together with her husband Innokenty A. Balanowsky as well as with a dozen of other Pulkovites accused "in wrecking activities" in the framework of the so-called "Numerov (Pulkovo) Affair".

This period of time around the changing of centuries had definitely pre-determined, and laid foundations of, the further development of the astrophysical research in Solar Physics, Physics of Stars and Nebulosities at the Pulkovo Observatory before the WW II.

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1. From Otto Struve's letter of December 8, 1865:
   „Dagegen haben wir noch kurz vor Schluß der Schiffarth das langerwartete Photometer von Schwerd erhalten. Da aber gleichzeitig mit seinem Eintreffen hier auch bedeutende Kälte eintrat, könnten wir es nicht mehr in dem für dasselbe bestimmten Thurm aufstellen, sondern lieber es nur vorläufig in einem Saale zusammengelegt. Alle Versuche mit demselben müßen wir deshalb bis zum nächsten Frühjahre aufschieben."'
2. Ibidem: *„Von Donati hatte ich vor 4 Wochen die Mittheilung, daß ihm unser Spectrograph vortrefflich gelungen und daß dasselbe bereits abgesandt sei. Noch ist dasselbe nicht angelangt und das macht mich etwas besorgt, ob nicht bei der Absendung irgendein Versehen begangen ist."'*
3. From Otto Struve's letter of May 12, 1868:
   „Ihr neuestes Sternschnuppenopus haben wir noch nicht erhalten. Ich bin aber sehr gespannt auf dessen Inhalt und werde deshalb an Voß schreiben, daß er es nicht zu lange bei sich liegen läßt. Unser Klima ist entschieden nicht für derartige Beobachtungen qualificirt. Mehrfache Versuche, die wir im Laufe des vergangenen Jahres gemacht haben, sind alle kläglich ausgefallen. – Im Winter haben wir nur selten anhaltend klaren Himmel, oder wenn das der Fall ist, so findet auch zugleich strenge Kälte statt und von Mai bis August sind die Nächte zu hell."'
4. From Giovanni Schiaparelli's letter of January 4, 1901:
   "Pour le moment je crois que les recherches de Bélopolsky ne démontrent rien de bien positif sur la rotation de Vénus. L'incertitude de son résultat est très

considerable. Mais je crois, qu'on finira par arriver, en suivant cette voie, à une décision sur la question. Quant à moi, je n'ai aucun doute sur le résultat final. À dire vrai il se présente, dans ce problème, une difficulté théorétique, qu'il faudrait résoudre bien clairement; faut-il dans le calcul des expériences, considerer la vitesse relative de Vénus et de la Terre, ou le double de cette vitesse?"

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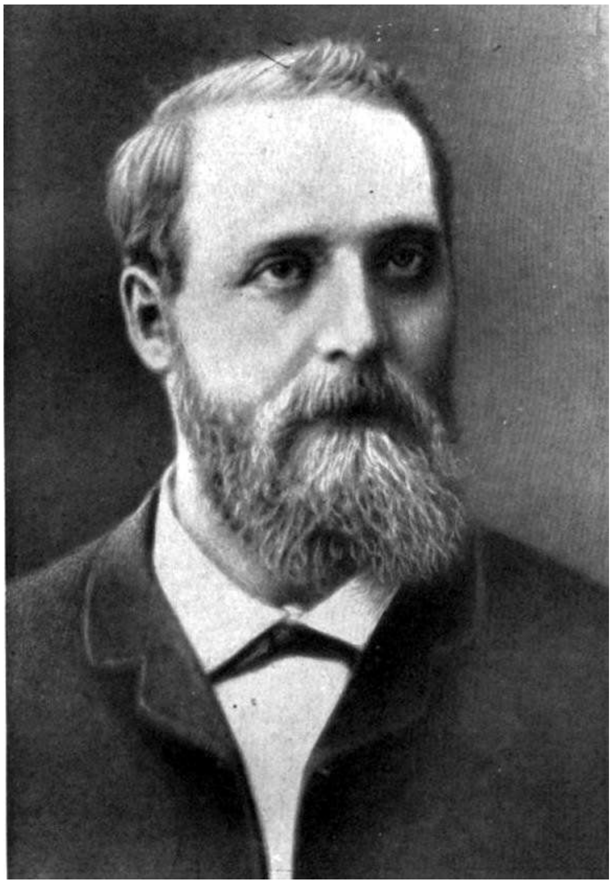


Figure 6.17: *Left: Theodore A. (Fyodor Alexandrovich) Bredikhin (1831–1904), director 1890 to 1895, Right: Aristarchos A. (Aristarkh Apollonovich) Belopolsky (1854–1934) (Pulkovo Observatory, St. Petersburg)*

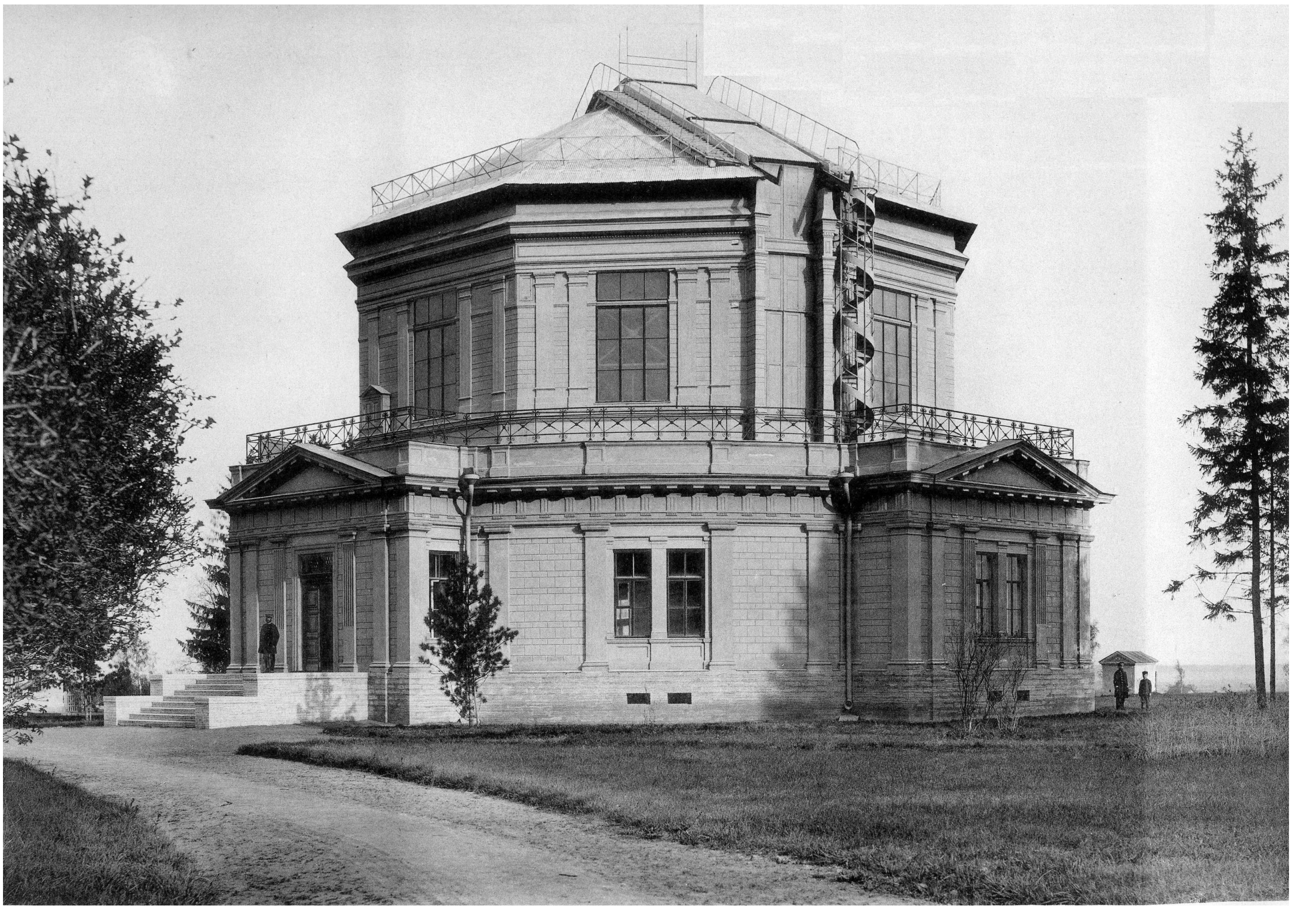


Figure 6.18: *The dome of the 30-inch refractor (Pulkovo Observatory, St. Petersburg)*

Figure 7.1: *Observatoire de Paris (Photo: Gudrun Wolfschmidt)*

7. Astronomy and Astrophysics at the Observatoire de Paris in the Belle Epoque

Suzanne Débarbat (Paris, France)

Abstract

The *Belle Epoque* considered at the Paris Observatory lies from about two decades before 1900 up to the beginning of World War I. Four directors were at its head during those years: Admiral Ernest Barthélémy Mouchez (1821–1892) from 1878 up to 1892, François-Félix Tisserand (1845–1896) during only four years between 1892 and 1896, Maurice Lœwy (1833–1907) from 1897 to 1907 and Benjamin Baillaud (1848–1934) from 1908 up to 1926, a long mandate which ended seven years after the end of World War I. All of them have marked the Observatory and its activities in different fields.

7.1 Admiral Mouchez, a Difficult Succession at the Head of the Observatory

After the difficult period of the collective directorship of the Paris Observatory by the *Bureau des Longitudes*, the French Board of Longitudes, from 1795 up to 1853 the year of the death of François Arago (1786–1853), had come the era of Urbain Le Verrier (1811–1877). His character was more or less difficult but it is known that he suffered from stomachal disease and such people are known for being not easy persons. After the success of the discovery of Neptune, Le Verrier, a man full of authority, developed mostly celestial mechanics when he was asked to be director of the Observatory, in 1854.

All the realizations he made during the years he was responsible of the Observatory activities are very often forgotten: a new and modern meridian circle is installed in 1863, the precision of time determinations is increased and its diffusion made through the electric telegraph; he developped meteorology leading, after his death to the creation, outside of the Observatory, of an independent *Bureau Météorologique*. He was also interested in geodesy, longitude and latitude; he is at the origin of the publication of all the observations performed at the Observatory during the directorship of the *Board of Longitudes* later useful for further developments in the field of celestial mechanics in the world including uses for space research.

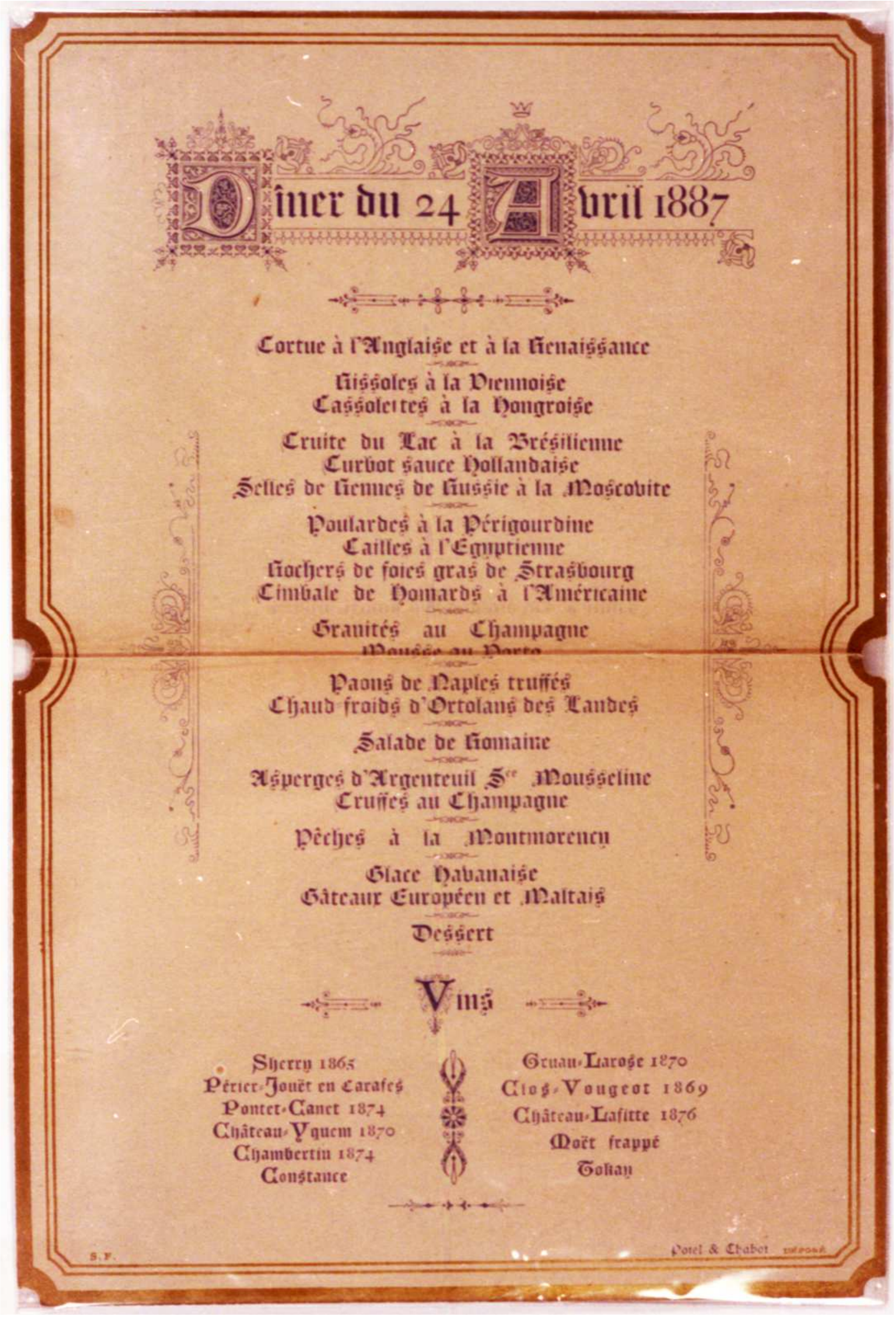
Such was the man to whom Admiral Ernest Mouchez had to succeed. At the death of Le Verrier, in 1877, Mouchez was a man of experience, fiftysix years old being an officer from the French Navy, who had made hydrographic campaigns in South America, Asia, Africa. Mouchez was also an astronomical observer of the 1874 transit of Venus, in view of a new determination of the solar parallax. He was just called to be *contre-amiral* in 1878 when asked to be director of the Paris Observatory the same year.

7.2 Admiral Mouchez's Program and Realizations

In 1847, when attending a meeting of the British Association for Advancement of Science in Oxford, Le Verrier had a lodging close to F. G. Wilhelm Struve (1793–1864), then the successful director of the Pulkovo Observatory he had created in 1839. Invited by Le Verrier to visit him in Paris he came and stayed to weeks at Le Verrier's apartment, in the *Quartier Latin.* Following this sojourn, Struve send a letter in which he answered questions raised by Le Verrier about how to organize new researches in an observatory. Le Verrier will, later, took only partially account of the advices so given but Mouchez will follow others during the eighteen years of his directorship.

As well as during the past decades the ancient tradition of classical astronomy which began at the time of the creation of the Louis XIV' *Observatoire Royal* in 1667, was pursued: time determinations, three instruments in the East Wing of the building and a new meridian circle installed as early as 1878; the telegraphic diffusion of time is reorganized for Paris and enlarged to ports from 1880 and to the main towns of France, in relation with the developpement of the railway.

Beside these current works usual in observatories, Mouchez is at the origin of several new fields of astronomy or related to this domain. One year after his nomination he created the *Musée de l'Observatoire* collecting instruments, objects, out of use, calling others



Dîner du 24 Avril 1887

Tortue à l'Anglaise et à la Renaissance

Rissoles à la Viennoise
Cassolettes à la Hongroise

Truite du Lac à la Brésilienne
Turbot sauce Hollandaise
Selles de Rennes de Russie à la Moscovite

Poulardes à la Périgourdine
Cailles à l'Egyptienne
Rochers de foies gras de Strasbourg
Timbale de Homards à l'Américaine

Granités au Champagne
Mousse au Porto

Paons de Naples truffés
Chaud froids d'Ortolans des Landes

Salade de Romaine

Asperges d'Argenteuil Sce Mousseline
Truffes au Champagne

Pêches à la Montmorency

Glace Havanaise
Gâteaux Européen et Maltais

Dessert

Vins

Sherry 1865
Périer-Jouët en carafes
Pontet-Canet 1874
Château-Yquem 1870
Chambertin 1874
Constance

Gruau-Larose 1870
Clos-Vougeot 1869
Château-Lafitte 1876
Moët frappé
Tokay

S.F.

Potel & Chabot

Figure 7.2: *Astrophotographic Congress in Paris (1887) (Observatoire de Paris, Bibliothèque)*

sites to return those which had been lended by the *Bureau des Longitudes*, requesting photographs from world observatories. He installed all them, on the first level of the building now named *Bâtiment Perrault*, from his architect, Claude Perrault (1613–1688), in what is called *Grande Galerie*; old pieces were displayed in the *Rotonde Ouest*, on the same level, others and photographs were placed in the *Rotonde Est*. The West one was then decorated with portraits of French astronomers while the East one was garnished with portraits of foreign astronomers.

Together with the *Bureau des Longitudes* and the French Navy, Mouchez created, the same year, the observatoire du Parc Montsouris to form to astronomical and geodesic observations astronomers and officers of *La Royale* often so called in France. This observatory, not far from the Paris Observatory, on its south side, was in function up to World War II. Students, following courses at *La Sorbonne* and officers could learn how to use instruments in the parc recently set up at the time of Napoléon III.

Always the same year 1878, Mouchez requested and obtained the creation of a position of vice-director and asked Maurice Lœwy, arrived from Vienna in 1860, to take it. Lœwy having described an *Equatorial coudé* (from the french word for elbow) in 1872, Mouchez decided to install a first one in the park of the Observatory in 1882; a second one will be installed later, in 1890, in an another building dated 1889.

The Henry brothers, Paul (1848–1905) and Prosper (1849–1903) were astronomers at the Observatory being mostly interested in photographic astrometry, photography having taken a great development from the thirties of the 19$^{\text{th}}$ century. Several authors succeeded, from 1840, to take pictures of the moon, later of the Sun. Some pictures of very bright stars were obtained from 1857, the year Warren De la Rue (1815–1889) predicted that a cartography of the sky would be obtained in the coming years. In 1882, David Gill (1843–1914), at the Cape, obtained a picture of a comet and, through its queue he was able to see 40 to 50 stars. The idea came to him of mapping the sky up to faint magnitudes.

In 1885, at Paris Observatory, using an astrograph from Gautier (1842–1909), the Henry brothers had installed at the Paris Observatory, were obtained, after one hour, images of stars up to magnitude 16. After exchange of letters, between Gill and Mouchez, an international meeting was organized in 1887, held at the *Observatoire*. At the opening, on April 16, the *Ministre des Affaires étrangères*, in his talk among others considerations, said *Une ère nouvelle s'ouvre pour l'astronomie physique comme pour l'Astronomie mathématique,* [...] *un moyen d'investigation qui étendra dans une proportion indéfinie la finalité de leurs recherches.* The new era and the way were open to what was called at that time *astronomie physique* not yet *astrophysique*.

There were 56 participants and, in the evenings, festive distractions were offered such as an official diner held in the *Grande Galerie*, including only one lady, the wife of Mouchez! At the closure, Mouchez said that he considered that the *Carte du Ciel* (the same expression in all languages for this international enterprise and its realization), is a very important one. A Struve, at this time Otto (1819–1905), one of the eighteen children of Wilhelm, was elected president; he was, at that time, the director of Pulkovo Observatory. Several meetings will be organized during the followings years including two during the Mouchez's life; in 1889 during which five observatories joined the eleven of 1887 and in 1891, with new adhering observatories; among them, the new *Specola Vaticana*, just created to join the international enterprise.

Meanwhile, in 1884, the *Bulletin Astronomique* was created, under the leadership of Henri Andoyer (1862–1930) a remarkable teacher, for celestial mechanics, in *La Sorbonne*. This publication disappeared in 1968, being mixed with other publications to give birth to "Astronomy and Astrophysics", from 1969.

En 1889, Mouchez created at the Paris Observatory for Henri Deslandres (1853–1948) a *Service de spectroscopie stellaire* offcially mentionned in the 1890 annual Report. Its includes a long texte by Deslandres himself after one year of activity concerning mostly the uses of several instruments: the great telescope installed in 1871 and a siderostat from Foucault (1819–1868), equipped with ancient spectroscopes, modern ones being not yet available.

In 1892, during February, Mouchez organized a *Bureau des mesures des clichés du catalogue* for the *Carte du Ciel* enterprise and surprisingly, in France and perhaps in other countries, a lady (Dorothea Klumpke, 1861–1942), was the head of the bureau. The first measuring machine employed was named macromicrometer; it was dismantled in the sixties of the 20$^{\text{th}}$ century.

Eighteen observatories were collaborating to the *Carte du Ciel* when Mouchez died suddenly in June 1892. Under his direction the garden of the Observatory was enlarged up to the *boulevard Arago* just created. At that time, nine services were existing plus the one in charge of the administration. Among them and simultaneously to the *Service de spectroscopie stellaire*, was in existence, under Charles Wolf (1827–1918) a *Service de Mathématique – Astronomie physique – Heure* but mostly, for astronomy physique, works on sismology and its relation with sunspots.

7.3 A few Years under Tisserand

Tisserand's father was a wet cooper in the town Nuits-Saint-Georges, famous for its burgondy wines. At the *École Normale Supérieure*, he went out first and was recruited at the Observatory by Le Verrier in 1866. The last one asked him to make a carefull study of the lunar theory recently published (1860) by his ennemy Charles-Eugène Delaunay (1816–1872) and in which he thought that the brilliant mathematician would find mistakes. Tisserand did not find any but, in doing so, he became a high level specialist in celestial mechanics. In 1868 he submitted a doctoral thesis giving to Delaunay's theory a more concise form and generalizing the results. Asked in 1873 to be director of the Toulouse observatory recently created and teacher in astronomy at the University.

In 1878, Tisserand was asked to return to Paris to be a teacher in rational mechanics and later, in 1883, celestial mechanics. His success in Toulouse and at the Sorbonne, explain why he was asked to be director of the Paris Observatory after the sudden death of Mouchez. Delaunay had been associated for the creation of the *Bulletin astronomique* in which were published important articles by Henri Poincaré (1854–1912). Tisserand's most important book was his *Traité de mécanique céleste* published in four volumes the years 1889 to 1896, and the last one the year of his death from a fatal stroke. The importance of this treatise can be measured by the fact that it took the third rank after the *Principia* by Isaac Newton (1643–1727) and the *Mécanique céleste* of Laplace (1749–1827) and before the works of Poincaré and Albert Einstein (1879–1955).

Tisserand's *Mécanique céleste*, still in French was republished in *facsimilé* in 1960 for volumes one and two and, in 1990, for the complete set of four volumes. It was said that it was made, mostly, upon request of specialists in the domaine from the US. His name is still known attached to the *critère de Tisserand* related to the apparition of comets to know if they are real new ones or correspond to a return of an old one.

Under his directorship Tisserand pursued in the fields developped by Mouchez following the evolution of researches and taking into consideration the equipment. The Arago refractor was employed for double stars and nebula. He had prepared, before his death, the meeting related to the *Carte du Ciel* to occur in 1896.

7.4 Lœwy, from 1896 to 1907

After the inexpected death of Tisserand, Lœwy and Deslandres are candidates to succeed him. Lœwy, already vice-director under Mouchez and under Tisserand, is chosen while Jules Janssen (1824–1907) who is at the origin of the creation of the *observatoire de Meudon*, in 1875/76, is seventytwo years old. Lœwy is younger of about ten years! Deslandres requested to be moved from Paris to Meudon. After having associated a spectroscope to Foucault's siderostat he had formed, in 1894, the project of a new instrument, the *spectrohéliographe*, at the same epoch as George Ellery Hale (1868–1938) in the US, independently.

Following Deslandres' departure from Paris Observatory, the *Service de spectroscopie stellaire* now mentionned under the form *Recherches spectroscopiques* will disappeared. In 1898, the *Service des équatoriaux,* responsible of all the equatorial refractors, was divided into the *Equatoriaux coudés* with Lœwy, the *Equatorial de la Tour de l'Ouest* under Guillaume Bigourdan (1851–1932), the *Equatorial de la Tour de l'Est* under Octave Callandreau (1852–1904), the *Carte photographique du ciel* being still, with its Gautier's equatorial, under Paul Henry.

The following year, 1900, last one of the Century, was held in Paris an *Exposition universelle* including what was called the *Grande lunette de 1900.* Many papers had been written on this subject from 1900 up to nowadays. The last one, by Françoise Launay from the History of astronomy group, included in the Paris Observatory Department SYRTE for *Systèmes de référence spatio-temporels,* appeared in the Journal for the History of Astronomy Vol. 38 Part 4 November 2007. This well documented paper includes eighteen pictures; among them an impressive view of the tube of a 60 metre long refractor with a Foucault's siderostat mounting and a general view of the instrument on which is seen the almost 2 metre mirror, nowadays in the Collections of the *Observatoire* together with the photographic objective (including flintglass and crown-glass) having 1.25 m in diameter; Gautier was the maker. F. Launay ends her article with informations and pictures, taken with this instrument by several observers, and very nice for the time being.

The astronomers of the Paris Observatory were not so much interested by the new gigantic instrument. They were engaged in other purely astronomical activities, the *Carte du Ciel*, the *Atlas de la Lune* and in an important astrographic conference (1900, July 19–26) to be held in Paris including decisions to be taken at the international level for the *Carte du Ciel* enterprise. During the same meeting an international campaign for the small planet Eros is decided, in view of a modern determination of the solar parallax; fortyeight observatories will take part in this new international form of cooperation.

Among the photographs presented by the *Observatoire de Paris* at the 1900 *Exposition Universelle,* were included pages of the *Atlas photographique de la Lune*, two observed from 1896 including enlarged ones (diameter 1.38 m) close to the first and the last quarter. The observations performed at the *Grand Coudé* were achieved in 1910, mostly taken by Lœwy himself and Puiseux (1855–1928) with the collaboration of Le Morvan (1865–1933) who, later, published a reduced *Atlas de la Lune* more easy to consult. All those who have travelled among observatories in the world may have seen several of them in each one at least from that time up to the space images of our satellite; they were of very high level quality. The collection of plates is still in the Collections of the Paris Observatory.

Among the new fields of research anounced by Lœwy in his annual report for the year concerns mostly the new spectroscope, from Gautier's workshop, to be installed on the *Grand Coudé.* Another field will be a new method by Nordmann (1881–1940), to begin experiences about heterochrom photometry for variable stars. In his 1906 annual report, Lœwy mentionnes that due to the importance of this field, Nordmann will be working mostly in this photometric domain. On the other hand a *Service d'astrophysique* is recreated, under this name, with Maurice Hamy (1861–1936) at its head. The new spectroscope was installed on the *Grand coudé*, the priority of the use of the instrument being the *Atlas de la Lune*.

The *Carte du Ciel* was also an important subject for Lœwy during the international meeting, held to uniformize the astronomical constants. Several of them resulted from a more or less mean of different determinations by several astronomers and, proposed by Lœwy, with one only issued from a further study to be made by Newcomb (1835–1909) from the US Naval Observatory.

Similarly to his predecessors, Lœwy died suddendly in October 1907 during a meeting of the *Conseil des observatoires.* Immediately Henri Deslandres took rank to suceed him, Pierre Jules Janssen (1824–1907) being not yet dead despite his age, eightythree years. Benjamin Baillaud, then director of the Toulouse Observatory and professor at the Faculty for sciences was chosen. Fortunately for Deslandres, Janssen died next December and he was asked to replace him at the *Observatoire de Meudon.*

7.5 Baillaud, Successor of Lœwy

Baillaud, already fiftynine, was known at the Paris Observatory of which he was a member in 1874 at the time of Le Verrier. After his doctoral thesis, he became supply teacher in 1877 at *La Sorbonne*, when Le Verrier began to be very ill and died in September, and in 1879 he went to Toulouse.

Baillaud was a remarkable organizer and a man full of dynamism. The Observatory will get a more extensive rôle, being a very active participant in the *Carte du Ciel* enterprise. After his nomination, in 1908, as director of the Paris Observatory Baillaud pursued his activities, non only in the field of this domain but also directed research to new and modern ones, and he was an astronomer very fond of international cooperation. Baillaud played an importanty rôle mostly in two domains: astronomical constants and ephemerides, time and longitude not only useful for the scientists but also for the world in general. Some of these subjects had already been engaged by his predecessor Lœwy.

In the domain of longitude and time, the development of the railways and of the electric telegraph will be at the origin of the evolution. The first modern occurence of time unification came during a geodetic international congress in Roma, in 1883, followed by another conference, in 1884, in Washington, for time zones including an unique meridian of reference for longitude and time, including also a "universal hour" as said at that time. The system was adopted with the choice of the Airy meridian (Greenwich Observatory) as the international reference. At that time France did not introduced it but, in 1891, time was unified at the national level with the reference to the Paris Observatory meridian.

In 1899 the very first time signals were launched from Hambourg, as Gudrun Wolfschmidt recalled, but nothing special came out. Nevertheless, longitude campaigns were organized under Lœwy from 1902, through the electric telegraph, to determine, with the best possible accuracy, longitude differences between Paris and important towns such as Greenwich, Bizerte, Uccle, Washington. The last campaign ended in 1914, under Benjamin Baillaud. Meanwhile commandant Ferrié (1868–1932), later general, in cooperation with the Paris Observatory, could launch time signals using the altitude of the Eiffel Tower to send them around it, up to five thousand kilometers. The French *Board of Longitudes* was associated in all these operations at that time its president was Poincaré (1854–1912); the very first regular time signals had been sent on November 21, 1910.

This success decided France, in 1911, to adopt the time zones and Greenwich meridian. The following year, 1912, an international scientific congress, held in Paris, made proposal for an international convention for a universal hour to become later *temps universel.* An official similar meeting was held in Paris, in 1913, with the creation in Paris of a *Bureau International de l'Heure (BIH)* under the responsability of the Paris Observatory, and more or less under the responsability of Baillaud who received the very effective help of Bigourdan to became director of the BIH, already head of the *Service de l'heure* from 1900. At the end, on October 25, the convention and the decisions proposed in 1912 were officially adopted by the participants but only signed by the duly authorized representatives of their Governements. 1913 was the year before World War I and it was more or less the end of the *Belle époque.*

Another international subject of Baillaud's time was the astronomical constants and the ephemerides. The system adopted in 1896, under Lœwy, was followed, in 1911 in Paris, by the *Congrès international des éphémérides astronomiques.* At the origin, Andoyer from the French Board of longitudes who was in charge of the scientific programme and the meeting organized by Baillaud.

During this Congress, important decisions were taken by the astronomers in charge of the six main national ephemerides: Allemagne, Angleterre, Espagne, Etats-Unis, Italie, France. The most important parts were the decisions to have a coordination of the realization of the ephemerides and to give similar presentation of the data in the different star catalogues and publications of the observations. When using different ephemerides, astronomical, nautical and aeronautical ones, data are easily found by users, even they don't know the language.

Not to be forgotten the rôle Baillaud played for the *observatoire du Pic-du-Midi* beside other people. From 1882, after France became in charge of the recently built observatory in the Pyrenees, he was asked to be a member of the committee in charge of checking for the establishment. In 1901, when in Toulouse, he was asked to study the possibility to equip for astronomical observations the Pic-du-Midi, in the surroundings of the meteorological station. Experiments were made with a Foucault's reflector of 30 cm in diameter. Under Baillaud's responsability building for astronomical observers and instruments are installed during the summers of 1904 to 1907, including a large cupola allowing to house a double equatorial with english mounting for an instrument having 6m for the focus. The double instrument, comprising a reflector and a refractor are ready for observations in August 1908 at 2860 meters for the altitude. Baillaud was then moved to the direction of the *Observatoire de Paris*. The international huge level of Baillaud led him to become, at the creation of the International Astronomical Union, after World War I, its first president. In commission 31 (Time) of this union, the BIH was officialy created and Baillaud was asked to be its director. It is said that the general name *Unions scientifiques internationales* was his proposal in 1919.

After having been director of the Paris Observatory up to 1927, Baillaud ended his life in Toulouse in 1934.

7.6 Nowadays' Heritage

From the mid19$^{\text{th}}$ century up to the *Belle Epoque* several astronomers of the Paris Observatory have played a important rôle, mostly at the French level and, in some fields, at the international one. Among all of them, four successive directors have been men of influence around the year 1900.

Some words can be written concerning their actions which have been of use or have led to actions nowadays. The *Bureau des longitudes* hosted by the building of the *Institut de France* (3 rue Mazarine, 75006 Paris) is still alive, including members being astronomers of the *Observatoire de Paris*. Meteorology, organized by Le Verrier, was separated of the Paris Observatory just after his death, nowadays being the *Météorologie nationale*. The *Musée de l'Observatoire* is installed, from about forty years, as in the past, in the *Grande Galerie* and also in the *Salle Picard* (northern tower), formerly the council room; from about the same time, the Curator of the *Observatoire de Paris*, introduces periodical changes in the showcases to make known, at least during several months to the public, what is preserved in the collections, through tours guided mostly by astronomers, engineers, high level technicians of the establishment. Most of the instruments and documents from the past, together with modern evolution, are appreciated as well by the public and by specialists of scientific subjects.

The *École d'astronomie* installed in the *Parc Montsouris* disappeared with World War II but, from many years, students have exercices organized inside professional observatories as in Paris. The *Laboratoire d'optique* created by Baillaud in 1924, disappeared in 1983, being to small, despite its size, for modern realization. Now, the *Salle Cassini*, its new name, houses exhibitions, colloquia, ... organized by the *Observatoire*.

The *Carte du Ciel* enterprise, so often criticized by the French community of astronomers as being responsible of the slow development of astrophysics in France, was employed, at the US level, in comparing its *Catalogue* with the space data obtained, by the end of the 20$^{\text{th}}$ century, from the artificial satellite Hipparcos to derive accurate proper motions of stars. The quality of the plates taken from Paris Observatory around 1900, allowed to remeasure, with a high powerful modern automatic measuring machine, some plates and, by the way, to discover an optical image of a pulsar. The astrometric quality of the site was confirmed, in 1987, by a US specialist of double stars in observing, for a test, very closed binary ones; he was discovering the stability of the images he could not think for the place ....

The *spectroscopie stellaire*, created by Mouchez for Deslandres, reappeared in 1906 with Maurice Hamy up to Henri Mineur (1899–1954), the last one employing for that purpose the *Grand coudé*. Meanwhile, Deslandres had obtained, from he Government of the time in 1926/27, to increase his salary, the junction of Paris and Meudon observatories under his directorship. A decade later, Mineur and Chalonge (1895–1977) obtained the creation, on the Campus of the *Observatoire*, of the *Institut d'Astrophysique de Paris* (IAP) remaining to the *Centre National de la Recherche Scientifique* (CNRS), using the financial credits obtained by the Paris Observatory director of the time. Mineur was director of the *IAP* up to his death; he was a high level astrophysicist, pursuing there researches he had launched when an astronomer of the *Observatoire de Paris*. After the large development of Solar research in Meudon, Astrophysics was mostly developped there, including from 1956 radioastronomy, and later Space Research.

The glassplates of the *Atlas de la Lune* and those from the Paris Observatory programme *Carte du Ciel* are preserved in the Collections of the Observatory. The last ones are employed to get positions of stars obtained one century ago, but they are also used for research of some faint objects, already seen at that time, such as nebulæ. The heterochrome photometry by Nordmann became, with Chalonge at the *IAP*, the *photométrie en quatre couleurs*, while research on time, mostly developped under Baillaud is still included in Paris Observatory while the time part of the *BIH* was moved, in 1985, to the *Bureau international des poids et mesures* (Sèvres, France), by Guinot then *BIH* director.

The old domains of astronomical activities have been pursued from the creation of the *Observatoire Royal* in 1667 up to nowadays, of course, in following the evolution of technics and ideas. But new fields have, meanwhile, appeared some of them, of value, introduced around the years 1900. Each epoch brings, in all countries of the world, its proper and specific evolution. *Et c'est ainsi que la recherche avance.*

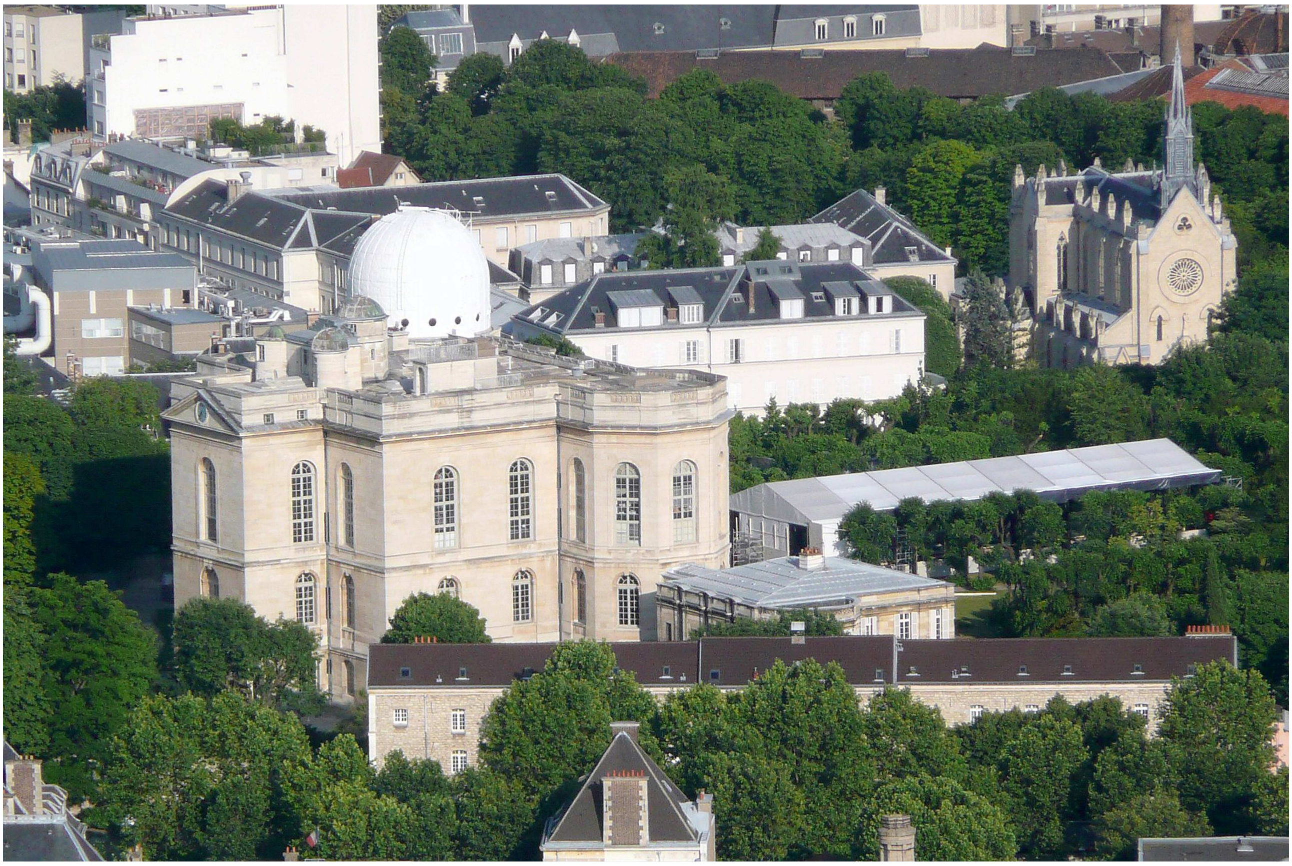


Figure 7.3: *Observatoire de Paris:* (*http://upload.wikimedia.org/wikipedia/commons/4/42/Observatoire_de_Paris.JPG*)

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Figure 8.1: *Schmidt Telescope (Askania, Berlin), Mérida Observatory, CIDA, Venezuela (Photo in the Archive of the Deutsches Technikmuseum Berlin, 2007): Gudrun Wolfschmidt, Askania-Warte 18 (1961), Heft 57)*

8. The Truncated Modernization (1950–1959): Eduardo Röhl and the Observatories of Cagigal and Hamburg

Pedro Chalbaud (Mérida, Venezuela)

At the end of the Second World War a large group of scientists returned to their labs; Astronomy was no exception. Newer and increasingly larger instruments were distinguishable on the horizon. New research programs were dedicated to seek a solution to specific problems and particular subjects and areas. International relations among the observatories of the world would set the stage for what the rest of the 20$^{\text{th}}$ century would be.

In Venezuela, the Director of the Observatory Cagigal at Caracas (1888), Dr. Eduardo Röhl (1891–1953) proposed the modernization of the observatory to the President of the Republic, Gen. Marcos Pérez Jiménez (1914–2001), to thus place it at level with other scientific institutions in Europe and the United States. His proposal consisted in obtaining a series of pieces of equipment with modest dimensions. However, he did not specify the scientific programmes or personnel that would work in the observatory.

Taking advantage of his skill for speaking English and German perfectly, Dr. Röhl started contacts with several observatories: Otto Heckmann (1901–1983) (Hamburg), Chester Burleigh Watts (1889–1971) (USA), André Danjon (1890–1967) (Paris); his attention was particularly focused on the Observatory of Hamburg-Bergedorf. There, he realized the advances in technology being implemented.

Similarly, the opportunity Venezuela represented to install the biggest and best technology and the advice offered by Otto Heckmann was not wasted. The contracts for the Modern Cagigal Observatory were signed in 1953.

The architects were from Hamburg; the Refractor, the Schmidt Telescope, the Reflector, the Astrograph and the Meridian Circle Telescope were built by Zeiss (Jena, Oberkochen) and Askania Werke of Berlin respectivly.

Figure 8.2: *Mérida Observatory, CIDA, Venezuela (1975)*

With the conclusion of the Military Government in Venezuela (1958), the sudden death of Röhl (1959), the radical change in the Directive of the Cagigal Observatory to the hands of the Marines; the modernization project suffered a serious blow. The equipment was stored away, the headquarters of the Observatory was transformed, the tools and equipment scattered and almost forgotten.

Finally the Mérida Observatory, CIDA, Venezuela, was opened in 1975 where Jürgen Stock (1923–2004) acted as director from 1973 until 1983.

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Figure 9.1: *Greenwich, Zwiebel-Kuppel (onion dome), 1858 (Photo: Peter Müller)*

9. Die Architektur der Hamburg-Bergedorfer Sternwarte 1906–1912 im Vergleich mit anderen Observatorien

Peter Müller (Köln, Germany)

Abstract: The Observatory of Hamburg-Bergedorf, compared with other Observatories

The foundation of the astrophysical observatories in Potsdam-Telegrafenberg in 1874, in Meudon near Paris in 1875 and in Mount Hamilton in California in 1875 resulted in a complete change of observatory architecture. Astrometry had become irrelevant; meridian halls, i. e. an exact north-south orientation, were no longer necessary. The location in the centre of a (university) town was disadvantageous, due to vibrations caused by traffic and artificial light at night.

New principles were defined: considerable distance (from the city center), secluded and exposed position (on a mountain) and construction of pavilions: inside a park a pavilion was built for each instrument. Other observatories of this type are: Pic du Midi in the French Alps, built as from 1878 as the fist permanent observatory in the high mountains; Nice, Mont Gros (1879); Brussels, Uccle (1883); Edinburgh, Blackford Hill (1892); Heidelberg, Königstuhl (1896); Barcelona, Monte Tibidado (1902).

The original Hamburg observatory was a modest rectangular building near the Millerntor; in 1833 it became a State institute. As from 1906 erection of a spacious complex in Bergedorf, 20 km northeast of the city center. Except for the unavailable position on a mountain this complex fulfilled all principles of a modern observatory: in a park pavilion architecture in an elegant neo-baroque style designed by Albert Erbe (architect of the new Hamburger Kunsthalle with cupola). At the Hamburg Observatory the domed structures were cleverly hierarchised leaving an open view to the south. At the beginning astrometry and astrophysics were equally important; there was still a meridian circle. Apart from that the instruments were manifold: a large refractor 0.60 m (installed by Repsold/Hamburg, 9 m focal length); a large reflector 1 m (Zeiss/Jena, 3 m focal length). Both were the largest instruments of their kind in the German Empire. In addition, there was the Lippert Astrograph on an elegant polar-axis-type mounting, used for astrophotography. In 1931, Bernhard Schmidt developed the Schmidt telescope here, consisting of a special correction plate and a spherical mirror – adequate for "coma-free" astrophotography. To this day, it is still used worldwide.

In the Second World War Hamburg was severely hit by Anglo-American bombings. Fortunately, the Bergedorf Observatory on the outskirts was spared. In the meantime, many buildings have been repeatedly restored – the entire complex is of high monument value.

9.1 Greenwich, Zwiebel-Kuppel (onion dome), 1858

Beim Greenwich Observatory erfolgte nach 1850 die einfachste Form der Erweiterung: ein zusätzlicher Kuppelbau wurde hier 1858 errichtet, südöstlich vom dortigen, später berühmten Meridianbau. Das Erdgeschoss hat einen achteckigen Grundriss. Später wurde ein größerer, 70 cm-Refraktor angeschafft, deshalb ist die ausladende, zwiebelförmige, Kuppel notwendig geworden – aus der Not wurde eine Tugend gemacht.

9.2 Meudon bei Paris (1875), 1877

Das Astrophysikalische Observatorium Meudon entstand aus dem historischen "Château Neuf", 1706 erbaut von Jules Hardouin-Mansart, Architekt des Invalidendoms in Paris (1675 bis 1706). Bei Meudon gibt es einen Niveau-Unterschied, denn ursprüglich gab es drei Geschosse. 1870 wurde das Schloß während der Belagerung durch die preußische Armee zerstört. Der Wiederaufbau als Observatorium ist eine einmalige Kuriosität.

Das Astrophysikalische Observatorium Meudon befindet sich im Flachland zwischen Paris und Versailles. Baubeginn war 1877. Die große Kuppel mit 18,5 m Durchmesser wurde für den Doppel-Refraktor (visuell/photographisch) von 16 m Brennweite (= Länge) errichtet.

1874/75 erfolgte hier eine Revolution in der Astronomie zu Gunsten der Astrophysik, die sich mit physikalisch-chemischen Zuständen auf den Oberflächen der Gestirne beschäftigt (Spektralanalyse). Dadurch wurde die Positions-Astronomie (= Astrometrie) weniger bedeutend. Es wurden keine Meridiansäle mehr gebraucht, eine strenge Nord-Süd-Orientierung war nicht mehr nötig. Wegen zunehmender Luftverschmutzung durch Fabriken, künstliche Beleuchtung bei Nacht, Erschütterung durch Eisenbahn ergaben sich neue Grundsätze: Observatorien wurden in beträchtlicher Entfernung von einer Stadt errichtet, in einsamer, erhöhter Berglage und in Pavillon-Bauweise: für jedes Instrument entstand ein eigener Bau in Parkanlage.

 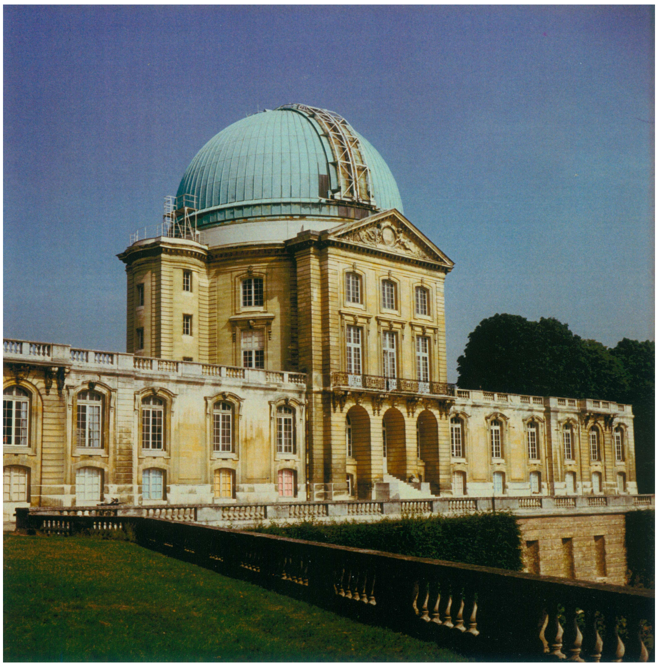

Abbildung 9.2: *Meudon bei Paris (1875), 1877, Vorderseite und Rückseite des Mittelbaus (Photo: Peter Müller)*

Erstes Beispiel für eine Parkanlage ist Potsdam-Telegraphenberg, eine kaiserliche preußische Gründung, 1874. Dies wird hier nicht gezeigt, da Potsdam der bisherigen Bauweise zugehörig ist nach dem Motto *Alles unter einem Dach*, vgl. auch den gleichzeitigen Bau der Universitäts-Sternwarte Wien von 1874.

9.3 Lick Observatory, Mt. Hamilton, 1875–1888

Das Lick Observatory auf dem Mount Hamilton in Kalifornien wurde 1875 gegründet als erstes, echtes, großes Berg-Observatorium nicht nur in den USA, sondern weltweit. Es liegt in 1283 m Höhe, im Vorgebirge der westlichen Rocky Mountains. Trockenes Bergklima und klare kalte Nächte ergeben günstige Beobachtungs-Bedingungen. Die nächste Stadt ist San José, 30 km nach Westen, San Francisco liegt 80 km im Nordwesten. Mühsame Wege mit Pferdefuhrwerken, lange vor Erfindung des Automobils, führen nach oben.

Gründer war der Astronom Edward S. Holden (1846–1914), der Geldgeber war James Lick (1796–1876).

Das alte Hauptgebäude mit einer 20 m-Kuppel für den 91 cm Refraktor besitzt keine Orientierung nach Himmelsrichtungen; die Bauzeit dauerte von 1875 bis 1888.

Die Gesamtansicht von Mount Hamilton in Ost-West-Richtung zeigt die Erweiterungsmöglichkeit; der Kuppelbau wurde 1959 vollendet für einen 3 m-Reflektor, damals der zweitgrößte der Welt (nach dem 5 m-Spiegel auf Mount Palomar).

9.4 Nizza auf dem Mont Gros, 1879

Das beste, zeitgenössische, leistungsfähigste Gegenbeispiel in Europa im Vergleich zum Lick Observatory stellt die Sternwarte Nizza auf Mont Gros in 372 m Höhe dar. Die Zeichnung der Anlage macht die perfekte Aufteilung in Einzelgebäude deutlich: Die hier vorliegende Gruppenform zeigt "verkleinerte kalifornische Verhältnisse". Die Sternwarte Nizza wurde 1879 gegründet. Die Mittelmeer-Küste, Côte d'Azur, ist von oben sichtbar.

Der 76 cm-Refraktor der Sternwarte Nizza mit 18 m Brennweite (= Länge) erforderte ein großes Gebäude mit riesiger Kuppel von 26,2 m Durchmesser. Das Gebäude, das Erdgeschoss aus Stein, wurde von Charles Garnier konstruiert, dem Erbauer der Pariser Oper, die eiserne Kuppel stammt von Gustave Eiffel, der etwa gleichzeitig seinen Eiffelturm erbaute. Die Architektur zeigt ein deutliches Renommiergehabe der Franzosen gegen deutsch-preußische Konkurrenten! Die Kuppel für den Refraktor war bereits damals die größte in Europa – und das gilt bis heute!

9.5 Das argentinische National-Observatorium in La Plata, 1883

Ein zeitgenössisches Beispiel (1883) stellt das Argentinische National-Observatorium in La Plata südlich von Buenos Aires dar. Es liegt im Flachland; ansonsten ist die Gruppenform verwirklicht durch Aufteilung in Einzelgebäude. Der Baustil weist deutlich einen aus Europa übernommen "Historismus" auf. Der Kuppelbau in La Plata ist in einen Park eingebettet.

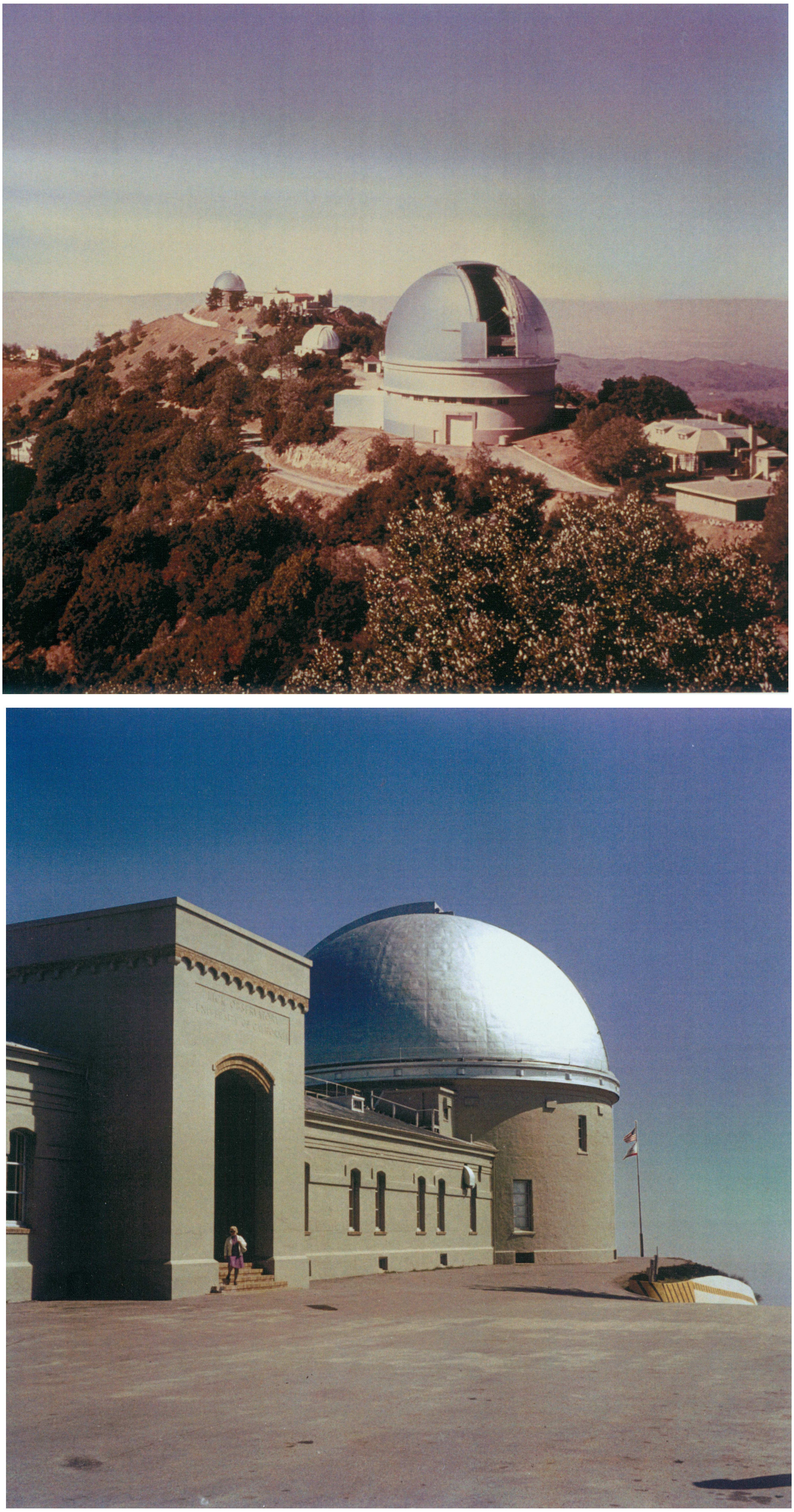

Abbildung 9.3: *Lick Observatory, Mt. Hamilton, 1875–1888, 20 m-Kuppel für den 91 cm Refraktor (Photo: Peter Müller)*

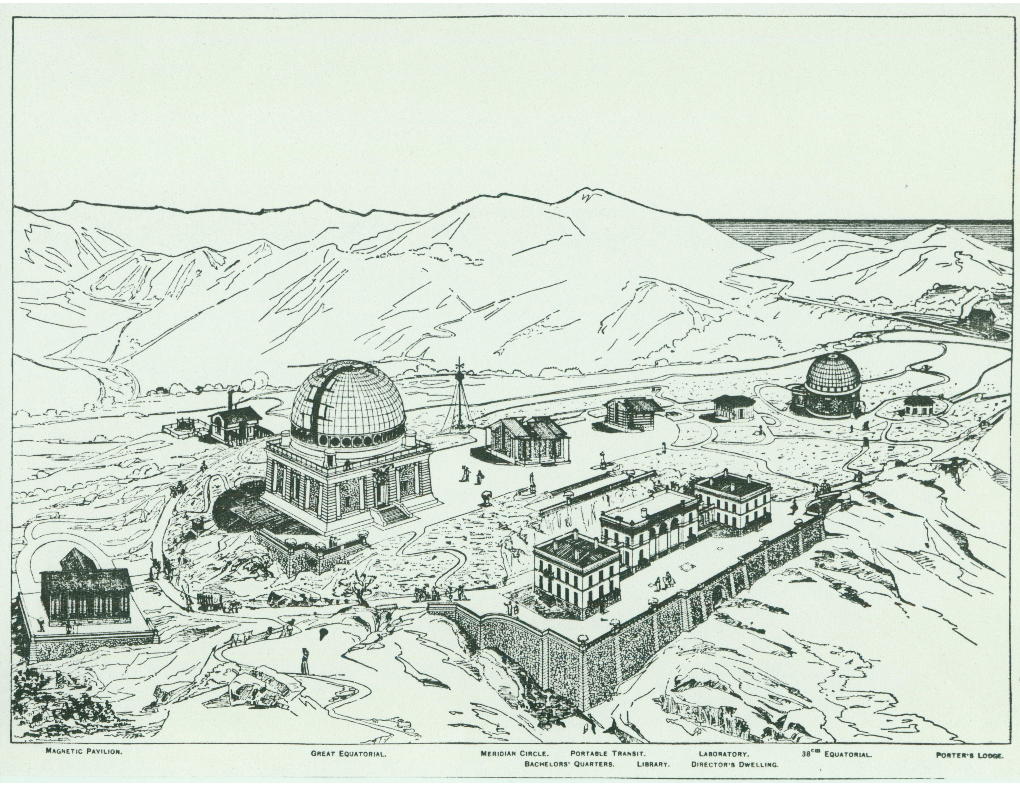

Abbildung 9.4: *Nizza auf dem Mont Gros, 1879 Kuppel von Gustave Eiffel (1832–1923) (Photo: Peter Müller)*

Abbildung 9.5: *Oben: Argentinische National-Observatorium in La Plata, 1883*
Unten: US Naval Observatorium in Washington D. C., 1887, großer Kuppelbau für den 66 cm-Refraktor (Photo: Peter Müller)

9.6 US Naval (Marine-) Observatorium in Washington D. C., 1887

Die Luftaufnahme des US Naval (Marine-) Observatoriums in Washington D. C. (fig. 23.1, p. 216) macht die Gruppenform in der Parkanlage deutlich; die Längsachse des Hauptgebäudes ist in Ost-West-Richtung orientiert. Das Observatorium liegt im Nordwesten von Washington an der Massachusetts Avenue. Es bezeugt die uralte Verbindung von Astronomie und Seefahrt (vergleiche Greenwich). Es handelt sich um eine repräsentative, historistische Architektur (1887). Bis heute ist es das Zeit-Institut der USA mit Atomuhren.

Der große Kuppelbau (14,4 m Durchmesser) des US Naval (Marine-) Observatoriums wurde für den 66 cm-Refraktor errichtet. In neuerer Zeit dient das Observatorium auch als Volks-Sternwarte.

9.7 Royal Observatory Blackford Hill in Edinburgh, 1888

Die Königlich Schottische Sternwarte auf Blackford Hill in Edinburgh liegt in nur 133 m Höhe. Trotzdem kann man sie als Berg-Observatorium betrachten. Es ist von einer Rundmauer umgeben. Über dem Haupt-Instrument, dem 91 cm-Reflektor, gibt es statt einer Kuppel einen zylinderförmigen, drehbaren Kuppel-Ersatz. Hierfür gibt es ältere Beispiele: Bonn, Helsinki, Pulkovo bei St. Petersburg.

9.8 Sternwarte Heidelberg-Königstuhl, 1896

Die (Badische) Landessternwarte Heidelberg-Königstuhl liegt in 564 m Höhe. Sie wurde vom Heidelberger Astronomen Max Wolf (1863–1932) gegründet. Der Bau begann 1896 und war später auch durch eine Zahnradbahn erreichbar. Es handelt sich um das erste große, moderne Berg-Observatorium in Deutschland, damals ideal gelegen, da Heidelberg im tiefen Neckartal nicht sichtbar war.

9.9 Sternwarte Kapstadt, 1820

Die Sternwarte Kapstadt wurde 1820 als Königliches Observatorium gegründet. Im damaligen Britischen Imperium war sie wichtig für die Seefahrt, besonders nach Indien.

Der große Kuppelbau von 12 m Durchmesser wurde für den Viktoria Doppel-Refraktor (46 cm/61 cm) etwa im Jahr 1900 erbaut. Südafrika war damals britische Kolonie. Der Kuppelbau ist typisch für die Zeit um 1900, Beispiel einer Erweiterung. Der Berg im Hintergrund, "Devils's Peak" (Teufels Spitze), gehört zum Tafelberg-Massiv. Die Hauptbeobachtungs-Richtung nach Norden hat freien Blick.

9.10 Observatoire Pic du Midi, 1903

Pic du Midi liegt in 2865 m Höhe in den Französischen Pyrenäen. Schon ab 1878 gab es erste naturwissenschaftliche Beobachtungen im Sommer. 1903 erfolgte der Anschluss an die Universität Toulouse; danach wurde die Institution ausgebaut zum bleibenden astronomischen Observatorium im Hochgebirge Begünstigt wurde das Observatorium 1952 durch den Bau der Seilbahn. Die Verwaltung befindet sich im Badeort Bagnères-de-Bigorre. Das Observatorium war erweiterungsfähig. Vor 1990 wurde ein 2 m-Reflektor aufgestellt, geschützt gegen Wind und Wetter: Er gehört zu den größten Europas.

9.11 Sternwarte Hamburg-Bergedorf, 1906–1912

Die Sternwarte Hamburg-Bergedorf wurde bereits 1802 durch den Feuerwehr-Hauptmann und Privat-Astronom Johann Georg Repsold gegründet; die Familie Repsold wurde später eine bedeutende Firma für wissenschaftliche Instrumente. Der ursprüngliche Standort mußte 1813 wegen der Besatzungstruppen Napoleons beseitigt werden; 1824/25 wurde die Sternwarte auf der Befestigungsanlage (Holstenwall) am Platz des späteren Museums für Hamburgische Geschichte neu errichtet und 1833 verstaatlicht. Es handelte sich um einen niedrigen Längsbau mit zwei Kuppeln. Wichtig war der Zeitdienst und es gab eine enge Verbindung mit der Navigationsschule (also nach dem Vorbild von Greenwich 1675). Nach dem Abriss verblieb nur das Repsold-Denkmal.

Die neue, derzeitige Universitäts-Sternwarte in Hamburg-Bergedorf liegt 20 km von Hamburgs Zentrum entfernt. Als Standort wurde der Gojenberg gewählt, auf einem Höhenzug parallel zum Nordufer der Elbe in 40 m Höhe; damals (1906) war das eine sehr einsame Lage. Außer der Berglage sind alle Merkmale eines modernen Observatoriums um 1900 erfüllt, vor allem die Gruppenform (see fig. 5.1, p. 42): Für jedes Instrument gibt es einen eigenen (Kuppel-)Bau. Beachtlich ist deren Staffelung, damit jedes Instrument die Haupt-beobachtungsrichtung nach Süden frei hat. Bei der Sternwarte gibt es eine absichtliche "Einbettung" in parkartige Vegetation (vgl. die vorige Luftaufnahme von La Plata). Denn jedes Bauwerk aus Stein kühlt bei der Abenddämmerung ab und verursacht störende Luftströmungen vor den Objektiv-Linsen der Fernrohre. Darum sind die großen Sternwarten-Gebäude wie Wien, Potsdam, Yerkes bei Chicago für die Beobachtungsqualität sehr nachteilig. Die Vegetation vermindert dagegen die Luftströmungen.

Das Gebäude für den großen Refraktor in Hamburg-Bergedorf wurde 1906 bis 1912 im neubarocken Stil erbaut, gleichzeitig mit dem Großbauwerk Hamburg Hauptbahnhof. Der Erbauer war Albert Erbe, der auch die *Neue Kunsthalle* mit Kuppel erbaut hatte.

Abbildung 9.6: *Royal Observatory Blackford Hill in Edinburgh, 1888 (Photo: Peter Müller)*

Vor 1900 war mit der 102 cm-Glaslinse für das Objektiv des Yerkes-Refraktors die Grenze des Möglichen bezüglich Glaslinsen-Fernrohren erreicht. Die weitere Entwicklung verlief zugunsten der Glasspiegel-Fernrohre (Reflektoren). Am Mount-Wilson-Observatorium (Berg-Observatorium) nördlich von Los Angeles, errichtet 1904–1917, gab es eine überwältigende Steigerung in der Größe von Reflektoren: 60-inch (1,50 m) und 100-inch (2,50 m) und dann 200-inch (5 m) auf Mount Palomar, 1935–1948. Die Perspektiven bzgl. Refraktor (1. Instrumenten-Gruppe) oder Reflektor (2. Instrumenten-Gruppe) waren zur Bauzeit der Sternwarte noch nicht klar entschieden. Darum entschied man sich traditionell für einen Großen Refraktor (60 cm : 9 m) (Montierung Repsold/Hamburg, Optik Seinheil/München) und für einen Großen Reflektor (1 m : 3 m) von Zeiss/Jena.

Aus Gründen der Tradition und wegen der Vollständigkeit beschaffte man auch einen Meridian-Kreis (3. Instrumenten-Gruppe) von der Firma Repsold; er wurde für den *Bergedorfer Sternkatalog* benutzt.

1931 wurde hier durch Optiker Bernhard Schmidt der Schmidt-Spiegel oder die Schmidt-Kamera erfunden (4. Instrumenten-Gruppe), bestehend aus einem sphärischen Spiegel und einer Korrektionsplatte aus Glas. Damit werden komafreie Fotos größerer Himmelsausschnitte ermöglicht, d. h. die Sterne werden ohne strichartige Verzerrungen auf den Photoplatten dargestellt. Das Original des Schmidtspiegels ist hier noch vorhanden. 1954 wurde der größere Schmidtspiegel von Zeiss/Jena angefertigt. Weltweit sind Schmidtspiegel in Gebrauch, zum Beispiel die Großen Schmidt-Teleskope in Tautenburg oder Mount Palomar.

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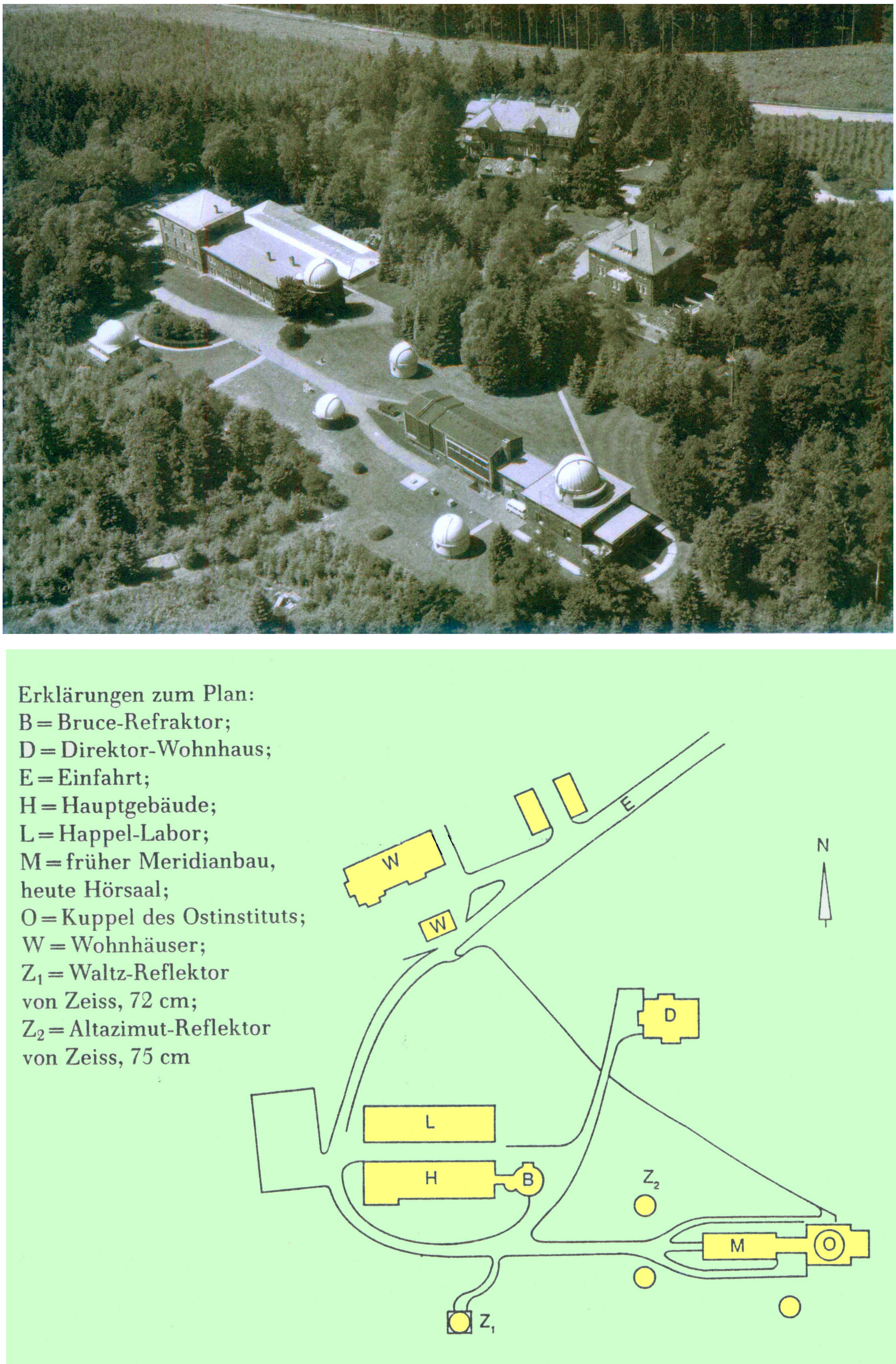

Abbildung 9.7: *Plan der Sternwarte Heidelberg-Königstuhl, gegründet 1896 (Photo: Peter Müller)*

Abbildung 9.8: *Sternwarte Kapstadt, 1820*

Abbildung 9.9: *Observatoire Pic du Midi (1878), 1903, Pic du Midi, neuere Gesamtaufnahme in Richtung Nord (Photo: Peter Müller)*

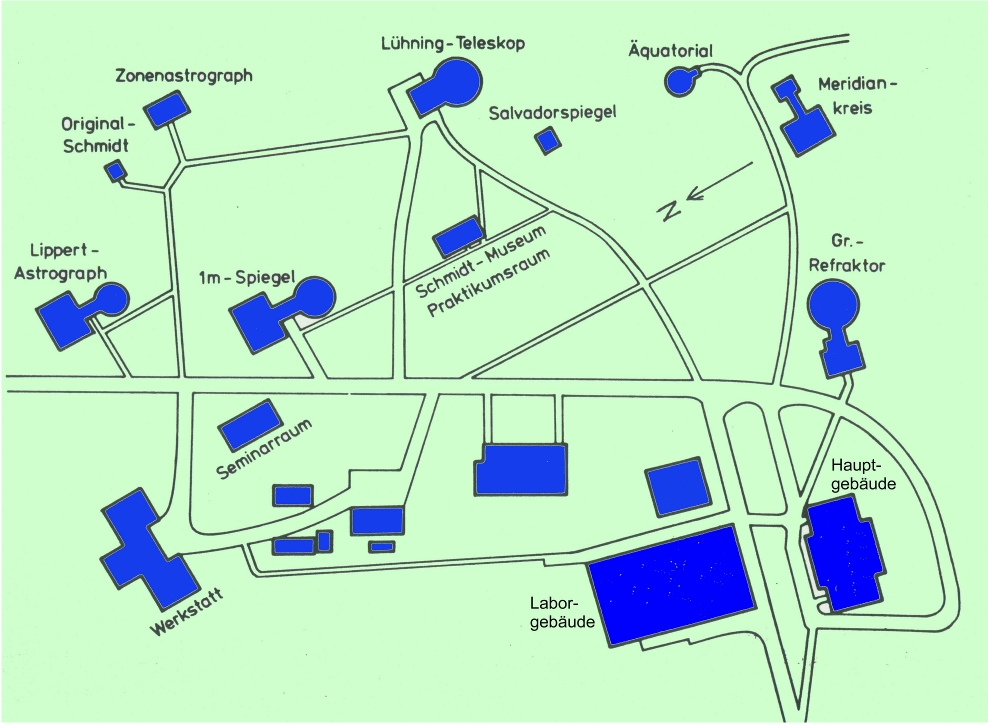

Abbildung 9.10: *Sternwarte Hamburg-Bergedorf, 1906–1912 (Photo: Peter Müller)*

Figure 10.1: *The entrance of the main building of the Astronomical Observatory of Lisbon (Photo: Pedro Raposo)*

10. The Material Culture of Nineteenth-Century Astrometry, its Circulation and Heritage at the Astronomical Observatory of Lisbon

Pedro Raposo (Oxford, UK / Lisbon, Portugal)

Abstract

The Astronomical Observatory of Lisbon was founded in 1857 in the sequence of a controversy on stellar parallax measurements involving astronomers from the Observatory of Paris and the Observatory of Pulkovo. The development of this discussion led the contenders to recognize Lisbon as a suitable place to carry out this kind of measurements and to foster the field of stellar astronomy. Some local actors strived to keep up with this wave of international interest and establish a first-rank astronomical institution in the Portuguese capital. In order to fulfil this goal, correspondence was intensively exchanged with leading foreigner astronomers and instrument makers. Besides, a Portuguese Navy officer bound to become the first director of the new institution was commissioned to visit several observatories and instrument workshops abroad, and to spend a few years in Pulkovo as a trainee astronomer. Although founded with generous financial support from the Portuguese crown and lavishly equipped and constructed, the Observatory of Lisbon was later affected by limiting budgets and a shortage of qualified personnel. Nevertheless, local efforts to improve instruments as well as observation and calculation techniques enabled its astronomers to yield important contributions to positional astronomy, especially towards the end of the nineteenth century and the beginnings of the twentieth century. The original instruments and spaces of the Observatory of Lisbon, strongly modelled on those of Pulkovo, are very well preserved, constituting an outstanding extant example of a mid-nineteenth century advanced observatory. The history they embody testifies the connectedness of the astronomical heritage worldwide.

10.1 Introduction

Astronomical observatories (and scientific institutions in general) have usually been established through the circulation and assimilation of models related to architecture, organisation, management, instrumentation and scientific practice, in accordance to local circumstances. The circulation of these models is fostered not only by correspondence through networks of practitioners but also by fact-finding travels and scientific expeditions. Besides, scientific production is, in a great extent, developed through the participation in international programmes, for instance to catalogue the sky and to refine the values of astronomical constants. These aspects must be taken into account not only to capture the whole international aspect the development of astronomy and its institutions but also to promote the legacy of astronomical observatories as true world heritage.

The Astronomical Observatory of Lisbon (AOL), whose cornerstone was laid in 1861, provides an interesting case of an institution created with a marked international dimension. (Fig. 10.1) It was modelled on the foremost observatory of the period, the Observatory of Pulkovo in Russia. In 1992 the AOL became a part of the University of Lisbon, and, in 1995, a unit of the Faculty of Sciences of the same University. Its main building and most of its instruments are generally well-preserved and significantly close to their original condition. The AOL was conceived as an observatory dedicated to the advancement of sidereal astronomy (*i. e*, the study of stars and nebulae), when astrophysics was just emerging and most observatories focused on the study of solar system objects or, at best, on the measurement of stellar positions for cataloguing purposes mainly. By 1850, a discussion on stellar parallax measurements between astronomers from the observatories of Paris and Pulkovo led them to realise the geographic suitability of Lisbon for studies in sidereal astronomy and, after a long and complex process of local demarches, the AOL was established with the aim of fostering the knowledge of stellar distances.

The first observations were carried out in 1867, but the Statutory Decree establishing the Royal Observatory of Lisbon was approved only in 1878. Its scientific outcome was hampered by limiting budgets and scarce personnel. No major contributions were given to the problem of stellar parallaxes but some relevant astrometric works were accomplished. The prime of AOL's scientific activity took place in the transition from the nineteenth-century to the twentieth century, in the context of international programmes promoted to refine the value of solar parallax. Observations were carried at the AOL until the 1980s, although in the 1920s the astronomers were already complaining about the growth of Lisbon and its lights.

Tied to the traditional astrometric work, the AOL was never transformed into an astrophysical observatory. In the one hand this represented a loss in terms of local scientific development, but in the other hand the University of Lisbon ended up in the possession of a scientific establishment with an especial historical value. The Observatory of Pulkovo served as a model for several observatories in the nineteenth century, but it was destroyed during the Second World War and reconstructed afterwards. Although the main characteristics of the buildings were respected in the reconstruction,[1] the AOL is likely to be the observatory which better reflects its original aspect, regarding both architecture and instrumentation.

The AOL is nowadays the host of a research group in astrophysics, a public provider of astronomical information and expertise, the national keeper of legal time and a centre for outreach activities (including guided tours to its historical facilities). Besides, the Observatory has a remarkable reference library in astronomy and astrophysics[2] and its historical archive has recently been organised and inventoried.[3] The content of the next sections draws significantly on research made in the AOL collections, including its historical instrumentation.

10.2 Scientific Context of the Foundation of the AOL: the Measurement of Stellar Distances

The measurement of stellar parallax[4] became a central issue since Copernicus, but only in the first half of the nineteenth century it was, for the first time, acceptably determined for a few stars. James Bradley (1693–1762), like Robert Hooke (1635–1703) before him, had tried to determine the parallax of the bright star Gamma Draconis, without success. Bradley concluded that even for the closer stars the value of parallax should fall under one second of arc.[5]

In 1838 Friedrich Bessel (1784–1846) presented a value of $0''.31$ for the parallax of the star 61 Cygni, based on observations carried out at the Observatory of Königsberg. By the same time two other astronomers announced values for stellar parallax that were deemed reliable. Wilhelm Struve had obtained a parallax of $0''.26$ for the star Vega (α Lyrae), from observations made at the Observatory of Dorpat (nowadays Tartu). Thomas Henderson (1798–1844) and his successor Thomas Maclear (1794–1879) observed the first magnitude star α Centauri at the Observatory of the Cape and derived a parallax of $0''.91$.

The values presented by Bessel, Struve and Henderson, when compared to later and more accurate measurements, constitute excellent approximations, but they were not definitive; they remained bound to discussion and reappraisal. Those astronomers themselves obtained discrepant values for the same star from different observational programmes. For instance, Bessel first found a value of $-0''.88$ for the parallax of 61 Cygni carrying out observations in right ascension (RA), and Wilhelm Struve's first value for the parallax Vega was 1/8 of a second of arc.[6]

10.3 The Controversy on the Parallax of 1830 Groombridge

In 1842, Argelander announced that the star 1830 of the Groombridge Catalogue had a proper motion of $7''$.[7] This was seen as an indication of proximity. Christian Peters (1806–1880) tried to determine the parallax of this star carrying out a series of observations between 1842 and 1843, using the vertical circle of the Observatory of Pulkovo. These observations led to a value of $0''.226 \pm 0''.141$.[8] Also in 1842 Heinrich Schlüter started an independent observational programme at the Observatory of Königsberg, employing the same instrument (a Fraunhofer heliometer) and techniques used by Bessel to determine the parallax of 61 Cygni. His observations were later reduced by Moritz Wichmann (1821–1859).

Between March and August 1846 Hervé Faye (1814–1902) observed the Argerlander's Star (as 1830 Groombridge also came to be known) in Paris, measuring its difference in right ascension to a nearby star of magnitude 9–10. In the meeting of 31 August 1846 Faye announced to the Academy of Sciences of Paris a parallax of $1''.06$.[9] In November of the same year, the astronomer presented a zenith telescope and collimator he had designed himself, arguing that this apparatus would serve as the basis of an observing system in which the errors associated with the use of the mural circle were eliminated.[10] In December 1846 Faye brought back the issue of 1830 Groombridge to the attention of the French Academy. Another three months of observations, he claimed, had confirmed his first value for the parallax of that star, which he had only readjusted to $1''.08$, with a probable error smaller than $0''.05$.[11]

Willhem Struve, the director of the Observatory of Pulkovo, visited Paris in 1847 and defended Peters' value in person, claiming that, in spite of its high probable error, the real value could be expected, with a chance of 5 to 1, to lie below $\frac{1}{2}$ second of arc.[12] He also announced that, following Faye's proposal, his son Otto Struve (1819–1905) would use the great 15-inch refractor of Pulkovo to make micrometric comparisons in declination between 1830 Groombridge and the same comparison star that Faye had observed in right ascension.

The works carried out in Königsberg were then brought into discussion. From the observations made by Heinrich Schlüter in 1842–43, Wichmann had deduced a value of $0''.182$.[13] Faye pointed out that there had been a perturbation in the observations of 1843, due to an unknown cause, that rendered them unsuitable for parallax determination purposes.[14]

Struve defended the quality of Wichman's work and the validity shown by its small errors.[15] He also remarked that stellar parallax measurements required the use of all the resources available to the astronomers. This was desirable even for the established parallaxes of 61 Cygni and Alpha Lyrae. Faye replied reinforcing his objections with the argument that the true nature of the errors affecting the observations Wichmann had used was unclear and that a small parallax for 1830 Groombridge would imply such a high velocity in space that science had no resources to explain it.[16]

The discussion was resumed in 1850. Otto Struve presented the results of the observations made with the great refractor of Pulkovo between 1847 and 1849, which had rendered a parallax of $0''.034 \pm 0''.029$.[17] He was cautious with regard to this result, acknowledging that taking the value as an exact notion of the distance of 1830 Groombridge was risky. However, he considered that his observations clearly demonstrated that the parallax was lower than $0''.1$. In his reaction to Otto's observations and results, Faye argued that it could not really be accepted as a definitive value, especially because of its consequences in terms of the motion of the star (the argument he had already adduced), but he accepted that Otto's investigations had clearly demonstrated the impossibility of the high value he had previously deduced.[18] He praised Otto's method, deeming it very complete: in his own words, Otto had done everything that was humanly possible as far his method was concerned, and new series of observations following to the same method would not eliminate the small regular errors that could be suspected to be affecting the observations. Faye suggested instead that new methods should be adopted.

There was still a reply by Otto[19] and a response by Faye,[20] where they simply reinforced their previous arguments and counter-arguments. The discussion on 1830 Groombridge had essentially led them to acknowledge that the accurate determination of stellar parallaxes was still an open field requiring major refinements.

Faye proposed zenith observations with his telescope as an alternative method. All sources of error could be eliminated in the measurement of small zenith distances; only the accidental errors remained but could be naturally eliminated in a great number of observations. The zenith telescope should be taken to places suitable for such observations, and he cited the example of the observatory of Lisbon, which was actually the Royal Observatory of the Navy. The Observatory of Washington was close in latitude but its location was not equally favourable. According to Faye, the parallaxes of some fifteen stars, from the first to the sixth magnitude, could be determined in the Portuguese capital. Wilhelm Struve agreed in general with these ideas. The news did not take long to reach Portugal.

10.4 An Astronomical Challenge to Portugal

In 26 March 1850 Francisco de Almeida Portugal, Count of Lavradio (1797–1870), took the word at the Portuguese Parliament to inform that foreigner astronomers intended to carry out astronomical observations in Lisbon. Lavradio stressed the idea that the observations should be made by Portuguese astronomers and then handed to their foreigner counterparts. After all, there was an astronomical observatory in Lisbon, the aforementioned Royal Observatory of the Navy, and allowing them to do the work that local scientists were unable to provide would be shameful for the Portuguese record.[21]

A prompt response came from the council of the Naval School of Lisbon in 13 April 1850: the situation of the Royal Observatory of the Navy was not suitable to carry out delicate astronomical observations. After many changes of facilities (always more or less improvised) since its foundation in 1798, it was then located at the Arsenal of the Navy, in conditions not compatible with advanced astronomical work.[22] The establishment of a new observatory should be considered.

The Portuguese government proceeded with a plan to purchase new instruments to upgrade the Observatory of the Navy. By the end of July 1850, an order for a zenith telescope had been placed. A commission had been appointed to carry out preliminary studies on the establishment of a new observatory, but the delay in appointing a president for the commission made it useless.[23] In 24 August, Faye announced to the Academy of Paris that, according to the ambassador of Portugal, the government of the country had a plan to improve the Observatory of the Navy, in order to promote the study of zenith stars. The list of instruments to purchase was submitted to Faye, who suggested some modifications. He also remarked that, although stellar astronomy was to remain on the top of the observatory's commitments, observations of comets and minor planets, as well as systematic observations of lunar transits for navigational purposes, could also be carried out.[24] However, bureaucratic blockages between different ministries and political instability led these early demarches into oblivion.

10.5 The AOL in the Context of Portuguese Regeneration

Somehow paradoxically, the first steps towards the institutionalization of advanced astronomical practice in Portugal came to a halt, at least partially, due to political events that, in 1851, inaugurated a period marked by a commitment to progress, the Regeneration. The Astronomical Observatory of Lisbon was, in a considerable extent, a product of the Regeneration's spirit. However, the inscription of the project in its social and political picture is not to be taken as evident. The Regeneration was marked, indeed, by a major effort aiming at the social, technological and cultural enhancement of the nation, but the foundation of the observatory was mainly due to the convergent visions of a sovereign willing to patronize the undertaking, the King Pedro V (1837–1861; enthroned in 1855), and a local practitioner who realized the importance and impact of the project, the geodesist Filipe Folque (1800–1874).

Regeneration also represented the attempt to pacify Portuguese political and social life. In fact, the country had spent the first half of the nineteenth century in turmoil; it had suffered the French invasions, a civil war between liberals and absolutists, and great political instability since the establishment of the constitutional monarchy in 1820 (40 governments succeeded between that year and 1851).[25]

The foundation of a new astronomical observatory fitted in well with the spirit of Regeneration, but it was necessary to rescue the ideas and intentions spurred by the discussion on 1830 Groombridge. Filipe Folque took the lead. He was a military officer, geodesist, professor of astronomy and the Portuguese princes' teacher of mathematics.[26] He was also one of the members of the first commission appointed to study the establishment of a new observatory. In December 1855, Folque was interviewed by a commission charged with the inspection of the Navy departments. In his deposal he stressed the importance of founding a new observatory.[27] He remarked that Portugal was in a shameful situation since the attempts to foster local astronomical work following the debate on the Argelander star had been left to oblivion. He informed the commission that most of the instruments of the Observatory of the Navy had been taken away when the royal family fled to Brazil during the French invasions. From that point forward its functions had been just the practical teaching of the pupils of the Naval Academy, the observation of satellites and the maintenance of sea chronometers. Due to the lack of instruments no other works were maintained. And the observatory of the University of Coimbra, he argued, was compromised by a tendency to theoretical studies. The establishment of a new observatory was thus urging. Competition between similar institutions would be, in his opinion, beneficial to the advancement of science. A great new observatory should be specifically committed to this purpose. It was to function as an independent institution, with its director responding directly to the government, like Folque allegedly had seen abroad. In 1853–54 he had travelled Europe in the entourage of Prince Pedro (later the king Pedro V) and visited some astronomical observatories: Greenwich, Liverpool, Brussels and the observatory of the Jesuits in Rome). These travels allowed him to get a general picture of observatory buildings, instruments, and administration

In the sequence of Folque's testimony, in 19 February 1856 the politician and historian José Silvestre Ribeiro (1807–1891), an enthusiast of the foundation of the observatory himself,[28] presented to the Parliament a recommendation regarding the construction of a new observatory. In 31 January 1857 he submitted a proposal which was accepted and forwarded to the Commission for Public Instruction. In the same day, Pedro V declared his wish to fund the project with roughly one third of his annual stipend.[29] In 14 February a commission was appointed to choose the location and the main instruments for the new observatory, and to outline a budget for the construction works. After many discussions, epistolary exchanges and political demarches, the foundation stone of the future Royal Astronomical Observatory of Lisbon was laid on Tapada da Ajuda, in a hill over the River Tagus, in 11 March 1861.

10.6 Mobilising Astronomical *Know-How* to Lisbon

Several astronomers were consulted with regard to buildings, instruments and organizational issues, among them the *Astronomer Royal* George Biddell Airy (1801–1892), Johann Franz Encke (1791–1865), Karl Rümker (1788–1862), Christian Peters, and obviously the protagonists of the discussion on the Argelander Star: Faye, Wilhelm Struve and Otto Struve. It is likely that, in face of the delays and bureaucratic intricacies that marked the first demarches aiming at the improvement of the Royal Observatory of the Navy, Faye's enthusiasm about an astronomical endeavour in Lisbon faded out. When the foundation of the new observatory started to take shape after Folque's testimony, Wilhelm Struve, assisted by his son Otto, became the most enthusiastic supporter of the undertaking and its chief advisor. Support from Pulkovo was a valuable asset for the Portuguese project; it reinforced its international dimension and allowed it to secure a foundational link with one of the most respected institutions of the international astronomical scene.[30]

The architectural plans of the Pulkovo Observatory and the advice of the Struves provided the main guidelines for the edification of the new observatory. All the details were carefully analysed and submitted to the appreciation of the foreigner advisors, including the choice of the site and the definition of its main field of activity. With regard to this point Wilhelm Struve's vision was similar to Faye's: the new observatory should embrace the advancement of sidereal astronomy as its principal scientific commitment.

Pulkovo was a model and a source of inspiration for several astronomers and observatories in Europe and America,[31] but the Lisbon project offered an opportunity for a special engagement of the Russian Observatory in the establishment of what is likely to have been its most similar descendant abroad.

W. Struve offered apprenticeship positions at Pulkovo and the young navy officer Frederico Augusto Oom (1830–1890), who would become the first director of the AOL (Fig. 10.2), was sent to the Russian observatory, where he stayed from 1858 to 1863 as a trainee astronomer under the supervision of Otto Struve. F. A. Oom also had the chance to visit several observatories and instrument workshops, acquiring a broad perspective on the trends in European astronomy.

Figure 10.2: *Frederico Augusto Oom, 1830–1890 (Archives of the AOL)*

10.7 Organising the Observatory

Back in Lisbon, Oom played a central role in the installation of the instruments, the construction of functional elements of the building (namely the central rotating tower) and the organization of the new observatory.

The organizational principles and scientific aims of the Royal Astronomical Observatory of Lisbon[32] were officially established by a statutory decree only in 1878. Folque died in 1874, when the observatory was still a section of the Portuguese Geodetic Works of which he was the director. By this time the long process of building and equipping the observatory was coming close to completion and it was time to proceed with its formal recognition as an autonomous scientific institution. Oom took an active role in establishing the observatory according to the original ideas of Wilhelm Struve.[33] He had the support from the Academy of Sciences of Lisbon, but the Low Chamber of the Parliament issued a statutory proposal pervaded by the interests of the University of Coimbra. According to this proposal, the new institution should be something akin to a university observatory,[34] with professors and lecturers developing practical work when not busy with teaching duties. This was not compatible with the principle of exclusive dedication suggested by W. Struve. With the political support from the High Chamber of the Parliament, the ideas defended by Oom took advantage and the approved statutory established that the Royal Astronomical Observatory of Lisbon was to work primarily for the advancement of sidereal astronomy. Solar system astronomy, practical contributions to navigation and geography, and time keeping were secondary functions. The staff would comprise five astronomers, who were expected to work exclusively for the Observatory.[35]

In practice, these principles and dispositions were too ambitious for the local reality in which the observatory was embedded. Tapada da Ajuda was located in the western outskirts of Lisbon, then significantly apart from the core of the city. Besides demanding high academic qualifications and at least 2 years of practice before a definitive appointment (which was not guaranteed), the access to the career of astronomer, if successfully accomplished, would result in a life of almost reclusion. Not surprisingly, the observatory remained little attractive to prospective astronomers. And even those who were in a position of getting into the Observatory by their influence or prestige did not always have the required practical skills. For instance, the first three first-class astronomers[36] appointed in 1878, after the approval of the Statutory Decree, were Frederico Augusto Oom, his fellow navy officer and hydrograph engineer César Augusto de Campos Rodrigues (1836–1919), and the mathematician Francisco Gomes Teixeira (1851–1933). Both Oom and Rodrigues had years of practice in astronomical observation, especially the

Figure 10.3: *César Augusto de Campos Rodrigues (1836–1919) (Archives of the AOL)*

first. Rodrigues was already known for his proficiency in instrumentation matters. Teixeira, however, was a young theoretical mathematician from the University of Coimbra, already recognised for his brilliancy (in fact, he was one of the greatest Portuguese mathematicians ever) but lacking any practical experience. He could not adapt himself to the type of work developed at the observatory and left after a few months. The same happened to other national mathematicians and professors, like the military engineer and historian of mathematics Rodolfo Guimaraes (1866–1918) and Alfredo da Rocha Peixoto (1848–1904), a professor of Astronomy at the University of Coimbra.

Nevertheless, Oom found the right colleague and successor in Campos Rodrigues (Fig. 10.3). Before joining the Observatory in 1869, he had already shown a particular talent to improve instrumentation and data-gathering techniques whilst engaged in hydrographical surveys. He was amenable to assimilate and fulfil the profile of practical astronomer that Oom had developed in Poulkovo through his apprenticeship. Rodrigues spent the rest of his long life in a sort of scientific retreat at the AOL and committed himself to the careful study and improvement of almost all the instrumentation available, also seeking to perfect techniques of observation and calculation. His directorship (from 1890 to his death in 1919) corresponded to the most successful period of the AOL in terms of observational results.

10.8 A Monumental and Technical Assemblage to Measure the Universe

The site chosen for the construction of the Observatory was Tapada da Ajuda, a royal estate over the river Tagus originally used for hunting activities. Among other prospective locations, it was recognised as the site which provided the best conditions of visibility and stability for the instruments. Another aspect, which had been emphasized by Otto Struve, was that the Observatory could be seen from the ships anchored in the river. This was favourable to the transmission of visual time signals.[37] Besides, the scientific monument of Lisbon would appear with its whole majesty to those arriving at Lisbon by the waterfront.

The main building of the AOL, strongly inspired in Pulkovo, was conceived to combine a monumental appearance with the technical demands of exact astronomical measurement. The original plans were made by the French architect Jean Colson (1814–?), who worked for the Portuguese Ministry of Public Affairs. He had authored several projects for buildings in the capital, including the adaptation of the Monastery of Sao Bento into a Parliament, the adaptation of Monastery of Jeronimos in order to incorporate the headquarters of Casa Pia (a public charity for orphans), a Chapel in the Royal Palace of Necessidades and the Vilalva Palace. He also made plans for the Customs building in Oporto. When engaged in the completion of the main building and the installations of the fixed instruments, Frederico Augusto Oom was assisted by Jose da Costa Sequeira, professor at the Lisbon School of Fine Arts, who might have played a very significant role in the architectural development of the project.[38]

Its building bears a neo-classical façade and consists, essentially, in a central block with three wings radiating to the East, North and West (Fig. 10.5). This reflects the pattern of Pulkovo; however, the Lisbon observatory is smaller and lacks the extensions of the east and west wings which, in the Russian Observatory, project to the south.

The general pattern of a central block with wings had evolved since the late eighteenth century.[39] It can be identified, for instance, in the observatories of Stockholm, Copenhagen, Oxford (Radcliffe Observatory) and Dunsink. As the astronomers became increasingly concerned about the stability of the instruments, those they used for exact measurements were brought to the ground level and installed in the wings, as the upper floor of a central tower was left for observations with portable instruments and eventually for the installation of a great refractor sheltered by a rotating dome. This pattern circulated and evolved during the nineteenth century, and can be found, with variations, in several observatories of the period, both in Europe and the United States. European examples include the observatories of Edinburgh (Carlton Hill), Vienna and the Copenhagen University Observatory. In the United States, a shape similar to that of the Observatory of Pulkovo can be found, in a reduced scale, in university observatories like those of the University of Mississipi, Georgetown College, and the Hopkins Observatory in Williamstown (Massachusetts). Another example is the first building of the U. S. Naval Observatory. Even the Observatory of Greenwich adopted the same basic pattern when, in the 1890s, the New Physical Observatory (nowadays known as the South Bulding) was built to give extra office and storage space and some architectural coherence to the old Royal Observatory. The extent of the influence exerted by the Observatory of Pulkovo in each case might vary significantly of course, but the importance of the Central Observatory of Russia in shaping the ideal astronomical observatory of the period can be accepted without major doubts.

Wilhelm Struve's *Déscription de l'Observatoire de Poulkova*, published in 1845 and now a rather rare book, became a kind of manual for the construction of a sophisticated astrometric observatory. Three exemplars were sent from St. Petersburg to Lisbon during the stage of planning the new Portuguese observatory, and it was used as one of the main sources throughout the process of planning the buildings and choosing the instruments. The book remained influential long after its release. For instance, in the late 1870s it was used as the source of inspiration and guidance for the establishment of the Observatory of Nice.[40]

Figure 10.4: *Steinheil-Repsold transit instrument in the prime vertical (Courtesy AOL)*

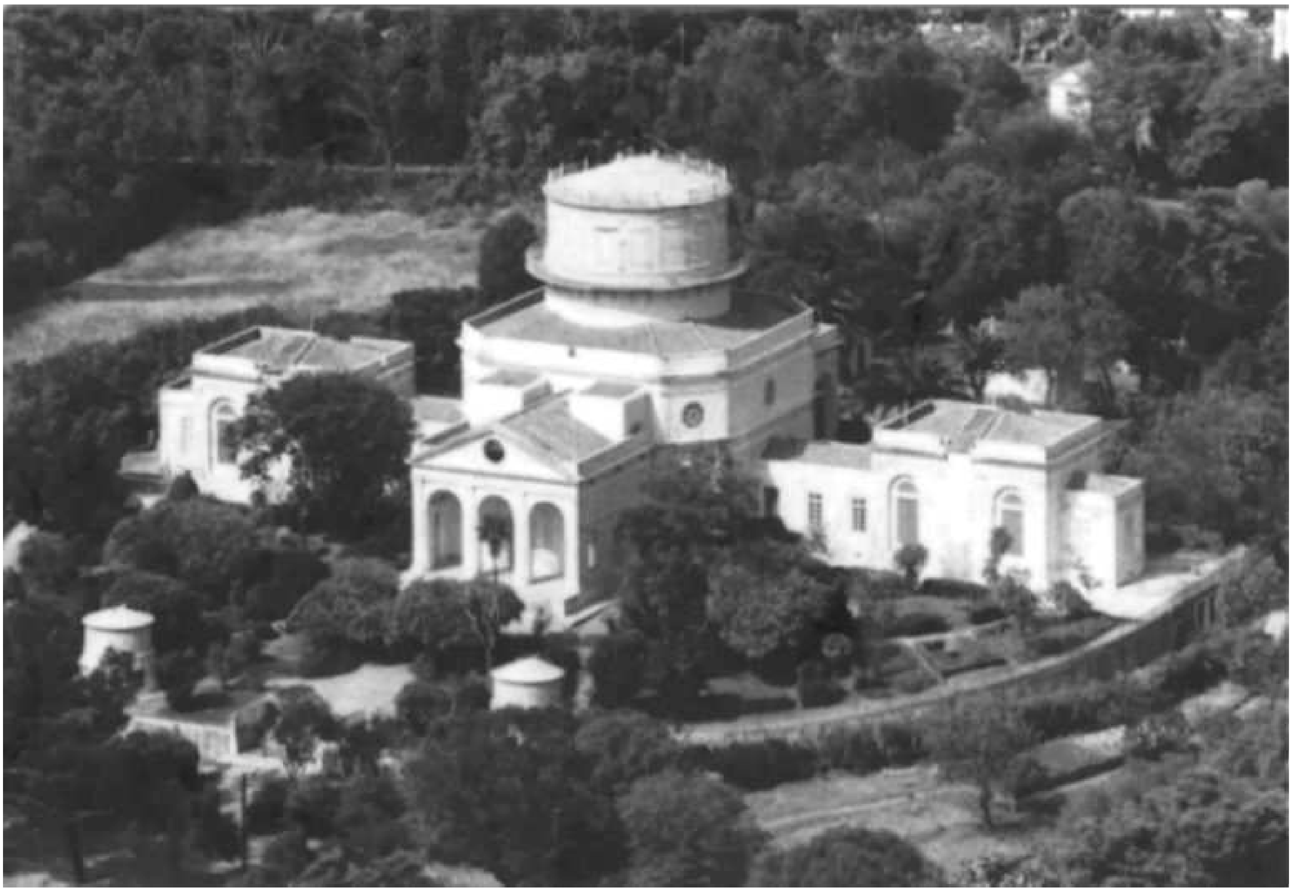

Figure 10.5: *Aerial view of the AOL (Archives of the AOL)*

The *Description* was not simply an account of the Central Observatory of Russia. It synthesised the forefront principles of observatory organisation, technology and practice of the period through the presentation of a real example. As the title indicates, it was written in French, and lavishly illustrated with detailed drawings and plans of the buildings, the instruments and their settings. Together with the scientific prestige of the author, all the necessary ingredients to create a reference work were combined, with the especial aspect that the book showed not how to carry out certain astronomical observations or calculations but how to create a cutting-edge observatory.

Wilhelm Struve was in the best position to author such a work not only for being an accomplished observer and the founding director of the Observatory of Pulkovo, but also because he travelled frequently, establishing direct contacts with an extensive network of European astronomers, and instrument makers as well. This allowed him to reinforce and further his prestige, and to remain on the forefront of the astronomical *know-how*.[41]

Before he was entrusted by the Tsar Nicholas I with the establishment of a central astronomical observatory for the Russian empire, Wilhelm had already accumulated an extensive experience with regard to astronomical buildings and instruments whilst running and upgrading the Observatory of the University of Dorpat, where he was a professor for many years.

The disposition of the main instruments at the central building of the Observatory of Lisbon reflects W. Struve's concept for its chief scientific assignments. The North wing houses a transit instrument in the prime vertical[42] which was to be the main instrument (Fig. 10.4). It is a modified version of its Pulkovo counterpart, which Struve used to measure the speed of light. It was meant to get benefit from the geographical situation of Lisbon, where, by the mid-nineteenth century, several stars deemed especially suitable for parallax measurements culminated very close to the zenith. Their absolute parallaxes were to be determined with this instrument and compared to relative measurements made with the great 15-inch equatorial refractor[43] placed inside the round tower that tops the central block of the building. The great refractor was also to be used in the observation of nebulae. This activity was difficult to foster in Pulkovo, not only for the great amount of work on course there but also due to the high latitude of St. Petersburg. Summer nights were very clear and thus reduced the chances of carrying out systematic and groundbreaking observations of these objects. A third possible field of work for the great refractor of Lisbon was the occasional observation of solar system bodies and phenomena.

The meridian circle[44] in the west wing (Fig. 10.6) was to provide the reference points for the observations with the great refractor, and W. Struve also recommended its use as the main instrument for time keeping observa-

Figure 10.6: *Repsold-Merz meridian circle (1864) (Courtesy AOL)*

tions. The east wing houses two small portable transit instruments[45] (fixed on piers), which actually became central in the timekeeping work of the Observatory. In fact, the observational activity of the AOL never corresponded to the scheme suggested by Struve. The instrument in the prime vertical and the great equatorial remained practically unused until the fist decades of the twentieth century. Wilhelm expected that one day the Observatory of Lisbon would announce the scale of stellar distances,[46] but no direct contributions were given in this topic.

The delay in the completion of the Observatory's structures and its organisation reduced the initial advantages with regard to the measurements of stellar parallax, as the precession of the Earth axis gradually sent the stars under attention away from their zenith (or very close) culminations.

As we shall see, relevant astrometric works, bearing a remarkable exactness, were carried out at the Observatory, but they represent the effort of the Lisbon astronomers to produce results with the resources available to them (both human and material), rather than the completion of the project envisioned by Wilhelm Struve.

10.9 Maximizing Tools and Techniques

The first works that Oom and Rodrigues carried out at the AOL were mainly related to the study and adjustment of the instruments, the elaboration of lists of stars to observe and the development of several mathematical tables and other calculation tools.

Rodrigues played a central role in this process.[47] He used his experience as an engineer to devise several diagrams and slide-rules adapted to astronomical calculation. They rendered the desired results with the required exactness, shortening significantly the time needed to complete the reduction of the observations. Some of Rodrigues' graphics were very similar to the three variable diagrams then used by English and French engineers, and later named *nomograms*.[48] These mathematical tools were a valuable asset in the equipments of the Observatory, given its scarce personnel and a statutory option for not giving permanent appointments to calculators.

Rodrigues contrived accessories and introduced modifications in many of the instruments. He also designed some original devices. For instance, the study of a Kaiser machine to determine the personal equation of observers[49] led him to conceive a new type of electric interrupter, in which the interruptions of an electric circuit were regulated by a tilting v-shaped piece.[50] This simple invention proved to be more reliable than the preexisting systems and Rodrigues applied it to the clocks of the Observatory.[51] He also created a new type of chronograph, with a single pen commanded by two electromagnets, one of which was set for a particular type of signal; for instance, in star observations comprising observational and clock signals, one electromagnet acted for the observational signals, and the other for the clock signals.[52] These contrivances were inscribed in the routine of the observatory but Rodrigues spent time and effort in the development of other devices. For instance, he designed a clock with a two-pendulum compensation mechanism[53] and a system for serial photography he intended to apply to the observation of the Venus transit of 1874,[54] which did not happen because a Portuguese expedition destined to Macau was cancelled.

As to the major instruments of the Observatory, Rodrigues clearly favoured the meridian circle. Its whole apparatus was subject to an intensive process of study and upgrading. The right-ascension micrometer and the reticules were modified; the objective lens was stabilized by means of a spring, and a special scale was adapted to the pointing circle so that preparatory calculations were not necessary. The illumination of the field of view and the reticule threads was improved by means of a device comprising an iris diaphragm that allowed the observer to adjust the light intensity. A symmetrical articulated chair could be adjusted according to the position of the instrument, providing comfortable seating for the observer. The chair could be quickly readjusted when the telescope had to be pointed to an object culminating in the opposite side of the zenith. The nadir observations were also improved in several respects. For example, Rodrigues developed a technique to produce a very smooth mercury surface, which consisted in pouring out the mercury against a collar-shaped piece. A similar procedure was independently developed by the French astronomer Périgaud.[55]

10.10 The Contribution of the AOL for the Determination of the Earth-Sun Distance

The most remarkable work carried out at the AOL was done in the context of a programme promoted in the late nineteenth century to refine the value of the solar parallax.[56] The main object to observe was the asteroid Eros, discovered in 1898 by Gustav Witt (Urania Observatory, Berlin) and, independently, by Auguste Charlois (Observatory of Nice). Eros was the first Earth-approaching asteroid to be discovered; in October 1900 it would be in opposition and very close to the Earth, reaching the minimum distance in December. This was seen as an excellent opportunity to make a new determination of the solar parallax and the Permanent International Committee for the Photographic Execution of the Sky-map established a temporary commission to coordinate an international programme with that goal. In the meeting of the Committee held in 25 July 1900 it was decided that the parallax determinations of Eros would be carried out by means of micrometric, heliometric and photographic observations. This would involve cooperation between European and North

American observatories, and between observatories located in the Northern and Southern Hemispheres. It was also pointed out that the celestial region crossed by the asteroid should be photographically surveyed, in order to determine the positions of comparison stars. The coordinates of comparison stars for the calibration of photographic plates should be determined by means of meridian observations. The programme involved 50 observatories worldwide and lead to values of solar parallax of $8''.807 \pm 0''.0028$ (based on photographic observations) and $8''.806 \pm 0''.004$ (based on micrometric measurements), both calculated by Arthur Hinks (1873–1945).[57]

The Observatory of Lisbon had no heliometer, lacked the needed photographic equipment and the micrometer of the great refractor was not in good order. Besides, the light gathering power of the meridian circle was not sufficient to allow useful observations of the asteroid.[58] There was only a small part of the programme the AOL could efficiently embrace: meridian observations for the catalogue of reference stars. 13 observatories, including the AOL,[59] were involved in the elaboration of this catalogue. The AOL contributed with the highest number of observations (about 3,800 in 19,000), yielding the highest average number of observations per star; the probable errors of the Lisbon observations were the lowest, both in right ascension and declination; there were no rejected observations and the weight in the final values of star positions was the highest of the group.[60]

In 1904, Rodriguez was awarded the Valz Prize of the Academy of Sciences of Paris. The board of the prize emphasized that the astronomer had obtained high precision results in a context of material limitation.[61] In fact, the contribution for the Eros programme represented the AOL in its prime, but also in the limits of its possibilities.

Other important works were done at the OAL in this period. Around 1890, whilst in charge of time keeping observations, Rodrigues refined the right ascensions of reference stars listed in the *Berliner Jahrbuch*.[62] This work was later used by Lewis Boss in his *Preliminary Catalogue*.[63] Boss was allegedly impressed by the exactness of Rodrigues' observations.[64]

In 1892, the AOL participated in a programme promoted by John Eastmann of the Naval Washington Observatory. Like the later Eros programme, the aim was to re-determine the solar parallax, in this case by observing Mars during its opposition in August that year. The low declination of the planet, bad weather in many locations, the delay in the call for to contributions and the complexity of the observational protocol proposed by Eastman rendered the programme unsuccessful. Nevertheless, the AOL contributed with accurate observations of Mars and reference stars, and its participation rendered a rather accurate determination of the diameter of the red planet.[65]

After the demise of Rodrigues, the Observatory, engulfed by a growing city, chained to the tradition of positional astronomy and essentially relying on mid-nineteenth century equipments, could not remain in this level of scientific accomplishment for too long. However, some further efforts are worth mentioning. The meridian circle was used, in the 1950s and 1960s, in an extensive determination of the declinations of stars listed in the almanac *Connaissance des Temps*. The transit instrument in the prime vertical was put into regular use from the late 1930s in the study of the variation of the Earth poles, at first by means of visual observations and then with the aid of photography.[66] Manuel Soares de Mello e Simas (1868–1934), who started working at the OAL in 1911, used the great equatorial in solar and planetary observations, as well as in the study of double stars. In 1923, he carried out, although with inconclusive results, an observational test of the theory of general relativity, which consisted in detecting the deflection of starlight by the mass of Jupiter during an occultation of a star by the planet.[67] After Simas, the great refractor was used in the systematic observation of occultations of stars by the Moon, for the determination of the Ephemeris Time.

Facing the same problems that affected old observatories engulfed by growing cities, the AOL only got back to the circuit of astronomical research when it became the host of the Centre for Astronomy and Astrophysics of the University of Lisbon in the 1990s.

10.11 Concluding Remarks

The history of the AOL provides a case where international collaboration and exchange are key elements to understand a scientific undertaking strongly framed by local ambitions for prestige and social development. It represents the effort to establish the dimensions of the Universe and to define the place of humankind in the cosmos, the same way it stands as a monument of the Portuguese aspirations for progress and cultural excellence. Its influence in social life through the function of time keeping testifies the fundamental role of astronomy in the emergence and development of civilization itself. Its heritage constitutes, at once, a valuable testimony of the architectural and technical trends of the time of its foundation and the creative agency of local practitioners. The heritage of the AOL represents not an arrival point of a surpassed way of making science, but rather the dynamic process of circulation and appropriation of applied forms of knowledge which thrive through the unstoppable movement of people, ideas and things, the very source of innovation that allows humankind to understand and transform the world in often unexpected ways.

Acknowledgement

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Figure 10.7: *Astronomical Observatory of Lisbon (Photo: Gudrun Wolfschmidt)*

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1. Gurshtein & Ivanov 1995.
2. See Naimova (undated).
3. See Raposo 2006a.
4. Stellar parallax is defined as the angle subtended by 1 Astronomical Unit (the mean Earth-Sun distance) at the distance of a nearby star. From the observational point of view, it consists in an annual shift in the position of a star due to the orbital motion of the Earth. In order to convert this angular shift into an actual distance, the knowledge of the length of the Astronomical Unit is needed. Its current standard value is 1.4959787×10^{13} cm. The Astronomical Unit is related to the solar parallax, which is defined as the angle subtended by the equatorial radius of the Earth at the Sun's mean distance.
5. On early attempts to determine stellar parallax see Williams 1982, and Siebert 2005. On the first measurements of stellar parallax taken as reliable see A. Pannekoek 1961, pp. 342–344, and Hetherington 1972.
6. This value is actually much closer to the contemporary value, 128.93 mas (SIMBAD, `http://simbad.u-strasbg.fr`, December 1st 2008).
7. Argelander 1842.
8. Wilhelm Struve 1847a.
9. Faye 1846a.
10. Faye 1846b.
11. Hervé Faye 1846c.
12. Wilhelm Struve, 1847b.
13. Peters 1853.
14. Faye 1847.
15. Wilhelm Struve, 1848.
16. Faye 1848.
17. Otto Struve 1850a.
18. Faye 1850a.
19. Otto Struve 1850b.
20. Faye 1850b.
21. Botelheiro 1961; Madeira 1961.

22. Folque 1866.
23. Archives of the AOL, FO1.
24. Faye 1850c.
25. For a comprehensive historical analysis of the nineteenth century in Portugal see Bonifßcio 2002.
26. For a biographic outline on Filipe Folque see Costa, 1986.
27. Folque's deposition is transcribed in *Inquerito ácerca das repartições de marinha* 1856, pp. 104–113.
28. He left a seminal account on the foundation of the OAL: see Ribeiro 1871.
29. The king's stipend for 1857 was worth 91,250$000 "réis", of which he conceded 30,000$000 to the foundation of the observatory. As a reference for currency rates: in the account of his visit to the Greenwich Observatory in 1854, Folque annotated that the total cost of the Airy transit circle, 2500 pounds, corresponded to 11,250$000 (Costa, note 27, p. 27).
30. On the prestige of the Observatory of Pulkovo in the nineteenth century, see Krisciunas 1984, 1990.
31. On the influence of Pulkovo in other observatories see, for instance: Dvoichenko-Markhoff 1943; Reingold 1964; Jones & Boyd 1971; Le Guet-Tully 2004.
32. The epithet "Royal" was dropped after 1910, when the Portuguese Monarchy was replaced by a Republican regime.
33. See Frederico Augusto Oom 1875.
34. Note that at the time the University of Lisbon had not yet been established; advanced teaching of scientific subjects was then maintained in the Portuguese capital at the Polytechnic School, which in 1911 became the Faculty of Sciences of Lisbon. Since the Astronomical Observatory of Lisbon was not meant to provide practical lessons, a teaching observatory, known as the Observatory of the Polytechnic School and later as the Observatory of the Faculty of Sciences, was founded in 1875. See Rivotti-Silva, 1998.
35. Lei Orgânica 1878.
36. The scientific personnel comprised three first-class astronomers and two second-class astronomers.
37. However, the time-signal devices used in Lisbon, a time-ball and later a system of lights, were installed close to river and not at the Observatory.
38. Abreu 2005.
39. Donnelly 1973.
40. Le Guet-Tully *op. cit.*
41. For a comprehensive approach to the life and works of Wilhelm and Otto Struve, see Batten 1987.
42. Optics by Steinheil and mechanical parts by A. & G. Repsold. Date of construction: 1863–1864. Aperture: 160 mm; focal length 2,31 m. For a detailed description see Santos 1938.
43. Optics by Merz and mechanical parts by A. & G. Repsold. Date of construction: 1864. Aperture: 38 cm; focal length 7 m.
44. Optics by Merz and mechanical parts by A. & G. Repsold. Date of construction: 1864. Aperture: 135 mm; focal length 1.995 m. For a detailed description see Observatório Astronómico de Lisboa, 1895.
45. For a detailed description of these instruments and the improvements they received at the OAL, see Rodrigues 1902, and Santos 1961.
46. Memorandum addressed to Lobo de Moira, 30 June 1857, transcribed in FO17 (Archives of the AOL).
47. For an overview on the activity of Campos Rodrigues as an instrument expert, see Raposo 2006b.
48. The term *nomogram* was introduced by Maurice d'Ocagne (1862–1938), a civil engineer who presented the study of these diagrams as a special branch of graphic calculation he called *Nomography*. See Evesham 1986.
49. Made by Boosman, Amsterdam, 1870. For a description of the machine see Observatório Astronómico de Lisboa, *op. cit.*
50. For a description of the interrupter see Oom 1906.
51. The main clock of the Observatory in his time was a Krille sidereal clock (no. 1647). Other pendulum clocks existing at the AOL include a Molyneux-Dent, a Leroy (no. 1327) and a clock designed by Campos Rodrigues (see note 54).
52. For a description of the chronograph see Observatório Astronómico de Lisboa, 1895.
53. This clock can be seen at the AOL in a workable state but with an unfinished dial. The two pendulums always move in opposite directions, thus the effect of any mechanical vibrations in one of the pendulums is compensated by the opposite effect in the motion of the other pendulum.
54. For a description of the system see Capello 1874.
55. See Périgaud 1888.
56. See note 5.
57. Pigatti & Zanini 2002.
58. Letter from Campos Rodrigues to Maurice Loewy, 20 September 1900 (Archives of the OAL: C235).
59. The other observatories were: Abbadia, Greenwich, Koenigsberg, Lick, Marseille, Nice, Paris, Rome (Vatican), San Fernando, Strasbourg, Toulouse and the U.S. Naval Observatory.
60. The values concerning the contribution of the Observatory of Lisbon were the following: probable error in RA: $\pm 0^s.014$ (first list), $\pm 0^s.011$ (second list); probable error in declination: $\pm 0''.15$ (first list), $\pm 0''.14$ (second list); mean number of observations per star: 5.4 (first list) and 6.0 (second list). In both lists the weight of the observations made at Lisbon was 4, in a scale ranging from 1 to 4 (*Institut de France . . . Circulaire* 11, 1904).
61. Académie des Sciences, 1904, 1075.
62. Rodrigues 1902.
63. Boss 1910.
64. Oom 1920.
65. The value determined for the equatorial diameter of Mars at the OAL was $9''.05 \pm 0.44$ (for the standard distance of 1 AU), which is a good approximation to the current value of $9''.36$. A comprehensive account of the instruments employed by the AOL and the results obtained is given in Observatório Astronómico de Lisboa, *op. cit.*
66. Several reports on these works and the methods employed can be found in the *Bulletin de l'Observatoire Astronomique de Lisbonne (Tapada)*, published between 1931 and 1971.
67. See Mota, Crawford and Simões, *in print.*

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C235: *Correspondência científica – cópias (1893–1929).*

Figure 11.1: *Kandilli Observatory, Istanbul*

11. Two Observatories in Istanbul: from the Late Ottoman Empire to the Young Turkish Republic

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Abstract

From the 17th century onward, the Ottoman Empire entered a phase of weakening, as a consequence of many factors including the dissolution of political stability, the loss of territory and decreasing revenue. In the second half of the 19th century, as an attempt to reinforce power of the central authority, the Ottomans undertook major reforms called *Tanzimat*. During this period, individuals started to establish professional and learned associations similar to those in the West which eventually led to the creation of a Faculty of Science and to the Ottoman University (*Darulfünun*, 1900).

In this context of reform and opening to the West, the Imperial Observatory (*Rasathane-i Amire*) was founded in 1868 with the support of France. Its primary aim was to exchange data between European and Ottoman meteorological stations. The Imperial Observatory occupied several locations before reaching its final setting in Kandilli (1911), on the Asian side of the Bosphorus where other activities were developed such as sismology, astronomy, meteorology and magnetic studies.

Following the spirit of the newly founded Republic in 1923, a serious reform of the academic programmes and a purging of the staff of the Ottoman University led to the establishment of the Istanbul University in the historical quarter of Beyazit (1933). The Istanbul astronomical Observatory was founded in the same year and its construction started in 1935. The university reform was largely influenced by the presence of German and other European scholars, many of them Jewish, escaping from Nazi persecution. In particular, Erwin Finlay-Freundlich from Potsdam Observatory became the first director of Istanbul Observatory.

Kandilli and Istanbul University observatories are briefly presented here, stressing the main steps of their creation and their astronomical heritage.

Introduction

After the demolition of the Istanbul's short lived Imperial observatory in 1580, no other state observatory was founded in the Ottoman Empire before the second half of the 19th century. The old 16th century Istanbul observatory followed a long tradition of astronomical observatories in the Islamic world including the Maragha (1258) and Samarkand (1424) observatories which served as models in the organisation and type of instruments that were used in Istanbul [1]. Despite the absence in the Ottoman Empire of similar institutions for almost three hundred years, astronomical activity continued mainly within medreses for administrating religious life (determining times of prayer and worship, etc.), and with the appointment of an astrologer dedicated to the Ottoman court called *müneccimbaşılık* (chief astrologership) whose main function was the preparation of calendars, fasting time tables and horoscopes [2]. These activities depending crucially on astronomical tables, the absence of a proper observatory led to the use first of Ulugh Beg's tables and, from the 18th century onwards, to the use of European tables such as those from Cassini or Lalande that had been translated into Turkish [3]. The position of chief astrologer was abolished in 1924 with the foundation of the Turkish Republic.

11.1 Kandilli Observatory

In 1868 Sultan Abdulaziz founded a new institution called *Rasathane-i Amire*, or Imperial Observatory [4]. However, this observatory was not dedicated to astronomy but rather to meteorology. Its creation was strongly influenced by the development in France at that time of an international meteorological network based on the electric telegraph. This had been set up in 1854 by Paris Observatory's director Urbain Le Verrier [5] who succeeded by the 1860's in centralizing daily meteorological data from most European countries. The main aim was the construction of synoptic maps for weather forecasting and storm tracking. Including data from the Ottoman Empire was essential in order to follow the motion of storms from the Atlantic to the Black Sea region and all the way to the Persian Golf. The creation of the Imperial Observatory of Constantinople was supported by Grand Vizier A'ali Pasha and also by Minister of Public Works Daoud Pasha who was at the head of the administration of the telegraph. Equipped with French instruments [6] and organized by its first director, the Greek-Ottoman Aristide Coumbary (1828–1896) who was following Le Verrier's recommendations, the new observatory quickly became operational. Through this new institution, the Ottoman Empire took part in the *International Meteorological Congress* in Vienna in 1873which established the rules of the emerging worldwide meteorological network.

Despite the continuous activity of the Imperial Observatory over the years, observations in Constantinople were made from the director's house in Pera until its destruction by the major 1894 earthquake. From the very beginning of the observatory's existence, several unsuccessful attempts were made to develop astronomical observations with professional equipment. After the 1894 earthquake the erection of a proper observatory with several buildings dedicated to geodynamics, astronomy, meteorology and magnetic studies was planned [7]. However, this project was never achieved and after Coumbary's death in 1896, the Rasathane-i Amire, then led by Salih Zeki (1864–1921), remained until 1909 in Maçka, in a state building where it had been relocated after the 1894 earthquake. During the Young Turks revolution of April 1909, most of the instruments were destroyed. In 1910 Fathin Gökmen (1877–1955) became the new director of the Imperial Observatory. Encouraged by Salih Zeki, in 1911, he provided the institution with a proper observational site and dedicated buildings, including a modern astronomical observatory. The new site was located in Kandilli, on the Asian side of the Bosphorus, on top of a 120 m hill, where original buildings can still be seen today.

In the first years, administrative, meteorological and seismological buildings were erected. In 1918, an equatorial telescope (20 cm diameter and 307 cm focal length) was ordered from the Zeiss Company. It was installed in 1925 and the building housing it was completed in the period 1926–1933 (Fig. 11.1, p. 114). The architectural style of the building reflects the Ottoman revivalist style of the early 20th century. The main astronomical activities were time service and solar physics. Astronomical instruments that remain from this period include naval chronometers, theodolites, electrical clocks, Leroy chronometers, sextants, etc.

Since 1982, Kandilli Observatory has been affiliated to the Bosphorus University and, as an institution, is named *Kandilli Observatory and Earthquake Research Institute*. Besides its site, its various buildings and its astronomical heritage – large instruments, clocks and other scientific instruments and accessories –, Kandilli Observatory hosts in its library a very rich collection of manuscripts. This collection was selected to be one of the ten pilot projects for the *Memory of the world* programme launched by UNESCO in 1992, aiming at the preservation, cataloguing and digitization of more than 1300 astronomical manuscripts written in Turkish, Persian and Arabic. In addition, since 2007, Kandilli Observatory has hosted a museum displaying 16th to 19th century astronomical instruments, as well as equipment and instruments that were used in the observatory.

11.2 Istanbul University Observatory

In the 19th century Ottoman Empire, during the reform period known as Tanzimat, several attempts were made to establish a new institution of higher education besides medreses. Such an institution was often called *Darulfünun* ("house of the sciences"), which in the late 19th century was considered to be the equivalent of a university. The first Ottoman university was eventually established under the name of *Darulfünun-i Sahane* on 31 August 1900. It was the foundation of present day Turkish universities [8]. In 1933, ten years after the founding of the Turkish Republic, Darülfünun was transformed into the "Istanbul University". The main consequences were a complete revision of the academic programs and a purging of the staff. The transition was helped by the influx to Turkey of large numbers of German and European scholars, many of them Jewish, fleeing Nazi intimidation or persecution [9]. Indeed, in April 1933, Germany's "Civil Service Law" established that civil servants who were not of "Aryan descent" as well as opponents to the Nazi regime were forced to retire from the civil service (teachers, professors, judges, etc.). Albert Malche, a Swiss professor of pedagogy, was invited in 1932 to come and help with the preparation of a report on the Turkish educational reform. In the same year, persecution of some scientists had already begun. Albert Malche was in contact with pathologist Philipp Schwarz who was among the first to be fired. Schwarz made the link between the new needs of the young Turkish university and European Jewish scholars: in March 1933 he established the "Emergency Assistance Organization for German Scientists" to help Jewish and other persecuted German scholars to find employment in countries accepting such refugees. Recognizing the opportunity, Turkey invited Dr. Schwarz to Ankara. This visit was quickly followed by the arrival in Turkey of 300 academics and 50 technicians who obtained positions both in Istanbul and Ankara Universities. In particular, leading astronomy professors were invited to set up an academic department and an observatory. Among these was Erwin Finlay Freundlich who had to resign from his position in Potsdam. He was offered a position at Istanbul University to launch and lead Turkey's first astronomical laboratory, a position that he kept until 1937.

The observatory was chosen to be located within the university gardens, at the heart of the historical quarters in Beyazit. It was built in 1935 by architect Arif Hikmet Holtay, who had been educated in the Stuttgart Technische Hochschule. At that time, he was also assisting Ernst Egli, Austrian architect at the head of the architectural section of the Academy of Fine Arts in Istanbul (1930–1936). Egli initiated radical changes in Turkish architecture with the introduction of the rationalist and functionalist principles of European modernism [10], well reflected by Holtay's Istanbul University Observatory (Fig. 11.2, p. 117).

The observatory consists of a single building with two domes (the smallest one has been recently destroyed) and a meridian room (the roof of which has been removed) housing all astronomical activities. The main

Figure 11.2: *Istanbul University Observatory*

instrument is an astrograph (30 cm diameter, 200 cm focal length) that was ordered from Zeiss in 1934 by Freundlich and installed in 1936. It is still operational today. Other main instruments installed in the 1930's include photosphere and chromosphere refractors. An inventory of instruments and archives has now started at the Observatory and since 2008 a room has been allocated to them and equipped for storage.

After Freundlich's departure in 1937, Wolfgang Gleissberg (originally from Breslau University and working with Freundlich in Istanbul) became head of the observatory and remained as such most of the time until 1958. After that, directorship went to Turkish scholars who had been trained by Freundlich and Gleissberg [11]. The Observatory is currently part of the Science Faculty of Istanbul University.

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Figure 11.4: *Sign of the Imperial Observatory (19$^{\text{th}}$ century) now visible at Kandilli observatory*

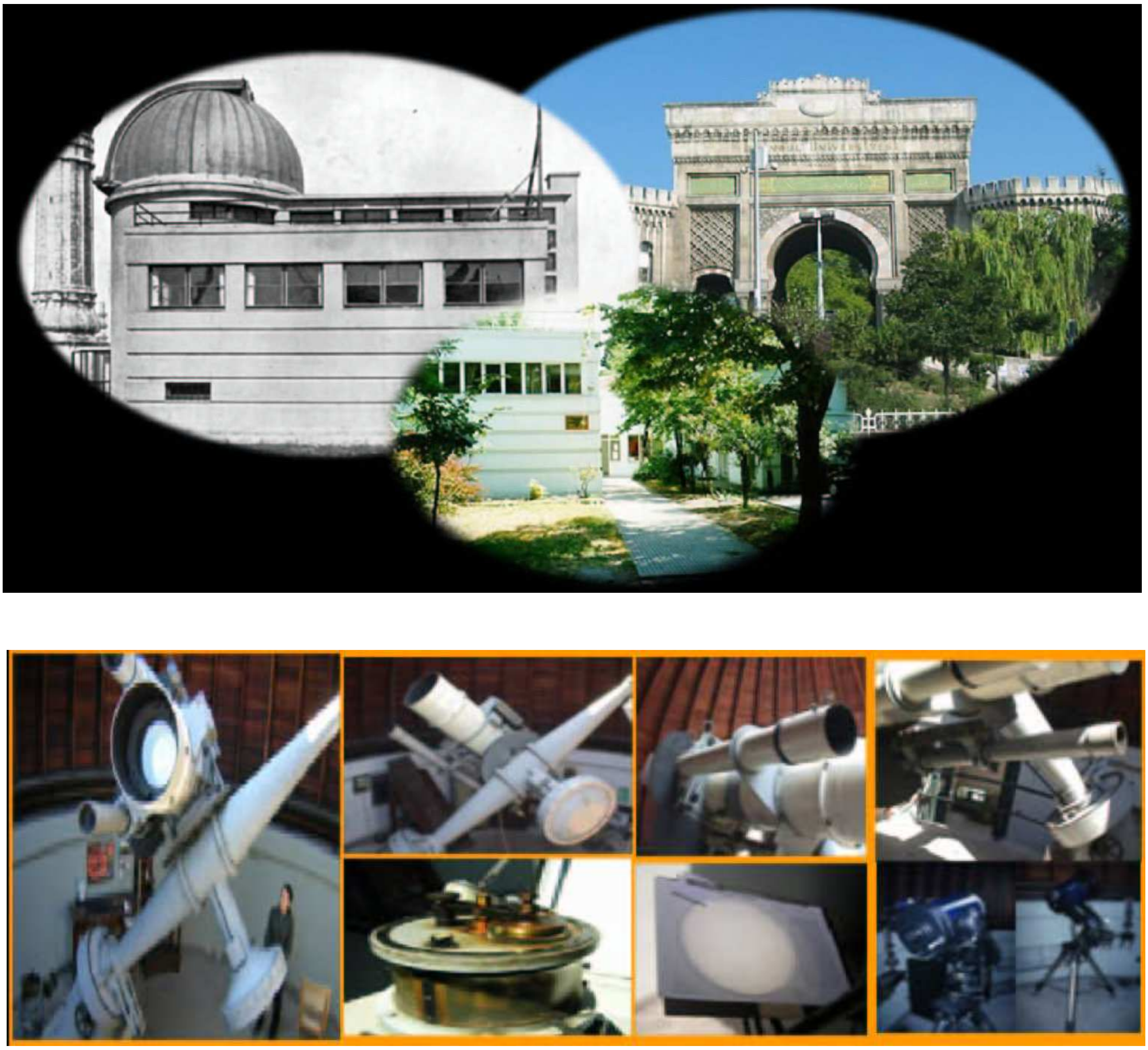

Figure 12.1: *Istanbul University Observatory and the telescopes*

12. Istanbul University Observatory with its Past, Present, and Future

Gaye Danişan and Füsun Limboz (Istanbul, Turkey)

Figure 12.2: *Istanbul University Observatory (Photo right: Andreas Schrimpf, Marburg)*

Here Istanbul University Observatory is introduced with its short history and present time situation. Istanbul University Observatory is the first education/-research institution of the Turkish Republic.

It was established under the directory of Dr. Erwin Finley Freundlich (1885–1964) after the University Reform which took place in 1933. Freundlich was until 1933 observing with the solar tower in the Einstein Institute in Potsdam and professor in Berlin.

In the history of Istanbul University Observatory the other important person was Prof. Dr. Wolfgang Gleißberg (1903–1986), also of Jewish origin, who worked as assistant in Breslau Observatory. After his dismission he came to Turkey and became professor in 1934 and stayed for 24 years.

The observatory building in the Beyazit University Campus was erected in 1935–1936 by the engineer Ekrem Hakki Ayverdi. An astrograph (30 cm, focal length 150 cm) was ordered by Gleißberg in 1934 from the Zeiss firm of Jena. Then it came over Trieste by ship and arrived in 1936 and was settled in the dome of the new building.

All research was in the field of theory until 1948 (space absorption, stellar strucure). Then the sunspot cycle and minor planets were observed and studied.

In the present, the Observatory, which is known with the solar photospheric and chromospheric observations, is a part of Istanbul University, Science Faculty, Astronomy and Space Science Department.

Figure 13.1: *Recent picture of the main building of MAST (Photo from the MAST archives)*

13. Heritage and Observatories in Brazil at the Turn of the Twentieth Century: an Overview

Marcus Granato (Rio de Janeiro, Brazil)

Abstract

The first systematic astronomical observations in the southern hemisphere were in Pernambuco, northeastern Brazil, in the short period of Dutch rule in the region (1637–1644). Later, in the late nineteenth and early twentieth centuries, there were three observatories on Brazilian soil: Imperial Observatório do Rio de Janeiro, Observatório da Escola Politécnica, both in Rio de Janeiro, and Observatório Central, in the southern city of Porto Alegre. The first was created by Imperial decree by D. Pedro I, on 15 October 1827, while the second, linked to Universidade do Brasil, was established on 5 July, 1881. The third was planned in 1889, but only inaugurated on 24 January, 1908 as part of the Escola de Engenharia. All three institutions exist to this day, and their scientific instruments of historical value are included in cultural heritage preservation projects. The largest collection of this kind of objects is at Museu de Astronomia e Ciências Afins (MAST), most of whose 2000 artefacts come from the Imperial Observatory (today the National Observatory). Many of them were produced in Germany by manufacturers such as Gustav Heyde, Carl Zeiss, Askania-Werke, Carl Bamberg and Max Kohl. The buildings of the Observatório Central (1921) and Observatório Nacional (1921) are listed by federal and state heritage protection agencies, particularly because they were purpose built for astronomical research and have architectural features typical of the late nineteenth and early twentieth centuries that have not been altered over the years.

13.1 Introduction

Astronomical observatories, which count among the oldest scientific institutions, are of special interest to the history of science and in particular the history of astronomy. They are a testament to the importance that many nations have given to this branch of science, but one that is lost over time. Kings, tsars, presidents and government representatives of every kind have channelled great sums into constructing buildings, buying instruments, paying personnel and developing projects and activities in the area. It is a comparable commitment to one that was inspired by a different way of observing the sky, with religious sentiment, for which the construction of buildings such as cathedrals and temples also merited great investments and efforts.

Over the years, these institutions amassed great collections of scientific instruments, which have gained historic value for the events they were used for, the discoveries they made and the development of technology and precision they exemplify.

Observatories are both the outcome of and a main factor behind the development of astronomy and astronomical instruments. In the seventeenth and eighteenth centuries, the observatories in France and England boasted unrivalled facilities and instruments. In the nineteenth century, the observatories in Germany and at Pulkovo in Russia surpassed their English and French counterparts, only to be gradually superseded from the middle of the century onwards by the observatories in the USA, which have since taken the lead in the development of astronomy. Prior to the nineteenth century, there were only some thirty major observatories in the world. Just one century later, there were over 200, as well as many smaller stations. Keeping pace with these advances, instruments of ever greater precision were also developed, spearheading a veritable technological revolution.

Recounting some of these developments, this paper will present an overview of the astronomical observatories that existed in Brazil at the turn of the twentieth century. The three institutions to be presented are Imperial Observatório do Rio de Janeiro [Imperial Observatory of Rio de Janeiro]), Observatório da Escola Politécnica [Observatory of the Polytechnic], both in Rio de Janeiro, and Observatório Central [Central Observatory], in the southern city of Porto Alegre. The first of these was created by Imperial decree by D. Pedro I on 15 October, 1827, and the second, linked to Universidade do Brasil [University of Brazil], on 5 July, 1881. The third, which was originally planned in 1889, was eventually inaugurated on 24 January, 1908.

13.2 Origins of some Observatories in Latin America

The difficulties that most European countries faced in establishing national observatories in the seventeenth century were great, but greater still were the hurdles to be overcome in Spain and Portugal's colonies in the New World. These two countries were going through a period of scientific stagnation that was mirrored in their colonies, where they also imposed a general policy of stifling free thought.

The Dutch had a different outlook, and made sure they took people to their colonies who were qualified to study the regions they had conquered. It was within this context that the first astronomical observatory in the American continent[1] and in the whole southern hemisphere[2] was built in 1639, in one of the towers of Friburgo palace, residence of Governor João Maurício de Nassau-Siegen, on Antonio Vaz island, Pernambuco, Brazil.[3] From this palace, the first ever systematic astronomical and meteorological observations in the southern hemisphere were made under Maurício de Nassau during the brief period of Dutch rule in Brazilian territory from 1637 to 1644.

The person in charge of these astronomical observations was George Marcgrave,[4] who was particularly keen to track the movement of Mercury, which was hard to observe from the northern hemisphere. Marcgrave arrived in Brazil in 1638 and died in 1644 in Angola; the fate of all his manuscripts is not known for sure. Abrahão de Moraes[5] uncovers some clues from the work of Pingré,[6] in which he describes Marcgrave's astronomical work, which highlights observations of Jupiter and Mercury, as well as the first solar eclipse ever to be observed scientifically in the Americas, on Antonio Vaz island in 1640.

The first national observatories in Latin America date back to the eighteenth and nineteenth centuries in Bogota (1803), Rio de Janeiro (1845), Santiago (1852), Cordoba (1870) and Mexico City (1878).[7] They all have some features in common. They came into existence thanks to the determination and enthusiasm of government officials, with the exception of Chile, where foreign expeditions to the country were the main driving force. Though some pragmatic concerns, such as measuring national territories and making geographical expeditions, were tied up with the creation of these institutions, the main aim of the observatories in Rio de Janeiro, Santiago, Cordoba and Mexico City was to contribute to pure research in astronomy. They all went through periods of stagnation, usually caused by political and/or economic factors, during which time only routine activities were carried out. Nonetheless, four of the original five have managed to survive, and exist to this day as active research centres.

13.3 Observatories in Brazil in the Nineteenth and Early Twentieth Centuries

The existence of observatories in Brazil is an indication of scientific activity in the country prior to the twentieth century, when Universidade do Brasil [University of Brazil] was created. At the cusp of the twentieth century, as mentioned before, three institutions were active in astronomical observations: Observatório Nacional [National Observatory], Observatório do Valongo [Valongo Observatory], linked to the Escola Politécnica (polytechnic) and Observatório Central [Central Observatory].

All three institutions continue to work to this day, and their scientific instruments of historical value are included in cultural heritage preservation projects. The largest collection of this kind of objects is at Museu de Astronomia e Ciências Afins (MAST), most of whose artefacts come from the Imperial Observatory (now the National Observatory). Many of them were produced by German manufacturers, including Gustav Heyde, Carl Zeiss, Askania-Werke, Carl Bamberg and Max Kohl. The buildings of the Central Observatory (1921) and National Observatory (1921) are listed by the federal heritage protection agency, particularly because they were purpose built for astronomy research and have architectural features that are typical of the late nineteenth and early twentieth centuries, which have not been altered over the years. Significant aspects of the history of these institutions and their collections of scientific instruments will now be discussed.

13.3.1 Observatório Imperial do Rio de Janeiro / Observatório Nacional [Imperial Observatory of Rio de Janeiro / National Observatory]

During the eighteenth century, the Portuguese government did little to encourage scientific activity in Brazil. It was only after D. João VI arrived in the country, fleeing Napoleon's invasion of Portugal, and later under the rule of D. Pedro I, that this situation took a turn for the better. Rudimentary astronomical observations were made as of the early nineteenth century at Escola Militar [Military School] in Rio de Janeiro, but it was only on 15 October, 1827 that the Emperor decreed the creation of an astronomical observatory with the purpose of producing astronomical and meteorological data, as well as giving courses in astronomy to students from the military and naval academies.[8]

For different reasons, the observatory only began its work in the middle of the century. It was first based at Escola Militar under the directorship of Soulier de Sauve, who died a year later. It was then transferred to a more suitable location on Castelo hill, Rio de Janeiro, in an unfinished Jesuit church.

In 1846, the observatory was given its official name, Imperial Observatório do Rio de Janeiro, in a decree that also established the work it should undertake.[9] It was to be responsible for making astronomical and meteorological observations, educating and training the students from Escola Militar and Academia da Marinha [Naval Academy], publishing an astronomical yearbook and supplying the right time for ships docked at the port.

In 1858 and 1865, the new director, Antonio Manuel de Melo, organised field observations of solar eclipses and published some astronomical tables. The largest instrument from this period of which there is mention was a Dollond refractor telescope with a 7 cm aperture. Fig. 13.2 shows a picture of the Imperial Observatory on Castelo hill.

After the Paraguay War (1870), Emperor D. Pedro II, who was keen on astronomy, reorganised the observatory and appointed French astronomer Emanuel Liais as its director. This was the beginning of a period during which much work was produced at the observatory and was presented by the director at European academies. According to a study of the period by Christina Barboza (1994),[10] the observatory was held in higher regard than the other scientific institutions of the day in the country. An indication of this is the invitation it received to take part in a major event organised by the French to observe the transit of Venus across the solar disk. Under Liais' directorship, the Imperial Observatory became a hothouse of scientific activity, yet little of the knowledge acquired was actually applied. Liais managed to split the observatory off from the Escola Militar, but his administration was also dogged by many controversies, until he was finally dismissed in 1881.[11]

Liais was succeeded by his main collaborator, a Belgian engineer called Luiz Cruls. Under his directorship a number of scientific expeditions were undertaken: to Punta Arenas to observe the transit of Venus across the solar disk (1882); to the Central plateau to demarcate the Brasilia quadrilateral, site of the future capital city (1890); and to the border with Peru and Bolivia to determine the exact location of the source of the Javari river, which was crucial in the conflict between the countries (1898).[12] At the same time, in 1887, the observatory was invited to take part in another major international event also organised by France: to completely map out the celestial dome (*Carte du Ciél*). The standard scientific instrument needed for this project, an equatorial photographic telescope, was even purchased, but the political upheavals surrounding the proclamation of the Republic in 1889 prevented the observatory from actually taking part in the project. The instrument was never assembled in its original pavilion.

With Brazil a republic, the observatory was renamed Observatório do Rio de Janeiro, and then in 1909, Observatório Nacional [National Observatory], which continues to be its name to this day. At the time, it was entrusted with organising a meteorological service for the entire national territory, much against the wishes of its Director, Henrique Morize. Many meteorology instruments were accordingly acquired by the observatory and are now part of the MAST collection.

The location of the observatory on Castelo hill had been the subject of much debate since the mid 1800s. Reports by its directors had repeatedly pointed to the unsuitability of the site because the land was unstable, making the use of large-scale astronomical instruments unfeasible and severely limiting its activities. A mixture of political factors and plans to modernise the city were instrumental in the decision to finally move it to São Januário hill in the aristocratic district of São Cristóvão.[13]

Work on the new architectural complex was begun in 1913 and completed in 1920, and the following year the observatory was moved there. Meanwhile, the demolition underway in the centre of town, including Castelo, inspired rumours that treasures hidden by the Jesuits were to be found there. Fig. 13.3 shows a picture of the National Observatory in its new premises on São Januário hill in 1922.

The remit of the observatory included the following technical and research activities: determining the official time of the country, weather forecasting, astronomical tables, the demarcation of Brazilian borders, systematic observations of solar eclipses from Brazilian territory, magnetic mapping of Brazilian soil and many others.[14] Many different scientific instruments were used for these tasks, which now make up a varied collection with some high quality instruments.

At this time, several institutional and financial hurdles stood in the way of the acquisition and functioning of these instruments. There are cases of instruments that took years to be repaired or years to be delivered. Naturally, this meant the set of instruments needed for research could not be kept up-to-date. Also, the number of people employed by the observatory was minimal, so much so that there was a shortage of technical staff, while the scientific personnel were often underqualified for the tasks. One example of how this affected the work at the observatory was an intended study of latitude variations. A programme was prepared for the project, but it had to be abandoned because there was not enough staff to do the calculations.[15]

These two factors illustrate a characteristic feature of the early Republican years: the absence of "institutionalised" research activity. This is only developed in the second half of the twentieth century, when the instruments needed for such work were gotten.

Almost all the directors made an effort to ensure the observatory was supplied with the latest equipment. This culture was passed down from the very first directors during the Imperial era, who had managed to assure the effective engagement of the work carried out at the observatory with the international scenario. The directors were fully aware of the institutional and financial restrictions, and what was needed for the practice of astronomy, but there were countless difficulties to be overcome.

The instruments in the MAST collection and the uses to which they were put give us a good picture of what kind of institution the National Observatory was: what role was envisaged for it and what its activities actually were. An analysis of these instruments shows us what could be done and allows us to draw inferences about the development, or in some cases the stagnation, of the

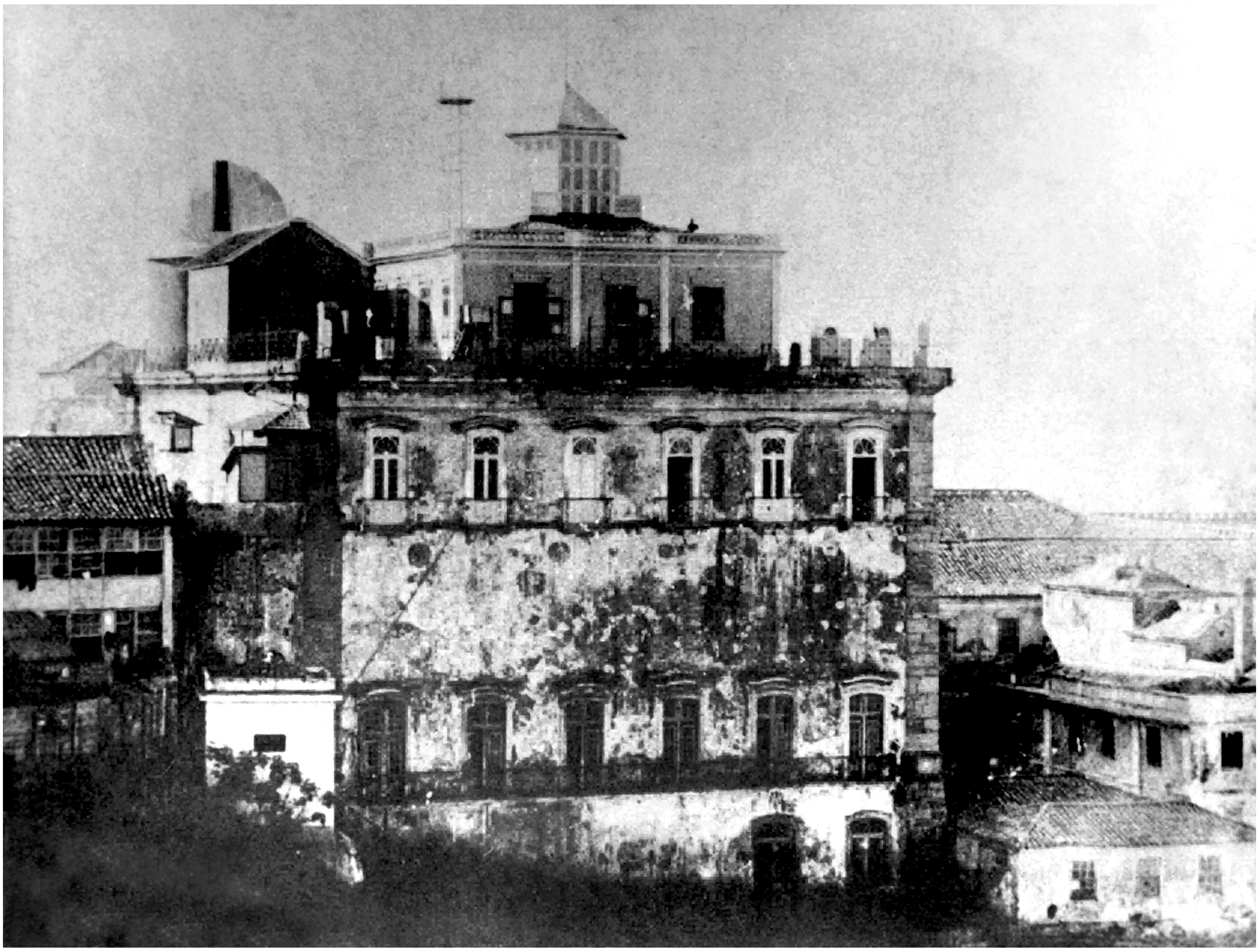

Figure 13.2: *Imperial Observatory on Castelo hill (second half of the 19th century) (Photo from the MAST archives)*

methods used. The National Observatory is an active research centre to this day, and still stands on the same historic site in new premises inaugurated in 1985.

13.3.2 The Collection of Historical Scientific Instruments at MAST

Museu de Astronomia e Ciências Afins (MAST) was first opened to the public in 1985. It is a research institute under the auspices of the Ministry of Science and Technology and one of its main activities is to preserve its collections, chief among which is the collection of scientific instruments, which is what defines MAST as a museum of science and technology. The museum occupies the former premises of the National Observatory in a number of buildings belonging to that institution. Both the buildings and the collections they hold are preserved by a federal law passed in 1986, and are registered in Livro Histórico [Historical Book] volume 1, pages 94–97, entry 509, of 14/08/1986.[16] The main building houses the museum's technical store, where much of the collection of historical scientific instruments is kept. Fig. 13.3 below shows a recent picture of the building.

The MAST collection currently contains 2000 objects, 1600 of which came from the National Observatory and were used in services and research of great importance to Brazil. Fig. 13.4 (a, b, c) contains pictures of some instruments in the MAST collection that originally came from the observatory and were manufactured in Germany.

Most of the instruments date back to the nineteenth and early twentieth centuries, though some of them, like the J. Sisson quadrant and the G. Adams theodolite, were made in the eighteenth century. It is a very rich collection and can hold its own against any of the great collections of its kind in the world.[17] Most of the objects were used for astronomy, topography, geodetics, geophysics, meteorology, metrology, time measurements and optics. These are all typical of this kind of institution, but the collection also has instruments from other scientific areas, such as electricity, magnetism and chemistry. As a collection, it has always grown, albeit not consistently. Its most recent additions have come from Instituto de Engenharia Nuclear [Institute of Nuclear Engineering] and Centro de Tecnologia Mineral [Centre of Mineral Technology], both also research institutes under the Brazilian Ministry of Science and Technology.

The set of listed buildings includes the MAST main building as well as a number of pavilions housing some of the largest instruments in the collection (equatorial

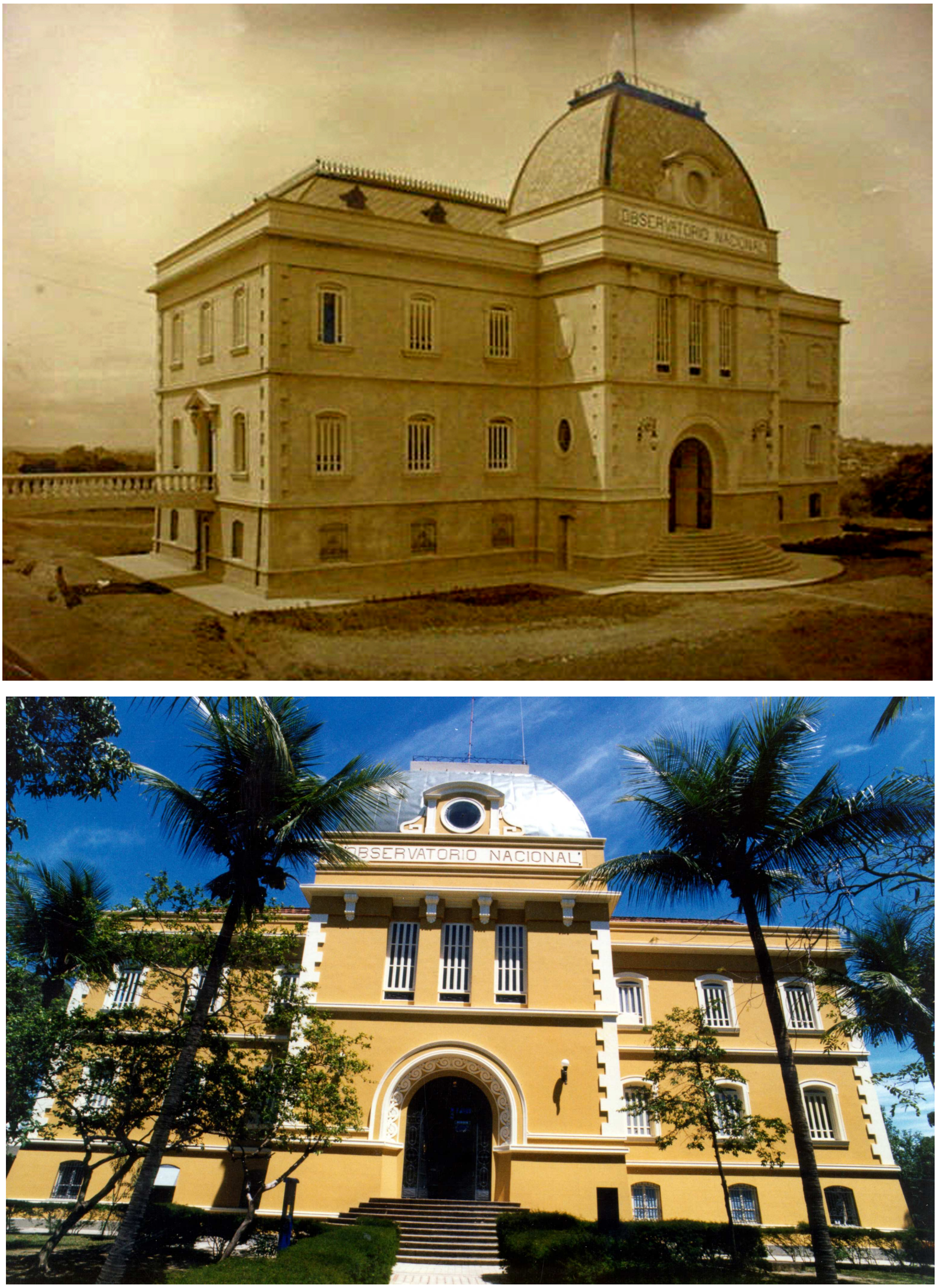

Figure 13.3: *Above: View of the main building of the National Observatory on São Januário hill (first half of the 20*$^{\text{th}}$ *century), Below: Recent picture of the main building of MAST (Photo from the MAST archives)*

Figure 13.4: *Instruments in the MAST collection (from left to right): meridian refractor (Askania), equatorial refractor (G. Heyde) and analytical balance (Max Kohl) (Photos from the MAST archives)*

telescopes with 32 cm and 21 cm objective lenses; meridian instruments manufactured by Heyde, Carl Bamberg and Cooke & Sons, and a Zeiss photoheliograph) in their original places. These instruments are in a good state of repair and have all their original parts. This is surprising if we bear in mind that at similar institutions across the world, many astronomical instruments were modernised after the Second World War and many elements, such as circle dividers, eyepieces and clockwork mechanisms were often removed and replaced with more modern parts.

Some of the pavilions and their domes were restored quite recently. One such example was the restoration of the pavilion that houses the 32 cm equatorial refractor telescope, which involved restoring the moving metal dome and building, and conserving the telescope.[18] Another was the rehabilitation of the pavilion for a meridian refractor telescope manufactured by Gautier, which included a complete restoration of the instrument.[19]

The smaller instruments are mostly kept in cabinets in seven storerooms, and most are protected by heritage agencies. A typological classification was devised for these instruments based on international criteria and with the help of an international consultant.[20] It divides the instruments into the following categories: astronomy, calculation and drawing, cosmography and geography, time measurement, electricity and magnetism, geodetics and topography, geophysics and oceanography, mechanics, meteorology, metrology, navigation, optics, thermology and chemistry.[21]

One interesting feature of the collection is the great variety of objects it contains. As well as instruments that can be found in institutions and museums of a similar ilk (telescopes, theodolites, meridian circles, transits, precision clocks, magnetometers, meteorology instruments, comparators, etc.), MAST also preserves some quite singular pieces, such as a Kelvin tide predictor, an Henrici harmonic analyser, an instrument by Salmoiraghi to determine personal equation errors, instruments to lay cross-wires in reticules, division machines and other special instruments. One of the instruments is unique, and highlights the capacity for quality manufacturing that existed in Brazil: an altazimuth from the late 1800s designed by astronomer Emanuel Liais and manufactured in the workshops of José Hermida Pazos in Rio de Janeiro.[22] optics workshop from Jose Maria dos Reis family) till 1910 This instrument won a number of awards at different exhibitions in Brazil and Europe.[23]

The manufacturers represented in the MAST collection were among the most acclaimed, skilled manufacturers in Europe and the leading names of the contemporary precision industry, including: Brunner Fréres, from Paris (magnetometers, meridian circles and theodolites); A. Hilger,[24] from London (spectroscopes and accessories); G. Heyde, from Dresden (transits and theodolites); Carl Zeiss,[25] from Jena (astronomical and optical instruments); Ph. Pellin,[26] from Paris (physical optics instruments); T. Cooke & Sons, from York (telescopes and accessories); Paul Gautier, from Paris (meridian circle and astronomy accessories); L. Leroy, U. Nardin and C. Riefler (astronomical clocks and chronometers); and Societé Genevoise des Instruments de Précision (comparator),[27] from Geneva. Added to which, as mentioned above, there are some quality instruments made in Rio de Janeiro by local manufacturer José Maria dos Reis and his successor, Hermida Pazos.[28]

An analysis of certain groups of objects in the collection together with the historical archives from the observatory raises interesting questions for historical analysis. Certain groups contain five, six or more identical instruments, like theodolites or thermometers. Many instruments were never even taken out of their original packaging and are in a perfect state of repair, as new. Some instruments belong to areas where the observatory never did any work.

These questions are central to the research of the collection that is being carried out to shed light on some obscure corners of the history of science in Brazil, even if they often uncover the least productive periods of the country's scientific institutions.

For certain periods of time, the observatory seems to have served as a repository for instruments to be loaned out to other government departments, such as for the many science and technology expeditions across the nation's territory or even to do meteorology work in different regions. The difficulty of finding and hiring specialised technical staff for the observatory may have been another factor that determined the fate of certain instruments that were purchased but never used.

Most of the instruments in the collection are in a good state of repair, a fact that is worthy of note, especially given the tropical climate in Rio de Janeiro. Additionally, the instruments have not been cannibalised, which means that most of them are complete, and many of these in working condition. This begs other questions, such as whether they were really used (the vast majority of them) or wether the observatory went through periods when its activities were stopped, which would explain the instruments' having been abandoned because they were no longer up-to-date.

In 1993, work was started on an inventory of the objects, which is still ongoing. All the objects have an inventory number[29] and set location. The instruments have also been photographed and an image archive has been created, as well as a database of digital images. Finally, a computerised record has been introduced using software developed by MAST especially for this kind of collection.

13.3.3 Observatório do Valongo – Escola Politécnica [Valongo Observatory / Polytechnic]

The roots of the current Observatório do Valongo date back to a small observatory built by astronomer Manoel Pereira Reis in partnership with Joaquim Galdino Pimentel and André Gustavo Paulo de Frontin. Pereira

Reis was a researcher, professor and astronomer at the former Imperial Observatório do Rio de Janeiro, which he left after falling out with its then director, Emmanuel Liais. The site chosen to build the new observatory in the capital city was Santo Antônio hill, near the Escola Politécnica in Largo de São Francisco square in the centre of Rio de Janeiro.

Galdino Pimentel and Pereira Reis joined the teaching staff at Escola Politécnica and donated the observatory to the institution, along with all the instruments, which had been donated by different researchers and institutions.

On 5 July, 1881, the Escola Politécnica observatory was officially instated on Santo Antônio hill, Rio de Janeiro, forming the beginnings of what is now the Observatório do Valongo.[30]

New instruments started to be purchased in 1901, and in 1907 a refractor equipped for astronomical photography manufactured by Cooke & Sons arrived. The same instrument still exists, having gone through reforms from 1997 to 2000. Fig. 13.5 shows the observatory in its original location.

When Santo Antonio hill was demolished in 1921 as part of the major urban reform of the centre of Rio de Janeiro, all the observatory's equipment was transferred to Valongo farm, a smallholding on Conceição hill. It was there in 1924 that the Observatório do Valongo was inaugurated, and where it remains to this day.[31] The premises at Conceição hill are almost the same as those on Santo Antônio hill, such as the entrance to the observatory and the buildings for the Cooke telescope and Pazos refractor domes.

The observatory was left virtually abandoned between 1930 and 1957,[32] then two astronomers were transferred from the National Observatory to begin organising an undergraduate course in Astronomy at the Faculdade Nacional de Filosofia [National Faculty of Philosophy],[33] part of the former Universidade do Brasil. The course was officially started on 22 September, 1958.

After the national higher education reform of 1968, the Observatório do Valongo came under the administration of the Federal University of Rio de Janeiro, and its premises were used by the Department of Astronomy. Since then, it has provided the infrastructure for the department's teaching, research and post-graduate activities.

Recently, MAST has been working in partnership with Valongo to preserve a set of scientific instruments that remain there. Though it is small, the collection provides a clear depiction of the history of the institution, most of whose instruments were manufactured between 1880 and 1921. These include two middle-sized telescopes, one by Cooke & Sons and the other by Zeiss (Jena), with a 300 mm and 150 mm objective lens, respectively. However, the most important instrument is a refractor manufactured by Brazilian maker José Hermida Pazos in 1880, with a 110 mm diameter objective lens. This has been installed in its own building since 1920. Fig. 13.6 shows a recent picture of the building that shelters this telescope.

The joint project has already recorded 150 objects, which have been cleaned, photographed and semi-permanently marked. The next step is to produce an inventory and input the computerised records into a database so the collection can be accessed via the Internet in the future.[34] The study undertaken has unearthed a number of instruments by German manufacturers, including an astronomical refractor telescope, a coudé refractor, an astrophotographic plate comparator, a diffraction grating, a polarising solar prism and case with eyepieces manufactured by Carl Zeiss, a barograph manufactured by R. Fuess, a meridian coudé refractor manufactured by Julius Wanschaff, and a bellows for macrophotography by Max Kohl. Fig. 13.7 (a, b, c) shows pictures of some of the instruments in the Observatório do Valongo collection.

On 22 September 2008, a small commemorative exhibition was opened to mark the fiftieth anniversary of the creation of the undergraduate course in Astronomy at the observatory, on the ground floor of the building that houses the Pazos refractory telescope.

The Observatório do Valongo is the only institution of its kind in Brazil that has an undergraduate course in Astronomy. Its first astronomy students graduated in 1961, and since 2003 it has offered a masters in Astronomy.

13.3.4 Instituto Astronômico e Meteorológico – Observatório Central (UFRGS) [Institute of Astronomy and Meteorology – Central Observatory]

In the late 1800s, Porto Alegre, a city in southern Brazil, was going through major reforms. These included introducing a comprehensive electricity network, a sewage system, electric transport, piped water, hospitals, a telephone network and industries. At the same time, the first higher education institutions in the region were also created, including the Escola de Engenharia [School of Engineering], which opened in 1886. A little later, in 1889, a project was drafted to build an observatory to be part of the school.

On 18 September, 1906,[35] Instituto Astronômico e Meteorológico (IAM) was founded as part of Escola de Engenharia, and works began to construct its premises. At the end of 1907, the building was finished[36] and in 24 January 1908,[37] the IAM[38] building was opened and months later the first scientific instruments installed: a 190 mm equatorial refractor telescope and a meridian circle with 75 mm, both manufactured by Gautier in Paris. By the end of the year, the observatory's four floors were occupied by a workshop, an administrative area, the Meridian Circle Room with the Time Service and the Equatorial Telescope Room topped by a metal dome for observing the sky. Fig. 13.8 shows a picture of the IAM and observatory buildings in 1909.

Figure 13.5: *Observatory of the Escola Politécnica (Observatório do Valongo archives)*

The most important work undertaken at this time was on the request of the Rio Grande do Sul state government: to introduce a state-wide meteorological service, which would involve establishing a meteorology network of 34 stations, 26 of which would be for meteorology and eight for pluviometry. In 1911, astronomer Friedrich Rahnenführer, from Königsberg, Germany, was hired to undertake the main tasks of determining the local time to a precision of 0.03 seconds, and giving the positional astronomy course to the students of Civil Engineering. The following year, a meridian circle telescope manufactured by A. Repsold & Söhne, Germany, was purchased, as well as two pendulums made by Riefler and naval chronometers. The instruments are installed in a shelter beside the observatory, with sufficient thermal insulation to assure the necessary stability of the clocks.

In June 1921,[39] the Meteorology Section was installed in a new building together with the IAM's administrative department. In 1942, the meteorology service was separated from the observatory, which continued to be linked to the Escola de Engenharia as the Institute of Astronomy.

The observatory first opened to the public in the 1960s. At the time, the most important research and teaching activities were: the training of engineers specialised in geodetics, the determination and distribution of the official local time, logistical support for and active participation in observations of the solar eclipse at Bagé (1966) – a small location in the south of the Rio Grande do Sul State, measurements of magnetic declination across the state, meteorological services and news bulletins, seismographic measurements, observations of double and variable stars, determination of the height of the pole (latitude) of Porto Alegre and photographic records of comets, planets and aspects of the moon. For decades, the observatory was also responsible for bringing out a monthly publication of astronomical tables, including a map of the sky, in the traditional regional newspaper *O Correio do Povo*.

In the early 1970s, when the Brazilian higher education system underwent a major reform, the observatory was annexed to the Institute of Physics, itself part of Universidade Federal do Rio Grande do Sul [Federal University of Rio Grande do Sul]. Astronomical research could no longer be carried out at Observatório Central because of the glare of the lights in Porto Alegre. In the same year, with the arrival of a 500 mm Zeiss telescope from the German Democratic Republic, works were begun for a new observatory on Santana hill, Morro de Santana Observatory, which was opened in 1972.

In 1986, the Department of Astronomy formed a team of observers to record the passage of Halley's comet, while in 1994, in a bid to resume the tradition of recording major astronomical events, an observation site was set up to observe the solar eclipse on 11 November in Erechim, a town in the same state.

In August 2002, the restoration of the Art Nouveau observatory building was concluded as part of a university project to reform its historical buildings. Fig. 13.8

Figure 13.6: *Recent picture of the building that shelters the refractor telescope (110 mm diameter) manufactured in the workshops of Hermida Pazos, Rio de Janeiro (MAST archives)*

Figure 13.7: *Some of the instruments in the Observatório do Valongo collection (from left to right): a pendulum clock, a refractor (Zeiss) and a meridian refractor (Julius Wanschaff) (MAST archives)*

shows a recent picture of the Observatório Central building.

Since 2006, MAST has been working in partnership with Universidade Federal do Rio Grande do Sul on a preservation project for the observatory archives. Diagnoses have been made of the state of the set of scientific instruments, the building and the paper and book archives. Additionally, software has been provided for the instruments to be recorded systematically and a project for an institutional exhibition has been prepared. The Observatório Central collection is not large – it has just 60 artefacts – but it contains objects produced by leading manufacturers, especially Maison Gautier. The most significant pieces in the collection are:

- 190 mm equatorial refractor by Gautier (1907), 75 mm meridian refractor by Gautier and a 75 mm meridian refractor by Repsold;
- printing chronograph (Gautier) and recording chronograph (Favarger);
- Naval chronometers: mean time (Kullberg) and sidereal time (Nardin);
- pendulum clocks: mean time pendulum (Oppermann), standard sidereal time pendulum (Riefler), electric sidereal time display (Riefler) and electric mean time display (Salmoiraghi);
- pocket sextant (Hurlimann), sextant (Zeiss) and sextant (Fairchild);
- theodolite with compass (W. & L. E. Gurley Troy), astronomical theodolite (Chasselon), astronomical theodolite (Gautier), theodolite (Troughton & Simms) and theodolite (Hurlimann, Ponthus & Therrode).
- thermograph with glass mounting (Richard), mercury barometer (Tonnelot), inclinometer (Casella), declinometer (Carl Bamberg).

Fig. 13.9 (a, b, c) shows pictures of some of the objects from the Observatório Central collection.

13.4 Final Considerations

Much of Brazil's scientific heritage is yet to be discovered. The current state of knowledge on the topic is limited, and many of the objects from the area may well have been modernised or thrown away as institutions have sought to acquire the most recent, up-to-date instrument or apparatus. Observatories and universities are a great potential source of such heritage. There are few institutions devoted to preserving collections of this kind, and their work is often hindered by a shortage of funding and qualified personnel. However, there are a few initiatives underway, such as those presented in this paper, while others can be learnt about in a previously published article.[40] This brief overview shows that astronomy research and teaching started in Brazil in the nineteenth century. It also notes the existence of preservation projects at the three institutions presented, with MAST taking responsibility for the collection from the former Imperial Observatório do Rio de Janeiro and for providing technical guidelines for the work carried out by the others. These projects are part of the institution's overall policy to salvage Brazil's science and technology heritage.

Chief amongst the collections of scientific instruments from the observatories presented here is the MAST collection, both for its size and for the quality of the objects and the extent of the work carried out. However, some rare items are contained in the other collections, such as the set of objects manufactured in Brazil by José Hermida Pazos, especially the astronomical refractor telescope, which belongs to the Observatório do Valongo collection, and the set of objects manufactured by

Figure 13.8: *View of the IAM and observatory buildings in 1909; Recent picture of the Observatório Central building (Observatório Central archives)*

Gautier, including letters written by the manufacturer himself, which belong to the Observatório Central collection.

There are some information published[41] mentioning a fourth observatory in Brazil at the beginning of the 20th century, at São Paulo city, sate of the same name, but they need to be checked. The building of the so called Observatório Oficial do Estado de São Paulo [Official Observatory of São Paulo State] could be started to be built in 1910 and opened in April, 1912.[42] Its mains activities might be related with the Diretoria do Serviço Meteorológico do Estado de São Paulo [Directorship of the Meteorology Service of the São Paulo State] and it could be in charge of the determination and distribution of the official local time, but everything about these should be checked.

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1. Mello 1986.
2. North 1980.
3. Cajori 1928.
4. Azevedo 1955.
5. Moraes 1984.
6. Pingre 1901, p. 126.
7. Keenan 1991.
8. Morize 1987.
9. Videira 2002.
10. Barboza 1994.
11. Videira 2002.
12. Brasil 1898.
13. Morize 1987.
14. Barreto 1987.
15. Morize 1987.
16. Iphan 1994.
17. Brenni 2000.
18. Granato et al. 2005.
19. Granato et al. 2007.
20. Brenni 2000.
21. MAST 2000.
22. Novo 1880.
23. CATTALOGUE 1889; EXPOSIÇÃO 1909.
24. Hilger 1924.
25. ZEISS 1926.
26. Pellin 1913.
27. SOCIETÉ 1914.
28. NOVO 1880.
29. MAST 2000.
30. UFRJ 2008, p. 43.
31. Boechat-Roberty, 2004, p. 180.
32. UFRJ 2008, p. 44.
33. Boechat-Roberty and Videira 2003, p. 10.
34. `http://www.ov.ufrj.br` (Jan. 2009).
35. Vasconcelos et al. 2008, p. 13.
36. Livi 1996, p. 48.
37. Vasconcelos et al. 2008, p. 13.

Figure 13.9: *Some of the instruments from the Observatório Central collection (MAST archives)*

38. Even called Observatório Central [Central Observatory].
39. Vasconcelos et al. 2008, p. 22.
40. Granato and Câmara 2008, p. 180.
41. Livi 1996, p. 52.
42. Mantovani and Santos 1994, p. 515.

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Figure 13.10: *Urania, the muse of astronomy, Rio de Janeiro, main building of the National Observatory (Photo: Gudrun Wolfschmidt)*

Figure 14.1: *Aerial view of Marseille Observatory (Marc Heller, 1997, ©Région Provence-Alpes-Côte d'Azur – Inventaire général)*

14. The Marseille Observatory: the Final Move – A Case Study in the Conservation of Astronomical Heritage

James Caplan (Marseille, France)

The 'Observatoire de Sainte Croix' began operations in 1702, during the reign of Louis XIV, as a Jesuit observatory financed by the French naval ministry. It was located in the heart of the old city. By 1750 it was called simply 'Observatoire de Marseille'. The naval ministry continued to finance the observatory, even after the suppression of the Jesuits in the 1760s; but during the French Revolution control was transferred to the newly-created Bureau des Longitudes. In the middle of the 19th century, responsibility for Marseille and other state observatories passed to the education ministry (this continues to the present day). In the 1860s, the Marseille Observatory was transferred to the Plateau Longchamp, about 3 km away. There, for a decade, it was run as an annexe to the Paris Observatory. Léon Foucault's 80 cm diameter telescope, then the world's largest with a silvered-glass mirror, was installed in the new site. Many instruments and archives were transferred from the old site; these now constitute the core of the observatory's historical heritage.

Becoming independent again in the 1870s, the Marseille Observatory was equipped with the standard observatory instruments of the late 19th century, including an equatorial refractor of diameter 26 cm, clocks, and a large meridian circle. At the end of the 19th century the Marseille observatory was officially attached to the University of Aix-Marseille.

The first half of the twentieth century was a less prosperous period for the observatory; relatively few new instruments were acquired. But the years following the second world war brought a complete change. Observing activities were shifted almost entirely to the Observatoire de Haute-Provence, about 100 km to the north. This modern observatory for visiting astronomers had been established before the war by the CNRS (Centre national de la recherche scientifique). But even as onsite observing came to a halt, the 'OM' received increased funding and staff. The astronomers were divided into research groups, one of which, that concerning observations from space, spun off in the 1960s, founding the CNRS's *Laboratoire d'Astronomie Spatiale* (LAS), some 7 km away.

In the second half of the 20th century, the Observatory and the LAS, with dozens of researchers (rather than just a handful), produced a volume of astronomical research that dwarfs all that was done previously. The historical remains of this modern period are quite different from those from the days when observations were made in-house: auxiliary instrumentation rather than telescopes, but a vast quantity of archives.

In 1990, several colleagues collected many of the historical instruments in the former director's office on the ground floor of the Observatory's Maison des Astronomes – the building begun in the 1860s to house the observatory director and his assistants. A decade later this Museum was extended to most of the ground floor (the former library), with additional instruments and the observatory archives up to ca 1950.

The present crisis concerning the astronomical heritage was triggered in 2000 by the (re-)merger of the Marseille Observatory and the LAS, to form the *Laboratoire d'Astrophysique de Marseille* (LAM). Finally, in the spring of 2008, these two components merged physically in a new building even farther from the city centre. This move presented an opportunity to assemble the more recent historical heritage of the two establishments. Indeed, this was a necessity, as the new building's volume is smaller than the sum of those of the buildings being abandoned. The plan was to store all of this material in the Marseille Observatory, no longer used for astronomical research, but which was to remain under the control of our university. A new establishment, the *Institut Méditerranéen de Recherches Avancées* (IMéRA), associated with the three local universities, began moving into the Marseille Observatory, but was not expected to use the totality of the space available, so that there was expected to be room for storage and exhibition space for our Museum – although not in the Maison des Astronomes we had originally planned to use. Also, the astronomical public outreach activities (run by an association called *Andromède*), will almost certainly be permitted to remain on the Observatory site.

The (modern) historical heritage of LAS, extremely voluminous and disorganized, was in fact transported for temporary storage to the Saint-Charles site of our university – the instruments in the old chemistry building and the archives in the university library. It is not

Figure 14.2: *Marseille Observatory composite image (1702 and today) (James Caplan)*

clear how long the university will agree to this storage. The modern heritage (post 1950) of the Observatory has been stored in the basement of the Astrophysics building, which we intended to convert to museum and archive storage. Unfortunately, since the upper floors of this building, which have been attributed to IMéRA, are to undergo conversion to offices and living quarters, we must remove all our material for the duration of the construction work. The destination of this material is not yet defined.

As for the older heritage, in our Museum located in the Maison des Astronomes, everything must be removed. Due to this material's great value (some twenty objects are officially 'protected' as historical monuments, and the archives must be stored in conformity with the rules of the Archives de France), they cannot be stored other than under good, well-protected conditions, while awaiting the availability of storage and exposition areas at the Observatory. The probable partial solution to this problem is as follows. Since March 2009, more than half of the old collection of the Museum has been exhibited in the Natural History Museum, 200 m from the Observatory, in the temporary exhibition *Telescopium* designed jointly by the Natural History Museum and the Observatoire Astronomique de Marseille-Provence. We hope that the exhibition can be shown in other museum environments elsewhere in France over the next few years, until we can return to the Observatory site. A secure storage solution for the instruments *not* in the exhibition has not yet been resolved. As for the old archives (18^{th} century to mid20^{th} century), they will be transferred to a secure site in Aix-en-Provence where they will be digitised. They will be returned to the Observatory after the construction work. Thus our archives will soon be available for consultation by all, on the Web.

The final configuration of our Museum is hard to predict, but I have every hope that within a few years, through collaborations with the university, the city of Marseille (owner of the land), IMéRA (whose interdisciplinary cultural programme is consistent with the presence of astronomical heritage and history) and other institutions, the historical Museum of the Marseille Observatory will become a permanent feature of the Longchamp Plateau in Marseille.

Where is the 'Observatoire de Marseille' today? Administratively, it still exists – for the moment! – as the astronomy unit of the University of Provence, but is now called the *Observatoire Astronomique Marseille-Provence*, which federates the LAM (the merged Marseille Observatory plus LAS) along with the *Observatoire de Haute-Provence*. Will the name 'Observatoire de Marseille' disappear to general indifference? Possibly, but we hope that the name will continue to designate the site on the Plateau Longchamp that has been devoted to astronomy for over 140 years.

Figure 14.3: *Foucault telescope, Marseille Observatory (Marc Heller, 1997, ©Région Provence-Alpes-Côte d'Azur – Inventaire général)*

Figure 15.1: *Staircase of Vienna Observatory (Institut für Astronomie der Universität Wien)*

15. The University Observatory Vienna

Anneliese Schnell (Vienna, Austria)

15.1 Introduction

In spring of 2008 the new Vienna Observatory was commemorating its 125th anniversary, it was officially opened by Emperor Franz Joseph in 1883. Regular observations had started in 1880. Viennese astronomers had planned that observatory for a long time. Already Karl von Littrow's father had plans early in the 19th century (at that time according to a letter from Joseph Johann Littrow to Gauß from December 1, 1823 the observatory of Turku was taken as model) (Reich 2008), but it lasted until 1867 when it was decided to build a new main building of the university of Vienna and also a new observatory. Viennese astronomers at that time had an excellent training in mathematics, they mostly worked on positional astronomy and celestial mechanics. They believed in F. W. Bessel's idea that the only task of astronomy is to find rules for the motion of any celestial object which allow the determination of its position for any time. They wanted to have an observatory outside of the centre of Vienna with the best and largest instruments available.

15.2 Karl Littrow and his "Theatre for Stars"

Karl Littrow (1811–1877) did even send Edmund Weiss (1837–1917) to the United States and England to inspect new observatories and firms which built telescopes. Weiss reported about that journey in 1873 in the *Vierteljahrsschrift der Astronomischen Gesellschaft.*

He visited Dudley Observatory, Hamilton College, Ann Arbor, Chicago University, Washington University, Cincinnati, the US Naval Observatory and Harvard College. Especially he describes meridian circles because a new meridian circle was one of the wishes of the Viennese astronomers (which never was fulfilled). I think that it is remarkable that even at Harvard Observatory where at that time already photographic techniques have been used and some spectroscopy has been done most of his attention had been attracted by the meridian circle. The institutions he visited in England he did not describe in such an extensive way because in his opinion they were well known from the literature. At the end of this publication Weiss puts a lot of emphasis on the description of reasons why one should prefer non-German instrument makers (E. Weiss 1873).

During a couple of years Vienna Observatory was editing an astronomical calendar. In the 1874 edition K. L. Littrow wrote a contribution about the new observatory in which he defined the instrumental needs:
"für Topographie des Himmels ein mächtiges parallaktisches Fernrohr, ein dioptrisches Instrument von 25 Zoll Öffnung. Da sich aber ein Werkzeug von solcher Größe für laufende Beobachtungen (Ortsbestimmung neuer Planeten und Kometen, fortgesetzte Doppelsternmessungen, etc.) nicht eignet, ein zweites, kleineres, daher leichter zu handhabendes, aber zur Beobachtung lichtschwacher Objekte immer noch hinreichendes Teleskop von etwa 10 Zoll Öffnung, und ein Meridiankreis ersten Ranges von beiläufig 8 Zoll Öffnung für eigentliche Fundamentalmessungen. Dieser Hauptpark der künftigen Sternwarte sollte durch die bereits vorhandenen, vielfach noch sehr brauchbaren Hilfsmittel ergänzt werden." (Littrow 1874).

This clearly shows the intention to do just the same work as before but with larger and better instruments. With this description and choice of instruments it was decided on astronomical work for the following decades.

As architects Ferdinand Fellner (1847–1916) and Hermann Helmer (1849–1919) were choosen, they became famous in the Austro-Hungarian Monarchy mainly for their theatre buildings. Nowadays there are 48 theatres which have been designed by them, examples are the *Deutsches Schauspielhaus* in Hamburg or the *Komische Oper* in Berlin. A complete list of all their buildings can be found in the *Architektenlexikon* compiled by the *Architekturzentrum Wien.* Probably for this reason Littrow spoke about a theatre for stars in which he would reside like a prince of science. When they started planning the observatory their cooperation had just begun (1873), and they fulfilled all of Littrow's wishes. They followed the example of Schinkel's observatory for Encke in Berlin with its shape of a cross. As building site a hilly area, the so called Türkenschanze, in the outskirts of the city of Vienna in northwestern direction had been choosen.

An area of about 55,000 square meters had been bought in 1872, now this area is protected by law, it should be preserved in its initial natural state. Since

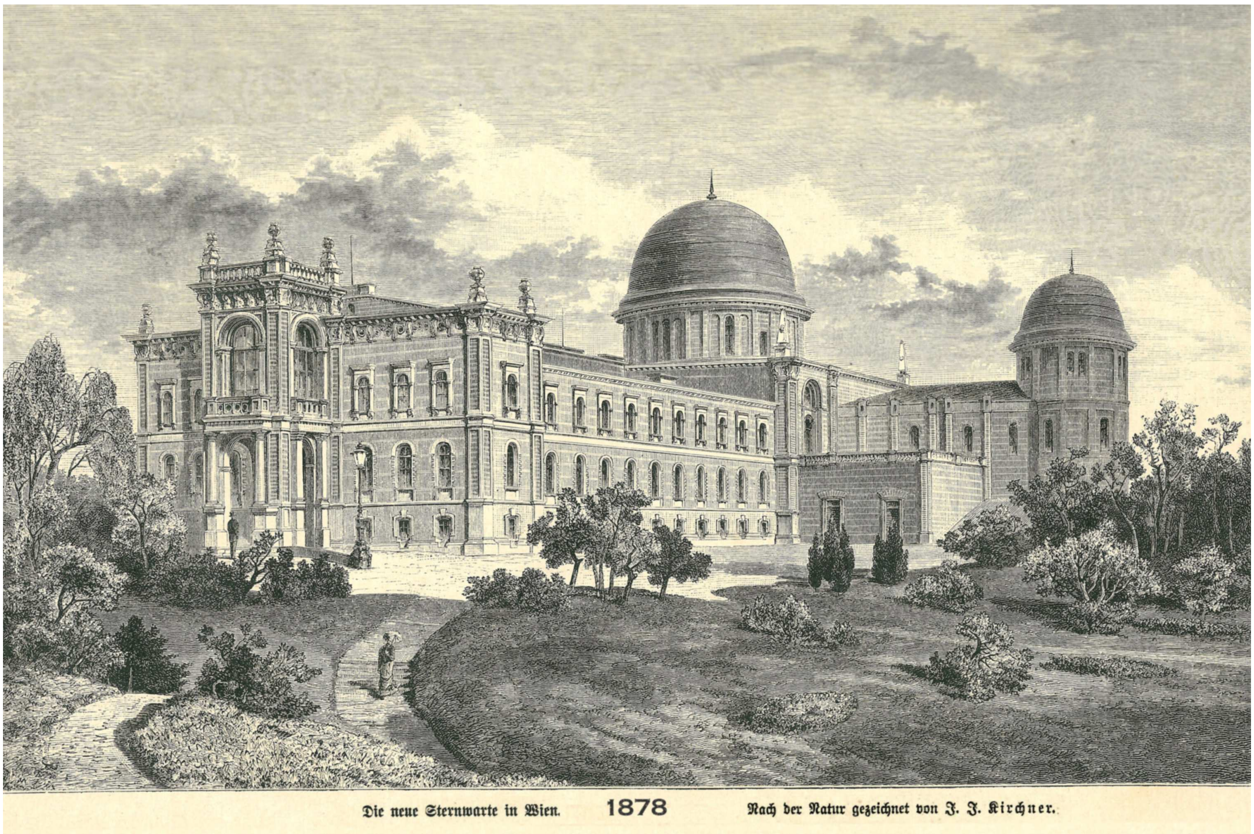

Figure 15.2: *Vienna Observatory (contemporary drawing by J. J. Kirchner, 1878)*

most parts never have been cultivated the observatory grounds now represent a real heritage in which for example some kinds of animals survived amidst town.

The cross-shaped building (Fig. 15.2 and 15.3) was and still is the world's largest observatory building, at the time of its erection combining both, the observatory and living quarters for the astronomers. The southern part of the long axis of the cross, north – south orientated (and thus turned for 90 degrees in respect to the old Berlin observatory) contained the library and the living quarters (first floor for the director, at the ground level for the astronomers and in the souterrain for servants). The staircase resembles to the entrance hall of a theatre and has a glass roof conveying the impression of being in a courtyard. It is surrounded by columns and by arcades on the first floor. Something special is the floor of a kind of stony mosaic.

Relief busts of Edmund Weiss (after his retirement 1908) and of Johann Palisa have been added next to the entrance of the building, in the staircase (Fig. 15.1) is a monument of Emperor Franz Joseph which was erected 1908 to commemorate 60 years of his emperorship, it was made by Edmund Hoffmann von Aspernburg (1847–1930).

15.3 Instruments of Vienna Observatory

In the centre of the building is the revolving dome for the largest instrument, the room leading to the meridian rooms was called "cirkulärer Saal". It is a huge representative room with fake marble at its walls. Painted lines on the ceiling pretend the existence of vaults. At the northern end of the cross is another revolving dome and two more are at the eastern and western ends of the second axis which also contained two meridian rooms. Soon astronomers found out that it was not a good idea to have the living quarters south of the main instrument. Vienna observatory was the last European observatory consisting of only one building, all other observatories which have been built later house only one telescope per building. A more detailed description is given by Peter Müller (1975).

Such a generous planning nowadays not always allows to solve space-problems, but it helps a lot. It was easy to turn the living quarters and one of the meridian rooms into offices, into the eastern meridian room the library was transferred, this happened 1967. It was done for the sake of innovation, the director of the observatory and the astronomers were not thinking on preservation of historic parts of the furniture. For this reason the library lost its original handmade furniture. In the western meridian room there are offices as well, lecture rooms have been added. In the souterrain later on a mechanical workshop has been installed. Originally there existed one workshop at the "Polytechnikum", nowadays the Technical University. This workshop was used by all Viennese institutions doing astronomical or geodetic research, as byproduct the firm Starke & Kammerer resulted.

Figure 15.3: *Vienna Observatory, photograph taken from the southern part of the roof of the building (Institut für Astronomie der Universität Wien)*

The main instrument, a 27-inch refractor (Fig. 15.4), and the revolving domes were ordered from Grubb of Dublin, a 12-inch refractor was built by Alvan Clark of Boston, the meridian circle made by Reichenbach was transferred from the old observatory. The 27-inch refractor at the time of its installation was the largest telescope of the world. Later on two more instruments were added in extra buildings; an Equatoreal Coudé with an aperture of 38 cm in 1890 through a donation by Albert von Rothschild and a so called "Photographic Pavillon" with a normal astrograph in 1907. At least the building for the Coudé telescope was also designed by Fellner and Helmer. The style of all buildings is the same: bricks. On the main building there are ornamental decorations made of sandstone above the windows of the first floor.

The optics of the Equatoreal Coudé came from the workshop of the brothers Henry, the mechanics was built by Gautier in Paris, it was the second largest instrument of that type ever built with an aperture of 380 mm and a focal length of 25 m, and the only one in a not French speaking country. A probable reason that Vienna observatory had such an instrument might be that the inventor of that kind of telescope, Maurice Lœwy (1833–1907), was born in Vienna, studied at the Polytechnikum and the University of Vienna and got his astronomical training at the old Vienna observatory. He emigrated to France because in Austria of that time as a jew he could not get a position at the university. In 1896 he became director of the observatory of Paris.

Nearly all of the instruments (Fig. 15.5) of the old observatory have been transferred to the new one, nowadays they are kept in a small museum which is located in the most representative room of the original apartment of the director. Vienna observatory also has a collection of rare books, catalogues have been published (Kerschbaum/Posch 2005; Lackner/Müller/Kerschbaum/Ottensamer/ Posch 2006).

15.4 Vienna Astronomers and their Activities

Littrow died in 1877, his successor became Edmund Weiss. Weiss with one exception did not publish annual reports in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, probably because he was aware that at the same time at the private Kuffner Observatory much more time adequate and modern work was done, another reason could be that he did not like to do this kind of work. But from their publications we know that astronomers did positional astronomy and orbit determination of asteroids and comets. A detailed description had been given by Maria G. Firneis (1985).

The best known Viennese astronomer of that time was Johann Palisa (1848–1925) who gave up his position as director of the Naval Observatory of Pola for the possibility of working with the world's largest telescope. Palisa was specialized on visual discovery of Minor Planets, in total he has found 121 objects. Palisa did not only discover new objects, much time he spent in observing objects which have been found by other colleagues to measure their positions to enable orbit determination. In cooperation with Max Wolf (1863–1932) from Heidelberg the Wolf-Palisa-Charts were produced, an early

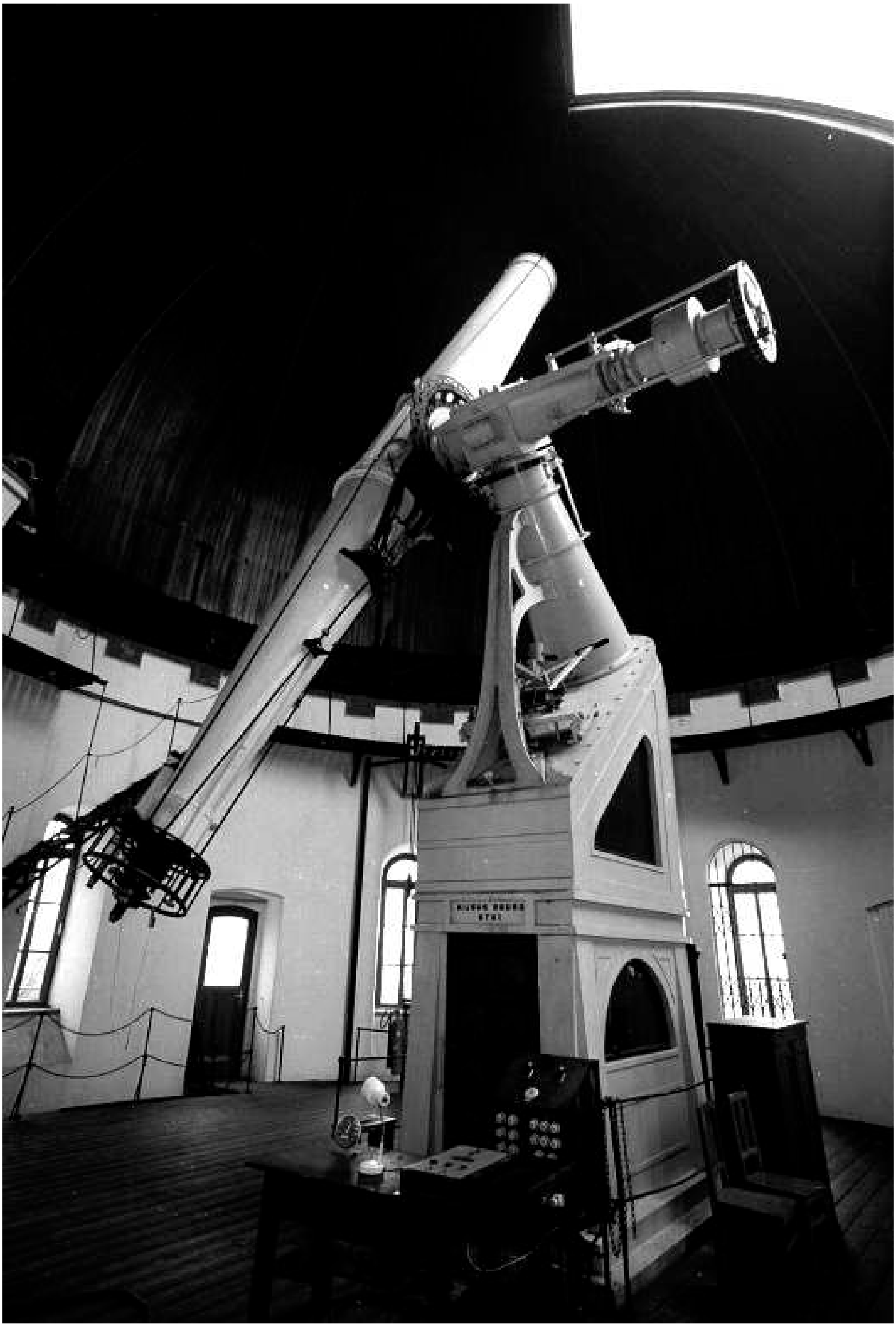

Figure 15.4: *The main telescope, a 27-inch refractor, Grubb of Dublin (1878) (Institut für Astronomie der Universität Wien)*

Figure 15.5: *Instruments in the museum in Vienna Observatory (Institut für Astronomie der Universität Wien)*

photographic stellar atlas along the northern part of the ecliptic. Due to World War 1 the production had been stopped. Palisa also published a so called "Sternlexikon" containing the exact positions of all reference stars he had used, partly in cooperation with his son in law Friedrich Bidschof (1864–1915). Bidschof was the first observer at the Equatoreal Coudé determining visually positions of stars and comets before he became director at the Naval Observatory of Trieste.

Johann Palisa was aware of the need of information for the public about astronomy as well. He was the first astronomer who gave popular talks at various societies, at the occasion of the reappearance of Halley's Comet he even spoke in the largest concert hall of Vienna, the *Musikvereinssaal*. His sons in law Bidschof and Josef Rheden (1873–1946) followed this example. This kind of popularizing and keeping public relations has been pioneering.

Other astronomers in Vienna working at that time were Johann Holetschek (1846–1923) who was the first astronomer at Vienna observatory who had not only studied astronomy and mathematics but also physics. He worked both as observer and as theoretician, mostly dealing with comets, their orbits and developed a method to determine their integral brightness – the first try of astrophysical work at Vienna observatory. With the old 6-inch Fraunhofer refractor which already existed at the old observatory he observed nebulae – most of them were as we know today galaxies – and determined their brightness as well. The catalogue of these objects was rereduced by Kasimir Graff in 1948.

Rudolf Spitaler (1859–1946) tried to establish photography at the 27-inch refractor. The difficulty he had to deal with was that the optics of the telescope was corrected for visual wavelength, the photographic plates used at that time were most sensitive in the blue spectral range. But his experience in later years helped with using this telescope for photography.

During the years before 1900 Vienna as capital of the Austro-Hungarian Monarchy grew enormously. While the number of inhabitants in 1870 was about 840,000, there were living about 2 millions of people in 1900 in Vienna. It is quite clear that the new observatory was amidst town and the observing conditions deteriorated, especially light pollution was high. Already in 1900 and in 1902 at the meetings of the *Astronomische Gesellschaft* in Heidelberg and Göttingen Karl Kostersitz spoke about a project of an astrophysical and meteorological observatory on top of the Schneeberg (2076 m high), the easternmost mountain of the Alps, or of the Sonnwendstein (1523 m high). The new observatory (Fig. 15.6) should be the main institution of the Monarchy and an exact copy of Vienna Observatory. Viennese astronomers, especially Palisa, supported that project, even meterological investigations started and had been carried out during a long time (K. Kostersitz 1900, 1902). This project was never realized, but in 1969 Vienna Observatory got a 1.5 meter telescope in the Vienna Woods.

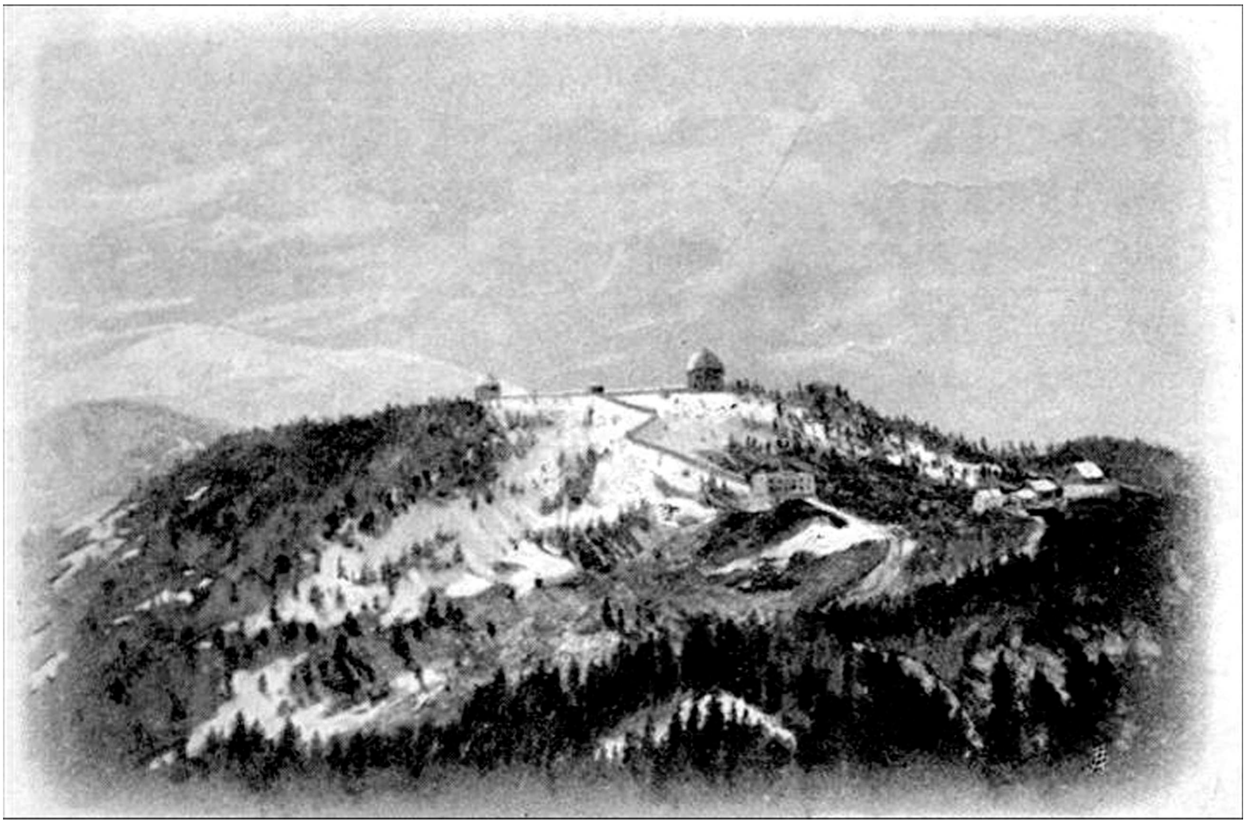

Figure 15.6: *Early drawing of a mountain observatory (Institut für Astronomie der Universität Wien)*

After the death of Edmund Weiss Josef Hepperger in 1909 became director of the observatory. Among observing astronomers which denied an offer to come to Vienna were Hugo von Seeliger and Max Wolf (Archive of University of Vienna). Hepperger was professor at Vienna University since 1901. He was a theoretician as well, but he had studied physics and he knew about the importance of astrophysics. Under his directorship Adolf Hnatek (1876–1960) who originally worked at the technical branch of the postal administration got a position at the observatory even before he had finished his studies of astronomy. Before he worked at the observatory Hnatek determined cometary orbits. With the astrograph he used Schwarzschild's method of extrafocal stellar images on photographic plates to do photographic photometry (A. Hnatek, 1911). For the Equatoreal Coudé a spectrograph from Askania has been bought and attached to the telescope.[1] Hnatek determined radial velocities of stars. It lasted until 1928 when Kasimir Graff became professor at the University of Vienna and director of the Vienna Observatory that Vienna Observatory had its first director who was not a theoretical astronomer but an observer.

15.5 The Kuffner Observatory in Vienna

Nearly at the same time between 1884 and 1887 a private observatory was financed by the beer brewer Moriz von Kuffner (1854–1939).[2] Directors there were Norbert Herz (1858–1927) and Leo de Ball (1853–1916). Other astronomers only were employed for a few years.

One of them was Samuel Oppenheim (1857–1928), who worked at the Kuffner Observatory between 1888 and 1896. He realized the importance of photography for astronomy and could convince Kuffner to add a photographic tube to the refractor. In 1894 he published a paper about GC 1166, in which as a byproduct he tried to determine the brightness of stars by their diameter on the photographic plate, he failed because he did cot take into account that such a method only works for stars of the same spectral type.

From 1897 to 1899 Karl Schwarzschild (1873–1916) worked at the Kuffner Observatory. He examined different photographic emulsions and developed a technique to determine stellar brightness by means of extrafocal records. Using plates taken from the Pleiades, Praesepe and h and χ Persei he found what what we now know as the Schwarzschild exponent. By his work he was able to show that photographic photometry was significantly superior to visual magnitude estimates. It demonstrates that astrophysical research and technology was earlier carried out at Kuffner Observatory than at the University Observatory. The former one could be proud to have hosted the young Karl Schwarzschhild, one of the world's most famous astronomers.

15.6 Heritage at Risk?

Today all buildings of the University Observatory are listed as historic monuments. In reality this is not helpful at all because of the lack of money, at least for the buildings of the aequatoreal coudé and of the astrograph. A gatekeepers lodge and one of the oldest houses of Währing have already been pulled down several years ago.

Acknowledgements

I am grateful to G. Hensler for the possibility of using facilities of the Institute for Astronomy of the University of Vienna, to H. M. Maitzen for valuable discussions and helpful comments, to C. Metz and I. Müller for help in finding literature and M. Rode-Paunzen with the figures.

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1. Schnell 2008.
2. Habison 2008.

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Figure 16.1: *The main building of the new institute at Budapest-Svábhegy, completed in 1927*

16. The First 50 Years of Konkoly Observatory

Lajos G. Balázs, Magda Vargha and Endre Zsoldos (Budapest, Hungary)

Abstract

The second half of the 19th century experienced a revolution in astronomy. It coincided with a new start of professional astronomy in Hungary through the work of Miklós Konkoly Thege (1842–1916) who is considered as a pioneer of current astrophysical activity in our country. He played an outstanding role in organizing scientific life and institutions, too. He started observations in his newly founded Observatory at Ógyalla in 1871. Sunspots were regularly observed in the observatory from 1872. In 1874 Konkoly began regular spectroscopic observations of comets and emphasized the importance of parallel laboratory works. An important field of Konkoly's astronomical activity was the observation of surface patterns of planets, particularly that of Jupiter and Mars. Spectroscopic observations of stars were also a significant part of the activity of Ógyalla Observatory. In the last period of the Konkoly era (starting in 1899) stellar photometry became the main field of research. At the end of WWI the institute was moved to Budapest from Ógyalla and started a new life based on a completely new infrastructure: *"... all era are followed by a new one, with its new tasks, in which the scope of activity changes correspondingly, in which enthusiasm is mostly manifested. It was different in the forties when our nation found itself following the word of the founder of our Academy, it was different in the fifties and sixties when we have to defend our nation against foreign aggression, and it became different since the sixties when, our existence being guarantied, we also have to make an effort, beside strengthening it, to get as distinguished a position among the civilized nations as possible."*[1]

16.1 Prelude

Cardinal Péter Pázmány founded the Jesuit University in Nagyszombat (today Trnava in Slovakia) in 1635. Calendars have been published already from 1665 regularly (Kiss 2005). In 1756 the University established an observatory which published astronomical observations in its "Observationes". The director Ferenc Weiss was in regular correspondence with his colleagues abroad (Vargha 1990–1992). In 1777 the Observatory was moved into the Royal Castle of Buda.

In 1815 a new Observatory began its work on the top of Gellért Hill (Blocksberg), Buda. It had permanent contact with other European Observatories. As a consequence of the fall of the Hungarian revolution in 1849, it was blown up by the Austrian Army in 1852, and for more than twenty years there was no astronomical observatory in Hungary (Kelényi 1930).

16.2 New Era in the Development of Astronomy in Hungary

Because there was no professional astronomical institute in Hungary after the destruction of the one on Gellért Hill, it had a great significance that a private observatory was established by Konkoly Thege (1842–1916) in Ógyalla in 1871. Its main profile was astrophysics. In this time the circumstances were appropriate for creating an institute devoted primarily for this new field of research. The 1870's saw revolutionary changes in astronomy.

Kirchoff and Bunsen (1860) discovered spectrum analysis – that is, the method by which it was possible to draw valid inferences about the composition and physical properties of the emitting sources from their spectra. Until this time astronomy was concerned mainly with determining the positions of celestial bodies – that is with helping navigation and cartography, or with developing mathematics by celestial mechanics (for example Gauß was nominally earning his wages as the director of Göttingen observatory).

The introduction of spectrum analysis into astronomy made it possible to study those physical processes that produce the electromagnetic radiation observed through the telescopes. The epoch-making importance of this discovery was immediately recognized by Konkoly Thege, who decided at the beginning to make observational astrophysics the primary objective of his institute.

16.3 Scientific Life at Ógyalla

Konkoly was not simply a rich landowner but an educated scientist as well. He started his studies at the Astronomy Department of the University of Berlin in 1860, where he could learn up-to-date astronomy under the guidance of Encke. Encke was the intellectual leader of a whole generation of astronomers, for example J. H. Mädler, J. G. Galle, G. Spörer, B. Gould.

Konkoly's contemporaries who studied under Encke were C. Rümker, A. Krüger, W. Förster, B. Hoffman and F. Tietjen.

Figure 16.2: *Miklós Konkoly Thege (1842–1916); he founded his observatory at Ógyalla in 1871*

Hermann Kobold who worked in the Ógyalla Observatory between 1880 and 1883 wrote about his director: *"Herr v. Konkoly hatte in Berlin Naturwissenschaften, besonders Physik und Cemie studiert. Er hatte aber auch anderen Gebieten, besonders in der Technik, grosse Kentnisse. Er besass auch das Befähigungszeugnis al Kaptän für die Donaudampfschiffahrt. In einem der Wirtschaftsgebäude in Ógyalla war ein Werkstatt mit Präzisionsdrehbasnk, an der Herr v. Konkoly häufig arbeitete. Nach den von ihm selbst angefertigten Werkzeichnungen waren hier schon manche physikalischen und astronomischen Instrumente hergestellt... Die wissenschaftliche Tätigkeit des Observatoriums hatte bis zu meinem Eintritt fast ausschlieslich auf dem Gebiet der Astrophysik gelegen, entsprechend den Neigungen des Herrn v. Konkoly und der Ausrüstung des Observatoriums, die eine grosse Anzahl von vorzüglichen Instrumenten für spektrometrometrische, photometrische und kolorimetrische Beobachtungen und Messungen umfasste."*[2]

16.3.1 Chronology of the Beginning of Scientific Activity in Ógyalla

In the following we give a short chronology of the main events of the first decade of regular activity in Ógyalla:

1872: Start of regular sunspot observations.

1874: New building was completed, equipped with a 10.5-inch Browning mirror telescope. Start of the long series of cometary observations.

1875: A network of meteor observers was established comprising several places in the country. The reductions was done at Ógyalla.

1879: Konkoly included the study of the Red Spot on Jupiter in the program of the institute.

1879: The first yearbook was published with observations from the first period (Vargha 1999).

This rapid and surprising development would not have been possible without using state of the art instrumentation

16.3.2 Instrumentation

At the beginning of the eighties the Observatory already acquired a wealth of excellent instruments, some of them made in Ógyalla. The following list gives a short inventory of the more important items:

Telescopes

- 10″ Browning reflector
- 10″ Merz refractor
- 6″ Merz refractor
- 3″ Rheinfelder & Hertel refractor for observing sunspots.

Chronographs, clocks

- 4 chronographs
- 7 pendulum clocks
- 4 chronometers

Spectroscopes

- 12 stellar spectroscope
- 4 laboratory spectroscope
- 3 mobile spectroscope

Miscellanea

- Several physical equipments (Vargha 1999).

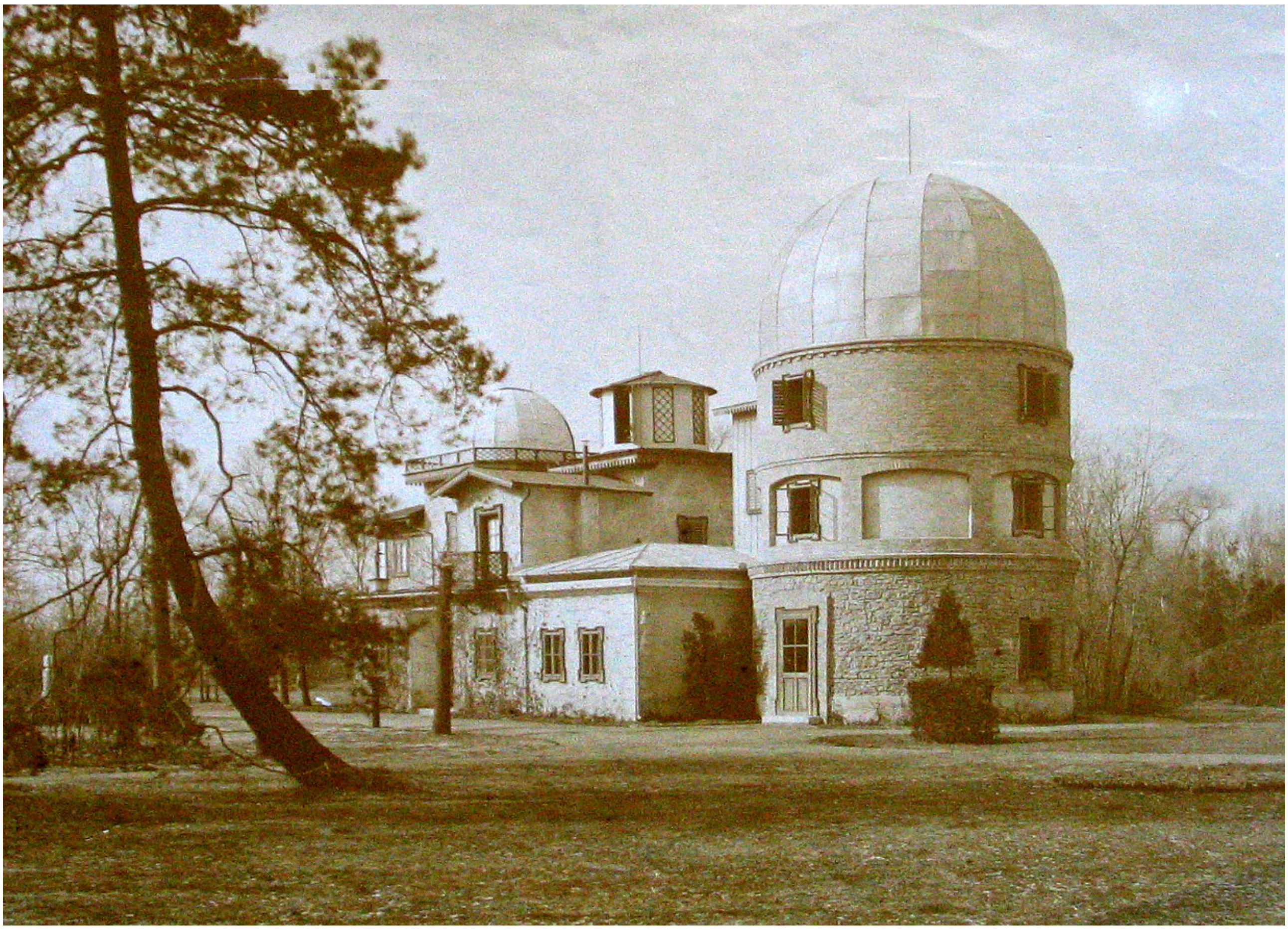

Figure 16.3: *Konkoly's observatory at the end of the 19th century*

16.3.3 Solar Physics in the Observatory

Although sunspots were discovered by Galilei and they provided continuous interest for astronomers all the time, though their regular and internationally coordinated observations started only in the second half of the 19th century.

Sunspots were regularly observed in Ógyalla since 1872 (e.g. Schrader 1877). Publication of heliocentric coordinates began in 1880. Since the beginning of 1885 the Wolf relative numbers were computed daily, reaching back to 1872 using the drawings that had been made in the observatory. The whole series for the period of 1872–1884, complete with the Zürich relative numbers, appeared in the publications of the observatory. Konkoly regularly sent the sunspot data to Zürich starting from 1885 (Konkoly 1885). The Hungarian contribution was especially significant after the death of Rudolf Wolf in 1893.

Beside good observations, Konkoly made a remarkable contribution to the instrumentation of Solar physics. He built a photoheliograph, and two spectroscopes for studying solar prominences in 1905 (Terkán 1913).

Konkoly played an important role in organizing other stations for solar observations in the country (the most important being the Haynald Observatory at Kalocsa, see Mojzes, 1986). Gyula Fényi, S. J. became the director of this observatory in 1885 and he regularly made hand drawings of solar prominences for 28 years. It is the longest and most complete series of observations on solar prominences in this period.

16.3.4 Comets, Meteors, Minor Planets

Historically, the observation of comets were connected with astrology. Later on the determination of the laws governing their motion was an important task of celestial mechanics. The study of their physical nature become possible only by regular spectroscopic observations. The observations relevant to the physical nature of comets belonged to a new field of research in the second half of the 19th century. When Konkoly started regular spectroscopic observations in 1874, he was among the first in the world to observe cometary spectra.

In order to identify the physical nature of comets Konkoly emphasized the importance of parallel laboratory works. He measured several gas mixtures in the laboratory at different pressures and temperatures, trying to simulate real cometary spectra. In some cases when the compound to be measured was too dangerous (e. g. case of the cyan) he was given free access to the well-equipped laboratories of the University of Budapest. Combining the observations with laboratory

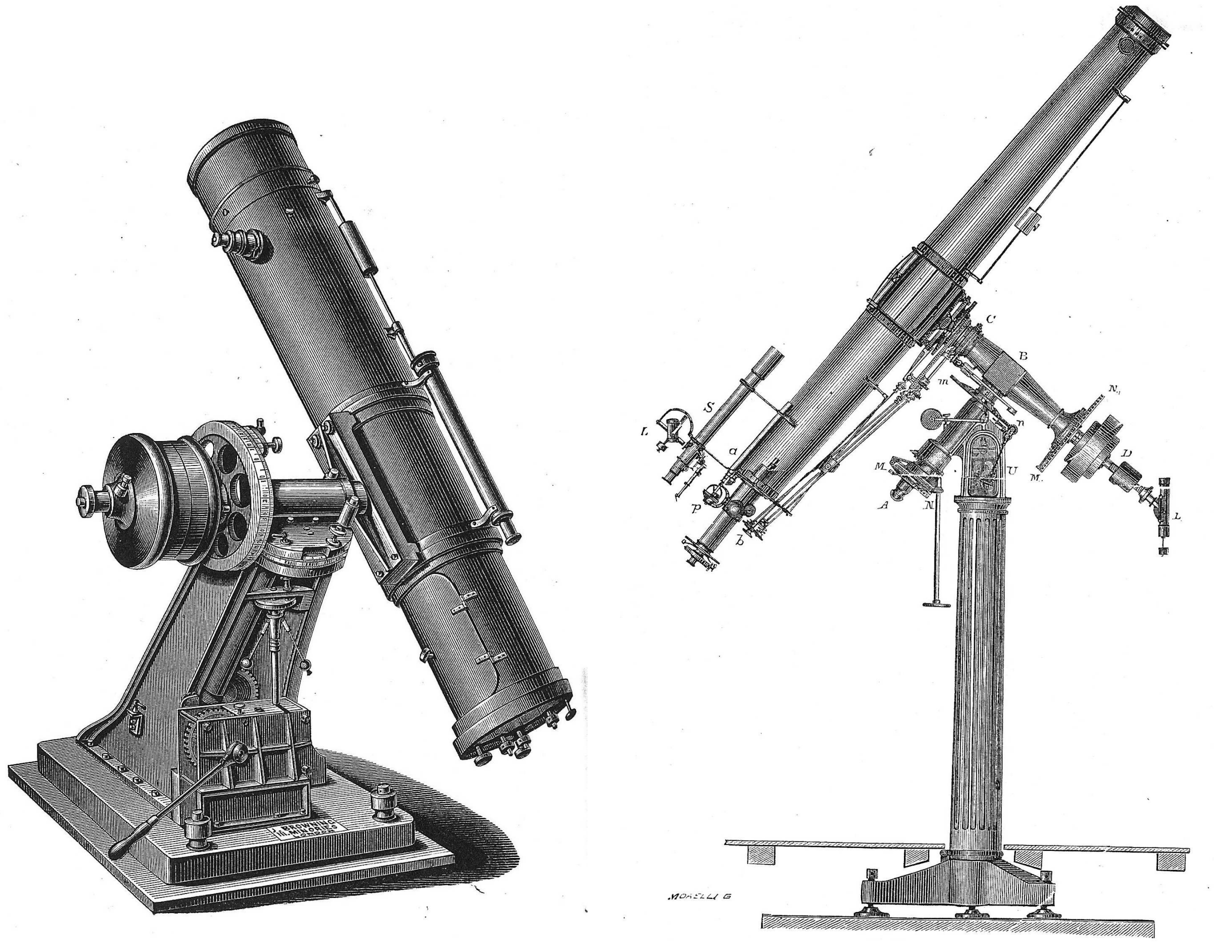

Figure 16.4: *Main observing instruments of Konkoly's observatory: 20-inch Browning reflector (until 1881, left). 20-inch Merz refractor (from 1882, right)*

results Konkoly confirmed the similarity of cometary and hydrocarbon spectra:
"I myself observed forty comets twenty-seven out of those were also evaluated spectroscopically. Thus I can assert without boasting, that in the field of observing and spectroscopically analyzing comets, the achievement secures for me the first place amongst European and American astronomers."[3]

The first comet he observed spectroscopically was comet Coggia (1874) and the last one he studied was comet Halley (1910). Comet Zlatinsky (1914) was the last in the series which was observed in Konkoly's era (Konkoly 1874, 1911, 1916).

A favorite topic of Konkoly's astronomical interest was an extensive study of meteors, particularly their spectra. He often observed the characteristic line of sodium projected onto a continuous spectrum and occasionally the lines of Mg, Li, Fe, etc. and carbohydrates. Based on the spectroscopic observations he recognized the relationship between comets and meteors.

He also organized an observational network for the determination of spatial positions of meteors at the request of E. Weiss, director of the Vienna Observatory. Konkoly equipped several stations with the appropriate instrumentation (microscope, time basis) in addition to his own institute. The observations were reduced in Ógyalla. The network enabled one to calculate the spatial positions and velocities of the meteors. Based on these results they established a close relationship between meteor streams and comets. Among the regular observations at Ógyalla a very spectacular meteor fall can be found on Nov. 27, 1872, when 38 meteors were observed in one minute.

Konkoly and his collaborators regularly observed minor planets using telescopes and meridian circles. They supplemented the observations with theoretical calculations of the orbits taking secular perturbations also into account. Honoring the international level of his research two minor planets were named after him and his observatory, namely (1259) Ógyalla (Reinmuth and Mündler 1933) and (1445) Konkolya (Kulin 1938a, 1938b).

16.3.5 Planetary Research

An important part of Konkoly's astronomical activity was the observation of surface patterns of planets, particularly that of Jupiter and Mars. These observations were regularly published in the observatory publications. Shortly after the appearance of the big red spot on Jupiter in 1878 they made regular follow up observations

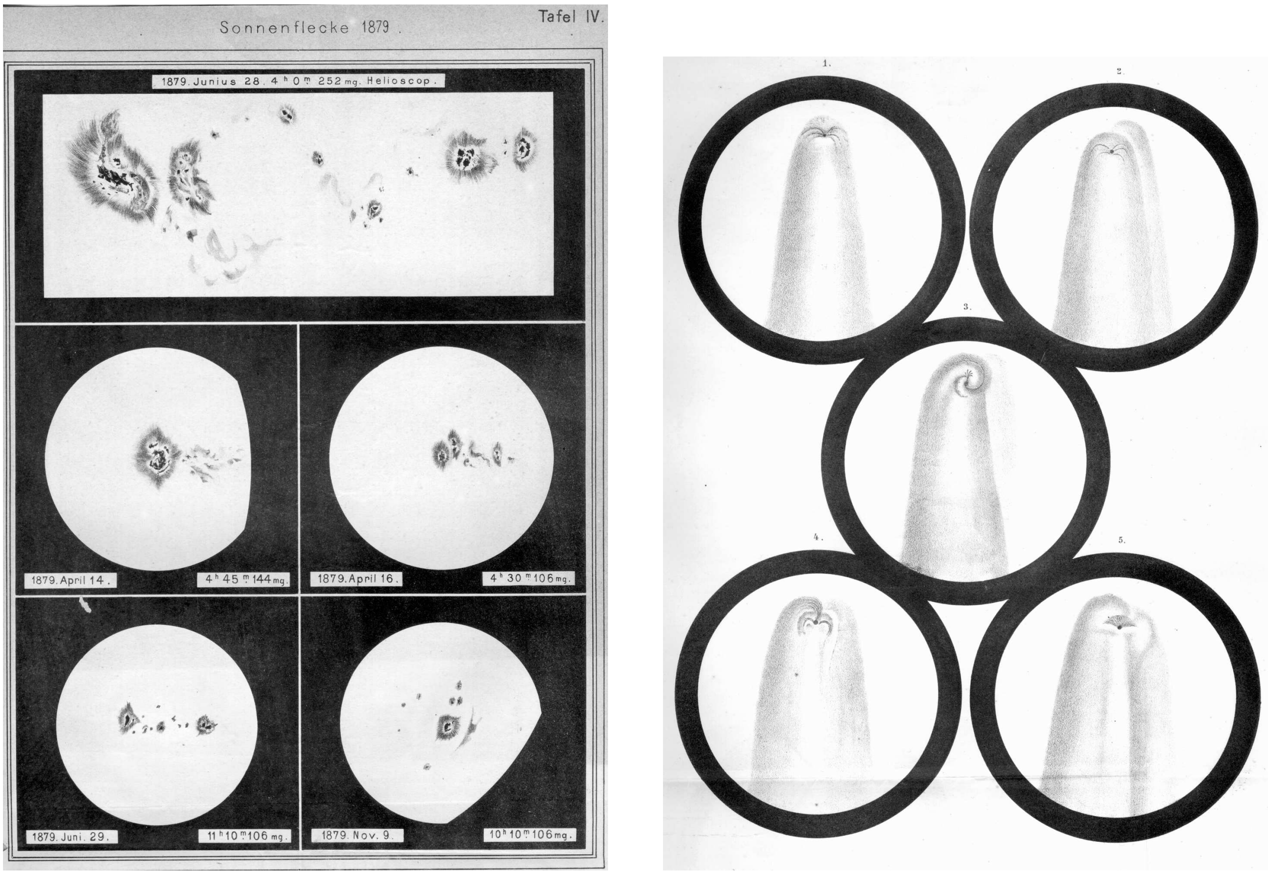

Figure 16.5: *Left: Hand drawings of sunspots made in Ógyalla Right: Hand drawing of the head and spectrum of Comet 1881 III*

for several years until the spot faded again. Between 1879 and 1885 Konkoly and his staff made 54 drawings which were used for determining the rotation period of the planet. When Hermann Kobold worked in Ógyalla in the period of 1880–1883 he did the bulk of the planetary observations.

Ernő Massányi added further 24 observations to this collection in 1902. Besides the determination of the rotational period of Jupiter he investigated the belt activity as well. On the basis of these observations Massányi rejected the idea of a connection between sunspot activity and the period of belt activity, but he did not have enough data to draw a conclusion on the possibility of a correlation with orbital phase. (Massányi 1904).

16.3.6 Stellar Spectroscopy – The Ógyalla Spectral Program

Thanks to the interest of Konkoly in astrophysics and to the rich collection of appropriate instruments stellar spectroscopy was a very important part of the observatory's scientific activity. H. C. Vogel, director of the Astronomical Observatory in Potsdam, motivated by the fundamental discovery of Kirchhoff and Bunsen and the necessity of making a spectroscopic reference system for future studies of spectral variations, initiated a spectral survey of the stars in 1875 which was completed in 1883 for the zone of $0° - 20°$ declination down to 6.5 magnitude. This survey was continued by Nils C. Dunér (1884) in Lund Observatory up to the North pole. Konkoly decided to participate in this work. He first observed and published the spectra of 160 stars (Konkoly 1877) and to extend Vogel's work he added the $-15° - 0°$ zone to the survey. The vast majority of the spectroscopic observations was carried out by Kövesligethy in the years 1883–1886. The instrument was a 6-inch Merz refractor equipped with a Zöllner stellar spectroscope. The catalogue (Konkoly 1887) 2022 stars down to 7.5 magnitude.

16.3.7 Kövesligethy's Spectral Theory

Kövesligethy was not satisfied simply to observe stellar spectra. He studied physics at the University Vienna from 1881 and he completed his PhD thesis in the theory of stellar spectra in 1884. He thought that thermodynamics will play the same role in interpreting the light emission properties of celestial bodies as Newtonian mechanics did it in the case of their motion. In his PhD thesis he derived an equation for describing the functional form of the continuous radiation of celestial bodies and its dependence on the temperature. As a byproduct he discovered Wien's displacement law. Developing his theory further he attempted to estimate the surface temperature of stars.

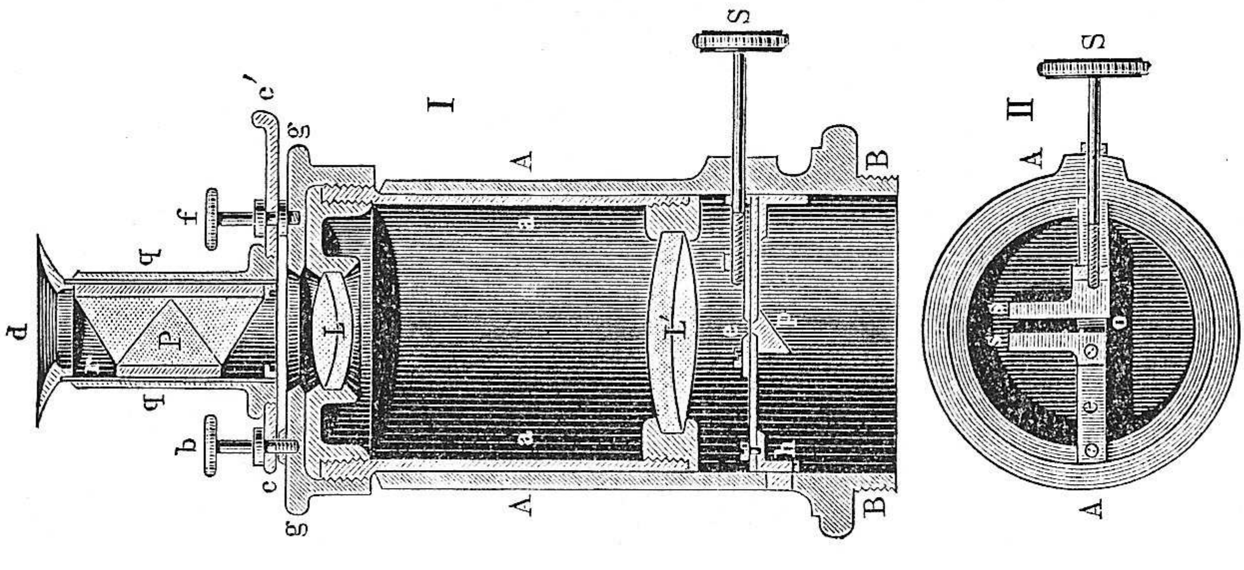

Figure 16.6: *Zöllner type ocular spectroscope used in the spectral programme*

For deriving his spectral equation Kövesligethy made several assumptions which were quite reasonable on the basis of the accepted views of contemporary theoretical physics. He made the following assumptions:

- the radiating matter consists of interacting particles,
- the form of interaction is an inverse power law,
- radiation field is represented by the aether,
- the aether also consists of interacting particles,
- the light is the propagation of the oscillation of the aether particles,
- there is an equipartition between the oscillation energies of material and aether particles.

Starting from the above assumptions he derived the spectral equation in the following form

$$L(\lambda) = \frac{4}{\pi}\mu\Lambda\frac{\lambda^2}{(\chi^2 + \mu^2)^2}$$

In the above equation μ means the wavelength of the maximum intensity and Λ is the total emitted energy.

Kirchhoff predicted the existence of the blackbody radiation function $B(\lambda)$ in 1860 by stating that the ratio of emission $e(\lambda)$ and absorption $a(\lambda)$ is $e(\lambda) / a(\lambda) = B(\lambda)$, where $B(\lambda)$ is independent of the quality of the radiating matter. Kirchhoff, however, could not determine the functional form of $B(\lambda)$. Kövesligethy emphasized that his spectral equation was also the solution of Kirchhoff's problem.

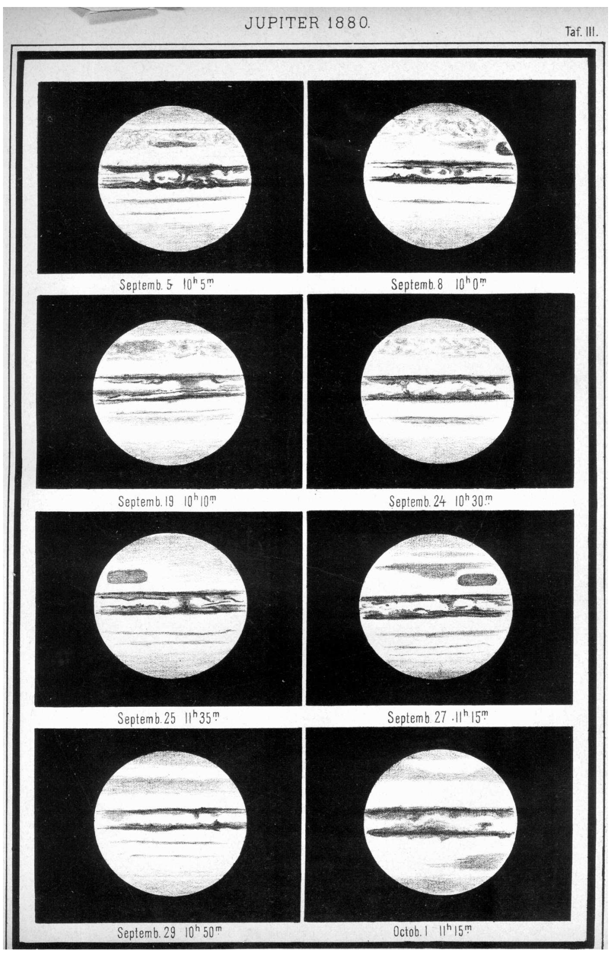

Figure 16.7: *Hand drawing of Jupiter's Red Spot*

16.3.8 Kövesligethy vs. Planck

It is the accepted view in the history of science that Max Planck succeeded to solve properly Kirchhoff's problem in 1900 by assuming the quantum hypothesis. As we mentioned at the end of the previous paragraph, Kövesligethy, however, succeeded 15 years before Planck. It is clear at the first glance that Köveligethy's spectral equation (discovered in 1885) does not have common assumptions with those of Planck (1900). However, it is worth making a comparison as we did it in Fig. 16.8, p. 158. This figure demonstrates that there is a striking similarity between the two curves, although their mathematical form is completely different.

Planck used state of the art results of statistical thermodynamics on the functional form of the most probable distribution of particles in phase space supplemented with the revolutionary assumption of the quantized nature of energy. In Kövesligethy's theory the radiating field, the aether, also consists of discrete oscillators, the energy, however, is not quantized. In this respect he can not be considered as a precursor of Planck. However, he was the first who solved Kirchhoff's problem by finding a spectral equation of the black body radiation which predicted a finite total emitted energy.

It is worth mentioning that Kövesligethy thought the observatory at Ógyalla was an ideal environment for theoretical works as well (Kövesligethy 2003).

16.3.9 Discovery of Wien's Law (Kövesligethy 1885) – Temperature of Celestial Bodies

Combining his spectral equation with the first law of thermodynamics and assuming an equipartition between the thermal energy of the emitting body and the oscillating aether particles Kövesligethy succeeded to obtain a relationship between the parameter μ in his spectral equation, which is in fact the wavelength where the *L(ë)* curve reaches its maximum, and the absolute temperature of the radiating source.

He discovered the displacement law of Wilhelm Wien (1893) eight years earlier than Wien himself. The inverse proportionality between the temperature and the parameter μ enables the observer to estimate the surface temperature of the emitting body.

Kövesligethy's spectral equation has a nice property: if at two different *ë'*, *ë''* wavelengths *L(ë')* = *L(ë'')*, then *ë'ë''*= μ^2. This property enables the observer to determine the surface temperature of a celestial body in a very elegant way. Since μ is a geometric mean of *ë'*, *ë''*, after estimating these two wavelengths it is very easy to obtain this parameter. The ratio of the two μ's in the spectral equation gives the ratio of two temperatures of the corresponding sources. Kövesligethy compared the spectrum of the Sun with that of melted platinum. He obtained μ^2=0.314 in the case of the Sun and μ^2=2.341 in the case of platinum. Since the melting temperature of platinum is 2045 K, the ratio of these *ì*'s resulted in T_{Sun}= 5584 K which is surprisingly close to the currently accepted value.

16.3.10 Impact on Contemporary Astrophysics

When Kövesligethy reached his significant theoretical results Konkoly's Observatory was already in the mainstream of developing astrophysics in Europe. Since 1873 Konkoly has been publishing his works regularly in *Astronomische Nachrichten*. He started his own observatory publications in 1879.

He regularly exchanged his *Beobachtungen* with other observatories, and had a regular correspondence with colleagues abroad, e. g. W. Huggins, A. Secchi, H. C. Vogel, J. K. F. Zöllner on spectroscopy, G. Spörer on Sun spots (Vargha 1999).

He performed an important role in establishing other observatories in Hungary: Kalocsa in 1877, Herény (Szombathely) in 1881 and Kiskartal in 1886.

Konkoly became director of the Hungarian Meteorological Service in 1890. As a director he helped Ógyalla Observatory whenever he could. There was a close connection between the Institute and the Observatory from 1890 until the nationalization of the latter.

16.4 Royal Hungarian Astrophysical Observatory

In the eighties Konkoly realized that his richness was not enough to keep his institute competitive on an international level and recognized that its operation by the state was the only way to survive:[4]
"As I am childless, constant fear is that my observatory built at great cost in time and effort , share the lamentable fate of other privately owned observatories. . . . Such was the fate of the observatory of the Baron Comphausen in Rüngsdorf, near Bonn; also of that Fr. Brödel, Saxony, the Umkrechtsberg in Olmütz and many others. Under the influence of these sad cases I have decided to donate my observatory to the state, as its stands, lock, stock, and barrel with three stipulations.

1. *The state will take responsibility for the operation of the observatory and employ three officials to do this.*
2. *The observatory will not be moved from Ógyalla during my life (it is hoped that, even after my demise, no minister will contemplate such as idiocy, considering , considering the investments which will have been made since nationalization).*
3. *As long as live and am capable, I shall remain the director of the Observatory, but without ever receiving any remuneration for my services."*

He was a member of the Astronomische Gesellschaft (AG) from 1873. Thanks to his personal contacts the AG meeting was held in Budapest in 1898. An important motivation for organizing this meeting in Budapest

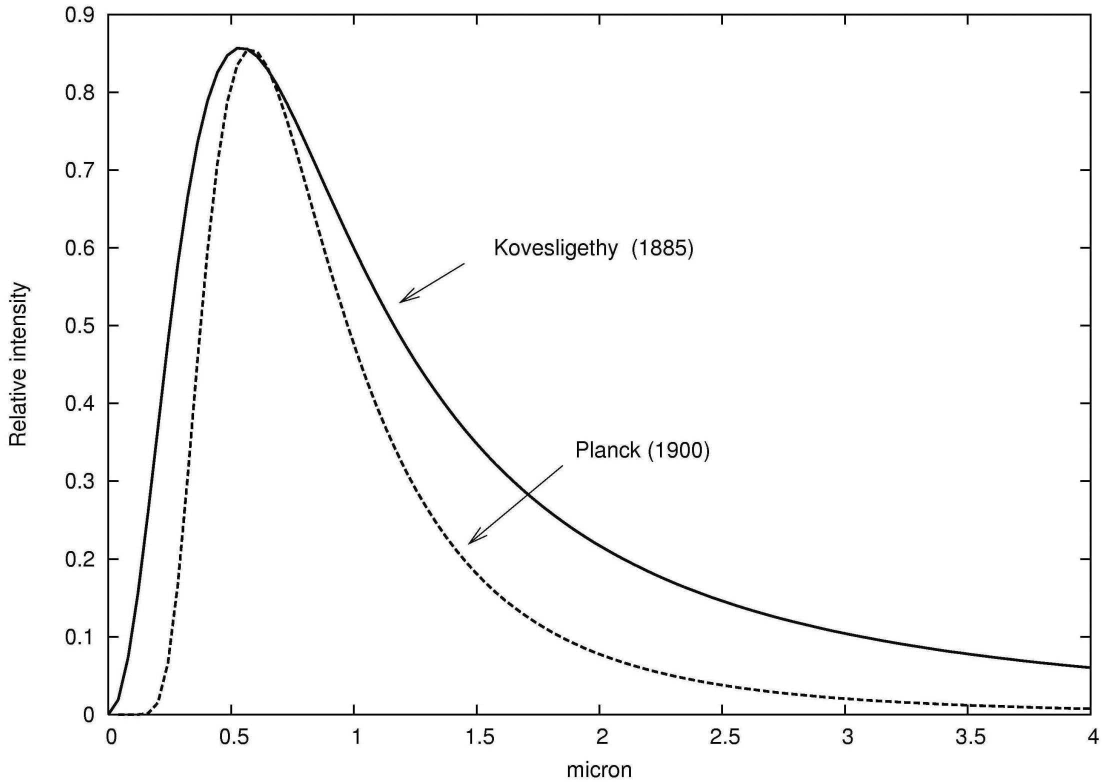

Figure 16.8: *Comparison of the spectral equations of Kövesligethy (1885) and Planck (1900) assuming T=5000 K black body temperature. The total radiated energy is finite in both cases. Note the striking similarity between the two curves although the assumptions and the functional forms are different in the two cases.*

was to have some international support for donating his institute to the Hungarian state.

The donation took place on May 20, 1899 and with the inauguration the Royal Hungarian Astrophysical Observatory began its activity. The scientific leadership of the Observatory consisted of

- Director: Miklós Konkoly Thege,
- Dep. Director: Radó Kövesligethy,
- Observer: Baron Béla Harkányi,
- Assistants : Antal Tass and Béla Szántó.

The donated institute was accepted by Baron Gyula Wlassics, minister of cultural affairs, who promised in the name of the state a new building and instruments.

16.4.1 The Scientific Programme of the 'Magyar Kir. Astrophysikai Obs'

The main program of the new institute (Royal Hungarian Astrophysical Observatory) was photometry. Photometry, that is the quantitative examination of light reaching us from celestial bodies, was born at the same time as spectroscopy and it was part of the process by which astrophysics revolutionized astronomy. They began photometry at Ógyalla by observing variable stars. The Observatory took part in the Potsdam program. Besides photometry regular observations of the Sun were carried out and simultaneous observations of meteors with other institutions were made, too. The Observatory provided "Time Services" for the Hungarian State Railways.

A significant event for them was the return of Comet Halley (1910). Regular observations of this comet were made at Ógyalla.

16.4.2 Stellar Photometry

As we mentioned above during the last period of the Konkoly era (starting with the donation in 1899) stellar photometry became the main field of research of the observatory. In order to get appropriate auxiliary equipments for stellar photometry they purchased a Töpfer wedge photometer and two (small and big) Zöllner photometers. Stellar photometry developed fast at the end of the 19^{th} century and the new state observatory joined this work. The photometric survey carried out at Ógyalla supplemented the work performed in Potsdam. The catalogue, containing the magnitude of 2122

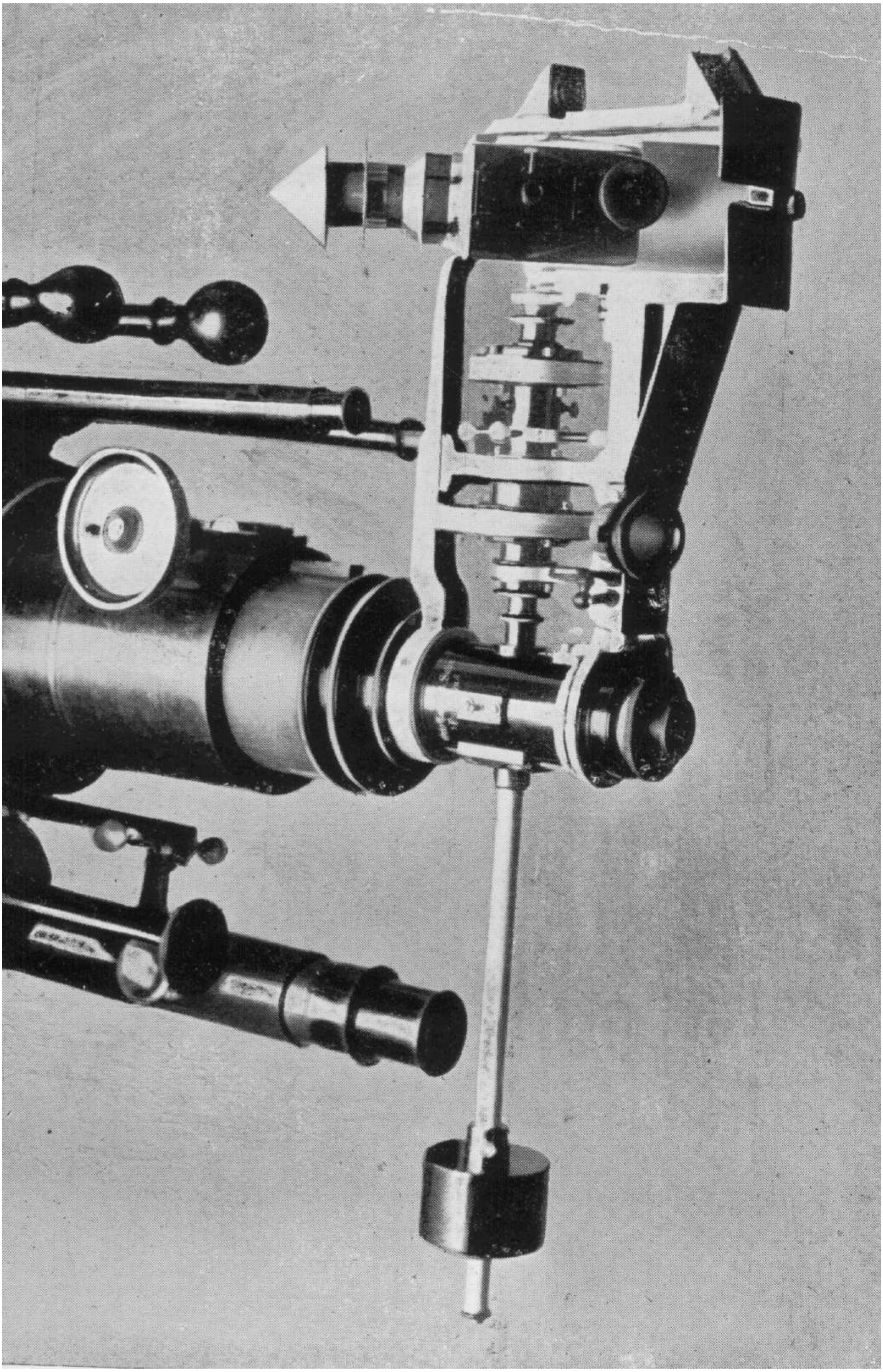

Figure 16.9: *Large and small Zöllner photometers, used in Ógyalla photometric programme*

stars brighter than 7.5 mag. in the $-10° - 0°$ zone, was published in 1916 (Tass & Terkán 1916).

Comparing the data with those made in the Harvard observatory, good agreement can be found (the standard deviation of the difference was about 0.1 mag., Zsoldos 1992).

They made photometric investigations of variable stars. From Sept. 19, 1900 regular observations of long period variables and some short period ones were made (from Tass (1904) to Tass (1918–1925).

A significant contribution was the 195 measurements of Nova Persei made by Baron Harkányi (Harkányi 1901). The last work on variables was the publication of the results on Nova Aquilae in 1918 (Kobold 1918).

16.4.3 Last Investments

In 1905 a new telescope – a photoheliograph – was purchased by the Hungarian State. It was followed by a 20-cm Heyde refractor in 1908.

The purchase of a 60-cm Heyde reflector was decided in 1913. The new state observatory also needed a bigger office building which was finished in 1913. The continuous development of this institution – among many other similar ones – was, however, broken by World War I. The purchase and installation of the 60-cm reflector was made only after the war and on the new place of the observatory at Svábhegy, Budapest.

The situation had changed from worse to disastrous. Miklós Konkoly Thege, the founder and the director of the Observatory died in 1916. The Austro-Hungarian Monarchy collapsed in 1918 and it resulted in separating Ógyalla from Hungary, being on the territory of the newly created Czechoslovak Republic. Since the instrumentation was the unalienable property of the Hungarian state it was transferred to Budapest.

16.5 Epilogue

It was decided in 1921 to build a new astronomical observatory on Svábhegy in Budapest. The first building, a small dome, housed a passage instrument: The observations started at the fall of 1922. The main building was completed in 1924–26, the big dome with a 60-cm telescope, Heyde-Zeiss, in 1927–28. The new era, the second 50 years has started.

1. Eötvös 1964.
2. Kobold 2004.
3. Vargha 1999.
4. Vargha 1999.

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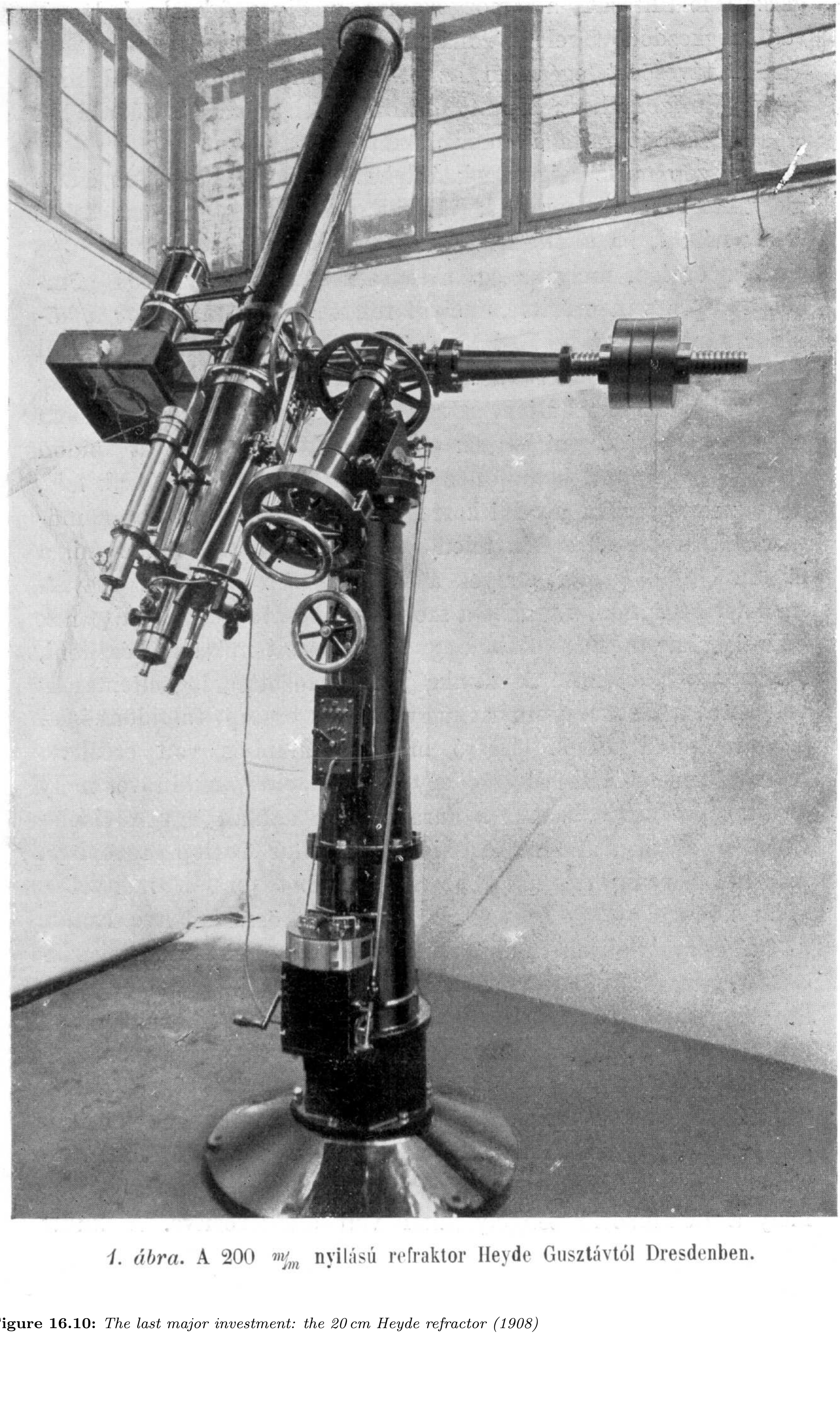

1. ábra. A 200 $^{m}/_{m}$ nyilású refraktor Heyde Gusztávtól Dresdenben.

Figure 16.10: *The last major investment: the 20 cm Heyde refractor (1908)*

Figure 16.11: *Main dome of the Konkoly Observatory*

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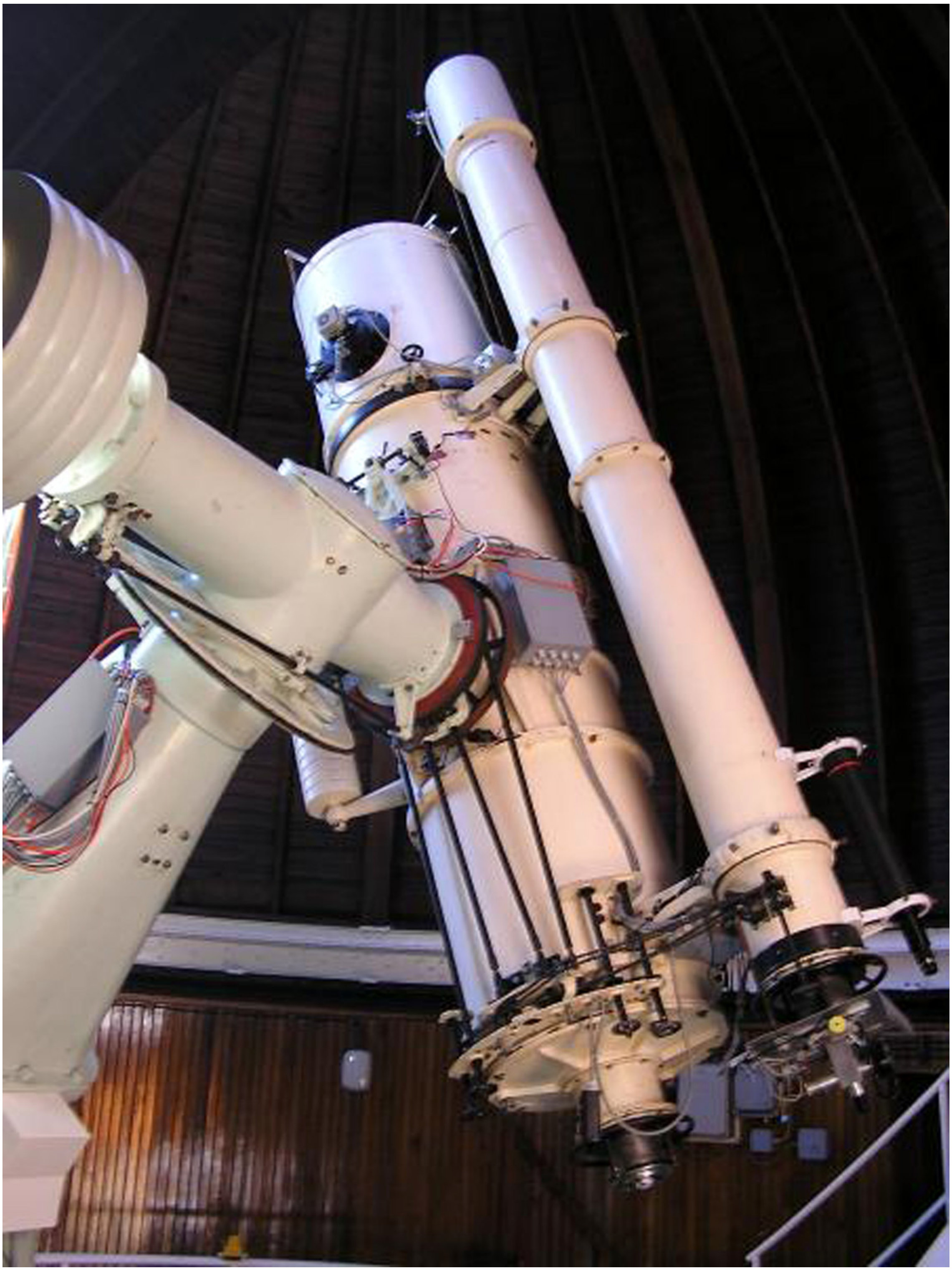


Figure 16.12: *Konkoly Observatory 60 cm Cassegrain reflector, Heyde-Zeiss (1928)*

Figure 17.1: *Bucharest Observatory*

17. Considering Heritage as Part of Astronomy – 100 Years of Bucharest Observatory

Magda Stavinschi and Catalin Mosoia (Bucharest, Romania)

Abstract

Anytime we are considering science's perspectives, thus astronomy, we have to go into the past for better knowing the observer's traditions or of the group in which we are working to see which are the main directions that can be continued or, on the contrary, what is already old and where should we go.

Astronomical experience in Romania is not an exception. There is evidence that proofs interests in knowing the sky of the local population – Sarmizegetusa Sanctuary, for two millennium and others more recently.

This year, the most important Astronomical Observatory from Romania is celebrating its 100 anniversary. Built in Bucharest by the first Romanian mathematicians at Sorbonne, it is nowadays nucleus of the Astronomical Institute of the Romanian Academy.

Marking the most important achievements in space research, in the last century but also those older, represents for the researchers and especially for the public an incentive for the advancement of astronomy in Romania. It happens that 2008, declared in our country the Romanian Astronomical Year, precedes the International Year of Astronomy. These two events brought together is favourable for education and information, and proves that, regardless of time, man can live increasingly better in a Universe that is increasingly knowing more profound.

17.1 Beginnings

Although we have very old testimonies of its existence on our lands, we can talk about Romanian scientific observatories only beginning with the last century. We have in mind the Observatory in the Charles I Park in Bucharest and the one on the right bank of the river Dniester (Nistru), at Dubasarii Vechi, today in the Republic of Moldavia (Moldova).

We can talk of astronomical traditions on our territories even beginning with the first millennium, when the Dacians built in the Meridional Carpathians, at Gradistea Muncelului, a sanctuary which still preserves evidence of their astronomical knowledge and implicitly, of an extremely precise calendar for those times.

Somewhat later, at the beginning of the 6$^{\text{th}}$ century, the Christian Church tried to establish a chronology as adequate as possible for the religious celebrations, of Easter in particular, set up in keeping with various astronomical moments. Its author was Dionisie the Small (Dionysius Exiguus), a monk born in the territory of Dobruja (Dobrogea). In 528 A.D. he introduced in *Liber de Paschal* the counting of the years since the birth of Jesus Christ.

17.2 The Middle Ages and Early Modern Time

The centuries which followed led to the considerable development of astronomical knowledge, but its truly scientific foundation dates back only to the 16$^{\text{th}}$ and 17$^{\text{th}}$ centuries, that is why 2009 is the International Year of Astronomy.

In the period preceding Galilei there were various astronomical preoccupations on these lands, too. It is worth mentioning, for instance, the first astronomical observations made in this part of Europe by the bishop Ioan Vitez (János Vitez) (1408–1472), the teacher of prince Iancu of Hunedoara's children. The Observatory in Oradea, an important centre of renaissance culture in that period, was created by Ioan Vitez in 1445, namely one century before the one set up at Uraniborg by Tycho Brahe.

A century later, Johannes Grass (Honterus) published notions of cosmography in *Rudimenta Cosmographica* (1568). The work had an important impact at the time, being issued in 26 successive editions, which were used for a long time in Germany as astronomy textbooks.

We should also mention Conrad Haas (1509–1579) who wrote a book, kept in the Sibiu public records, in which he describes rockets in stages and uses this term for the first time.

The 16$^{\text{th}}$ and 17$^{\text{th}}$ centuries are epochs of important spreading of astronomical knowledge in the ever more numerous colleges which were set up in Transylvania, Moldavia and Wallachia.

From among the teachers of the epoch we shall mention only the name of Hrisant Notara, who was a collab-

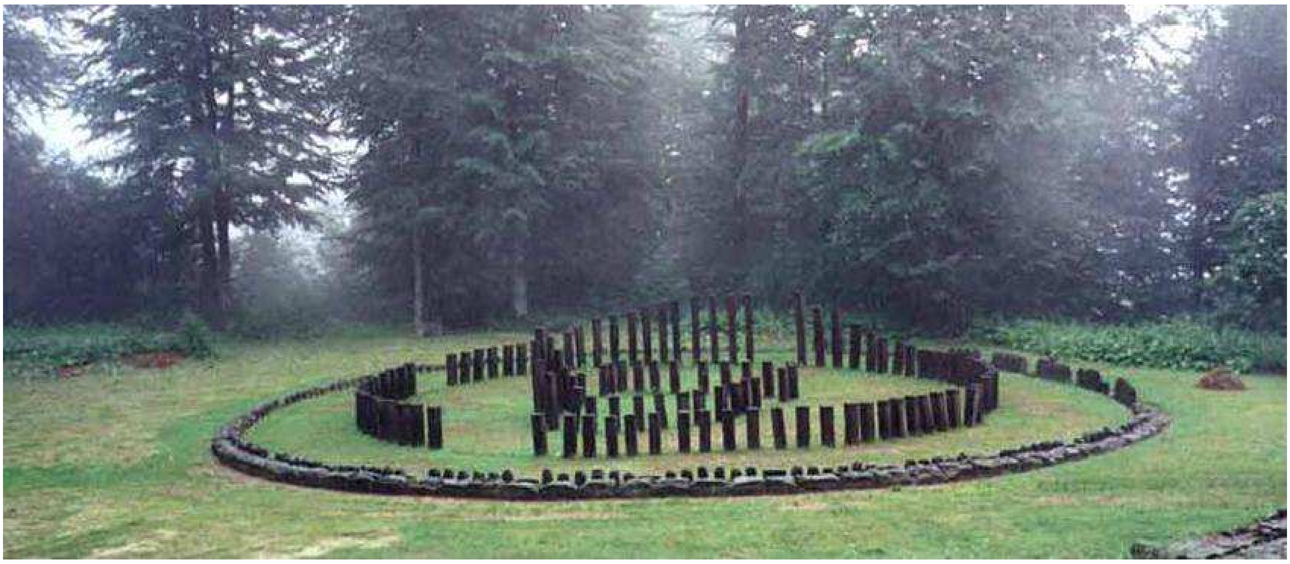


Figure 17.2: *Sarmizegetusa sanctuary*

orator of Giovanni Domenico Cassini (1625–1712), the first director of Paris Observatory, set up in 1667. He left us *Introductio ad geographiam et sphaeram* (published in Paris, 1716), the first scientific work with chapters dedicated to astronomy, where coordinates of Romanian cities are calculated.

The other observatories were built in Transylvania during the 18th century. Thus, the construction of the astronomical tower conducted by Maximilian Hell (1720–1790) was completed in 1759. The tower was destroyed by a fire in 1798 and restored in 1805.

The second observatory was set up in 1795 at Alba Iulia by the bishop Ignatius Batthyány – who founded the famous library that was to be called after his name. The Observatory ended its activity in 1860.

Meanwhile, astronomy also developed in the land across the Carpathians. Thus, in 1762, the Jesuit Ruggero Giuseppe Boscovich, one of the greatest astronomers of that time and founder of the Brera-Milan astronomical Observatoy, performed determinations of longitudes and latitudes, as well as other astronomical studies at Galati.

In 1773 the Russian astronomer Stephen Rumowski published *Determinatio Longitudinis et Latitudinis quorundam Moldaviae et Wallachiae locorum deducta ex Observationibus Johanne Islenieff institutis*, a work which he elaborated on the basis of the astronomical determination of the geographical coordinates for Bender, Akerman, Chilia Nouă, Ismail, Bucharest, Focşani, Jassy and Brăila, carried out by the Russian astronomer Ivan Isleniev.

17.3 The 19th Century

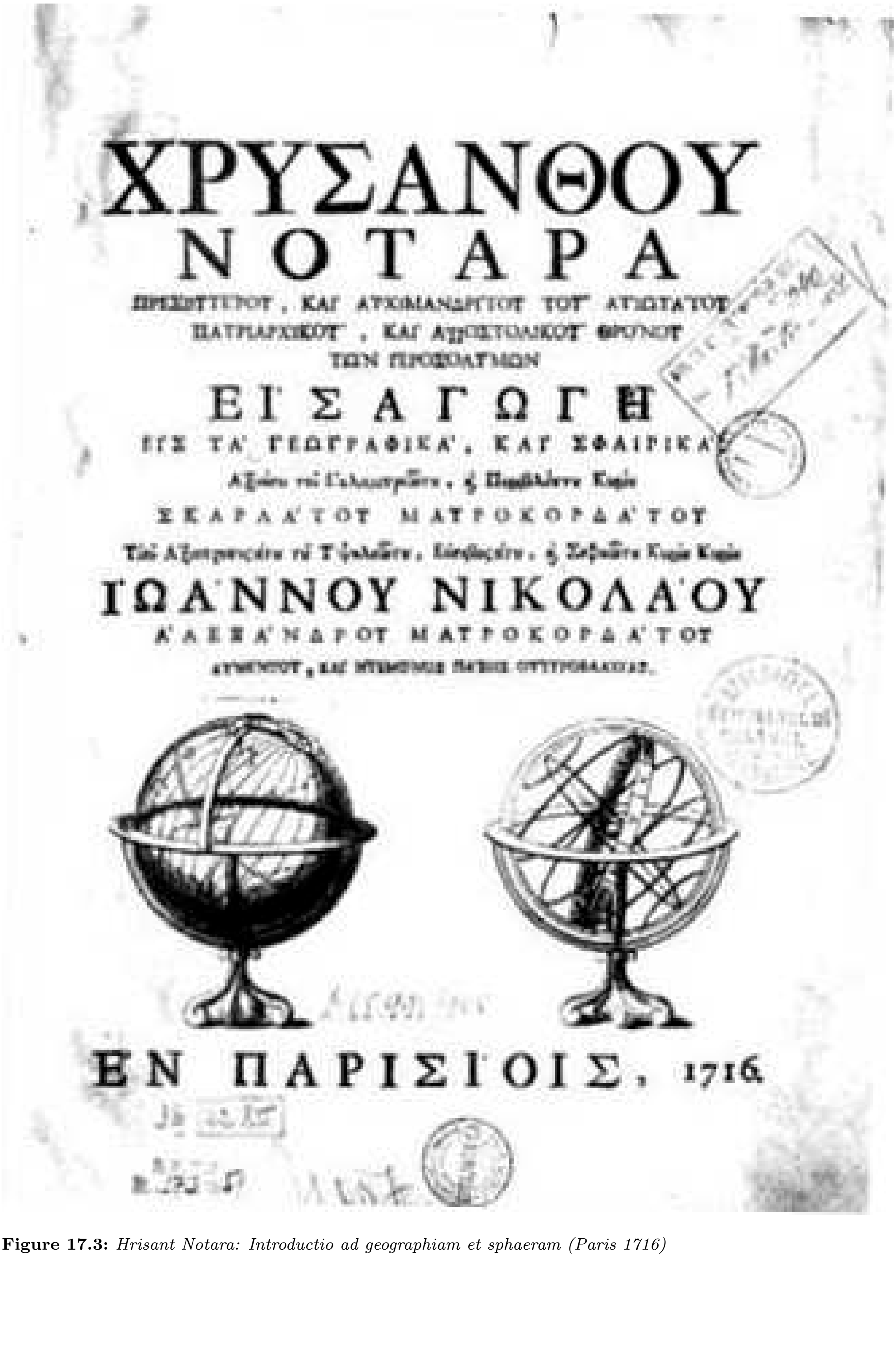
At the beginning of the 19th century, the first amateur astronomer was recorded again in Moldavia. In 1823, the poet Costache Conachi bought a telescope in Vienna, which had a focal distance of 2 m and a diameter of 157 mm and was later used by students in their practical studies. This telescope was handed down by his heirs to the Observatory in Jassy.

During the period 1828–1832 astronomic observations for the determination of different geographical coordinates were performed. Ortemberg, Wrontchenko and others determined the coordinates of the Romanian towns of Jassy, Galaţi, Roman, Bucharest, Călăraşi, Turnu-Măgurele, Calafat, Craiova, Babadag, Constanţa, Gurile Dunării.

Together with the development of the elementary and secondary educational systems, the first astronomy textbooks were issued, such as those by Gheorghe Asachi (1838), A. Marian (1829 – the first astronomy texbook written in Romanian) and August Treboniu Laurian (1859).

At the middle of the 19th century there were profound transformations not only in Europe, but also on the Romanian lands. In 1859 Moldavia and Wallachia united and thus the first modern Romanian state was created. This fact called for not only a reform of the political and social life, but also one of education, directed to Western culture, to the French one in particular.

The foundation of the first Romanian universities (Jassy, in 1860 and Bucharest, in 1864) marked the beginning of academic instruction. The first professor of astronomy was Neculai Culianu (1832–1915) in Jassy. In December 9, 1874, together with Professor Stefan Micle (1820–1879), he observed the transit of the planet Venus across the Sun's disk. The poor facilities available did not allow then the obtaining of good results such as those reported by Theodor von Oppolzer and Edmund Weiss, whose observations performed in Jassy proved to be even more accurate than the similar ones carried out in Vienna. Dimitrie Petrescu (1831–1896) was the first astronomy professor who delivered lectures at Bucharest University, where he was followed by Nicolae Coculescu.



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ΕΝ ΠΑΡΙΣΙΟΙΣ, 1716.

Figure 17.3: *Hrisant Notara: Introductio ad geographiam et sphaeram (Paris 1716)*

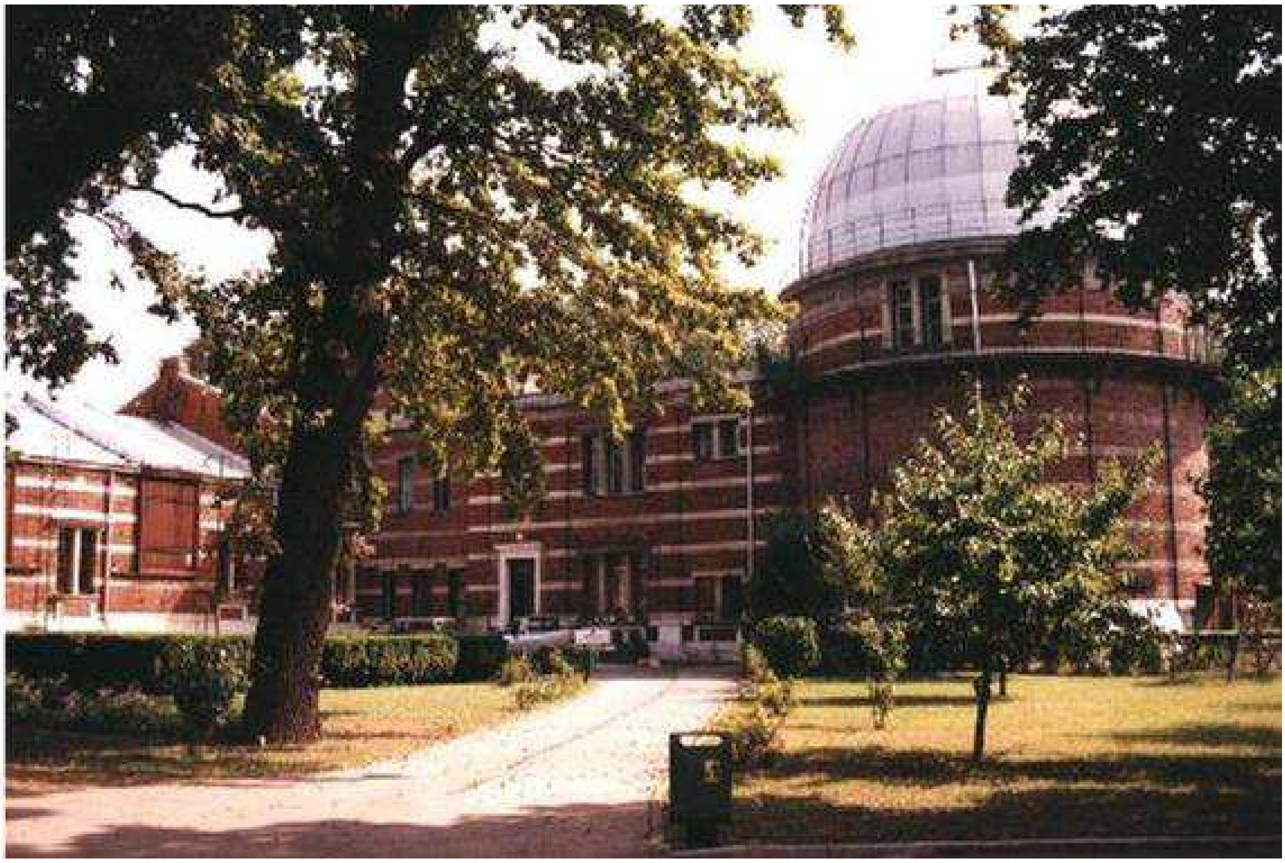

Figure 17.4: *Bucharest Astronomical Observatory*

Due to the development of astronomical academic education a large number of young students were sent abroad to improve their training in astronomy. It is worth mentioning especially Constantin Căpităneanu (1849–1895). After performing another training stage in Naples, he returned home (1873), were he was assigned a task of high responsibility, i. e., to draw up an accurate map of the country.

A telescope (field glass) for latitudes, two refracting telescopes, a chronograph, chronometers etc. were ordered for this purpose. These facilities helped him to construct in Jassy (1875) the first meridian dome on the Romanian territory. Seven years later a similar hall was also erected in Bucharest. In 1881 Căpităneanu and Kihnert published in Bucharest *A Determination of the longitudinal differences between Jassy and Cernăuţi*. This was the first publication of astronomical observations carried out by a Romanian scientist in his own country.

17.4 The First Doctoral Theses in Astronomy

The first theoretical studies in astronomy were also reported at the end of the 19$^{\text{th}}$ century. Out of the first four Romanian scientists who took their doctor's degrees in mathematics at Sorbonne, in Paris, three devoted their theses to celestial mechanics.

Spiru Haret (1851–1912) dedicated his doctoral thesis (1878) to the study of the invariability of the major axes of planetary orbits. Felix Tisserand, professor of celestial mechanics at the Sorbonne, later resumed this study and reached the same conclusions and even recommended that young Haret's methods be extended to other astronomic calculations.

At the same time, the well-known French mathematician Henri Poincaré highly appreciated Haret's thesis, concluding that is was a "great surprise". The same subject was resumed in 1955 by Jean Meffroy. Therefore, Spiru Haret can be considered as the first Romanian astronomical theorist.

In 1882 another Romanian got his PhD in Paris, namely Constantin Gogu (1854–1897), who concentrated on long-periodic inequalities in the Moon's orbital motion, confirming the accuracy of Delaunay's calculations against Stockwell's errors.

The third Romanian doctor in astronomy from the Sorbonne was Nicolae Coculescu (1866–1952) who gave a description of the interrelated movements of the three bodies for a particular case. His thesis (1895) concentrated on the perturbation function and supplied the approximated expressions of its higher order terms which were later mentioned in *Leçons de mécanique céleste* by H. Poincaré.

17.5 The Foundation of Bucharest Observatory

As the three scientists returned home, they could hardly go on with the work so brilliantly commenced abroad because of the lack of an adequately equipped astronomical observatory.

As early as 1870, P. S. Aurelian, an enthusiastic scholar and statesman, ventured to "ask the Government and the Legislative Bodies how long it would still take the Romanians to provide such an important research institution as those which already existed in other countries, whose national revenue was ten times lower than Romania's or even smaller". In 1873, he challenged the authorities again by stressing the necessity of building-up an astronomical observatory in Romania and wondering "... which of the ministers will have the honour of being regarded as founder of the Bucharest astronomical observatory?" The same questions were resumed later by S. C. Hepites, particularly in his notes to the Academy, as well as in his papers related to the history of astronomy (he distinguished himself as the author of the first history of Romanian astronomy).

It was in 1888 that the Minister of Agriculture succeeded to acquire the land of C. Bozianu, ex-councilor of the first Romanian Prince A. I. Cuza and for short time prime minister. This land is situated on the Filaret Hill (Cuţitul de Argint Street) and was used for the construction of the Meteorological Institute and Weights and Measures Centre (1889). Typical for the beginnings of any science in a country, in Romania meteorology was also at first mingled with geodesy and astronomical studies. The first astronomical requirement consisted in an accurate determination of the mean time.

The Set-up of the Observatory in Bucharest – 1 April 1908

After N. Coculescu returned to Romania, a master of an advanced scientific insight, greatly enriched by the total solar eclipse expedition which he had joined in Senegal (1893), he was appointed professor at the Bucharest University and managed to win the cooperative support of another astronomy supporter, Spiru Haret, who was at that time the minister of Public Instruction and Religious Affairs. Therefore, Coculescu came to be remembered as founder of the first modern astronomical observatory in Romania – one of the earliest scientific establishments of the country.

However the set-up of the astronomical Observatory on 1 April 1908 (including a meteorological department until 1920) marked the beginning and not the end of an unceasing strive for the development of this science in our country. Thus, during the same year (November 1908), in a relevant letter published in *Astronomische Nachrichten* N. Coculescu (Director of the Bucharest Observatory) pointed out:
"Since the existing meteorological institute, set up 24 years ago, is located in a most suitable area, it has been decided that an astronomy department be created on the same site. We only have a transit telescope of a simple design for keeping time and a 108 mm refracting telescope. In view of the astronomical research currently pursued at the Observatory, we have decided to order a twin refracting telescope provided with a 30 cm lens and 6.70 m focal distance. The mechanical part will be achieved by Paul Gautier and the lens by the G. & S. Merz Optics Institute. The design and construction of the building provided by an 11 m diameter dome have been entrusted to A. Engels, an architect of the Brussels (Uccle) Observatory." The staff of the facility was made up of only two astronomy students: A. Teodosiu and Maria Teohari. The latter can be considered the first Romanian woman astronomer, although there are previous records of observations made by two other women, namely Elena B. Vermont and F. Boerescu, on 4 February 1906, at −17.7°C!

In the same year when Bucharest Observatory was set up, Gheorghe Demetrescu (1885–1969), who was to become the founder of the Romanian astronomical research, was sent to Paris Observatory for a training period. There he concentrated on the study of variable star photometry, photographic determination of the precise position of minor planets and comets, solar physics related to the photospheric phenomena, lenses of astronomical instruments, interpretation of seismographic data.

The instruments ordered by N. Coculescu were installed after the main building was erected (1912). The first one was the refracting telescope, a Prin-Merz, mounted in 1912, tested in 1925, operational since 1930, and modified by Gheorghe Petrescu in 1935.

The Meridian circle Gauthier-Prin (mechanical part), Steinheil-Merz (optical part) was ordered in 1910, delivered in 1924, and installed in 1926 by G. Demetrescu.

17.6 Other Observatories

Also in 1908, on the right bank of the river Nistru, at Dubasarii Vechi, another astronomical observatory, this time a particular one, was created. It was founded by Nicolae Donici (1884–1956?), one of the most remarkable personalities of Romanian and world astronomy. His destiny was similar to that of the troubled lands where he was born. A founding member of the International Astronomical Union, an active participant in the first congresses of this union, an honorary member of the Romanian Academy, the author of important astrophysical works, the observer of no less than six total solar eclipses, the last years of his life are still surrounded by mystery, as there is no document left which should testify the date and place of his death.

After the Observatories in Bucharest and Dubasarii Vechi, another observatory was soon set up in Jassy (1913), headed by Professor Constantin Popovici (1878–1956) until 1937 and yet another one in Cluj (1920), under the leadership of Gheorghe Bratu (1881–1941). The Observatory in Timisoara was built much later (1959) through the efforts of Professor Ioan Curea (1901–1977).

Constantin Popovici and his pupil and collaborator Vintila Siadbei (1898–1944) did their best to endow the Observatory in Jassy with a meridian refractor, a Ressel equatorial, two chronometers (for mean and sidereal time), a Graff photometer, all largely deteriorated during WW II. Their work was continued by another outstanding astronomer, Victor Nadolschi (1911–1996), who was also the director of the observatory between 1948 and 1966.

17.7 The Astronomical Observatory of Cluj

Founded in 1920, built between 1924 and 1934, it belongs to the University of Cluj, later to the Romanian Academy. Moved in Timisoara (1940–1945) during WW2, then back in Cluj, it changed location in 1978, then moved to its actual site, in the Botanical Garden, in 1982. The University's didactical staff with astronomical tasks shares the building with the researchers of the Astronomical Institute of the Romanian Academy.

The main instruments were moved in 1976 to an observation station, situated on Feleacu Hill, 8 km southward the town, with excellent observational conditions. Since 1977 the station belongs to the Astronomical Institute.

Main Instruments

Prin refractor (20/300) and Newton reflector (50/250) – equatorial mounting, functional since 1934; Coudé refractor (15/225) (1982), Meade reflectors: (40/406; 30/245) endowed with CCD cameras (1995 and 2006, respectively).

Main Research Programs

Catalogue of the Photographic Map of the Sky, 20th Century, Zone +20 Degrees (1933–1947) – cooperation with Observatoire de Paris; artificial Earth satellite observations (Tracking Station 1132 – COSPAR): Interobs, Eurobs, Spin, Atmosphere, Moonwatch; observation of RR Lyrae-type variable stars (cooperation with the Odessa Observatory, Russia); Physics and Evolution of Stars (cooperation with the Academies of Sciences of the Central and East European countries); archiving of photographic plates (cooperation with the Institute of Astronomy of the Bulgarian Academy of Sciences).

In 1922 Romania accepted formally the invitation to join the International Astronomical Union (IAU) set up in Brussels in 1918. Romania was represented in the first General Assembly of this organization (May 1922, Rome) by its delegate, Nicolae Donici, elected as a member of two IAU Commissions: for Solar Physics and Physical Observations on Planets, Comets and Satellites. Other Romanians became step by step members of the IAU and of its commissions. Romania is represented in IAU and, beginning with 1990, in the European Astronomical Society and other international organizations by the Romanian National Astronomical Committee (RNAC), set up in 1930. Its first president was Nicolae Coculescu. Topics of the first RNAC meeting held on 4 April 1931 included the calendar and official time reform, as well as the participation of Bucharest Observatory in the world campaign of longitude measurements to be initiated in 1933.

To prepare for this world campaign, two pendulum clocks (a sidereal Leroy-type and a mean time Riefler-type one) and a reception station for wireless telegraphy time signals were installed in the basement, under constant pressure and temperature conditions.

During the next ten years the activities related to the programme for minor planets and comets concentrated on steadily obtaining accurate photographic positions whose magnitudes were however limited (to about 12.0). Bucharest Observatory largely contributed to the results acquired in this field.

To embark on the strenuous tasks of star cataloguing, the carrying out of investigations and data processing, as well as of theoretical studies, a new group was successively appointed in the years 1928 to 1930: Constantin Drâmbă (1907–1997), Gheorghe Petrescu (1905–1965), Călin Popovici (1910–1977), Nicolae Dinulescu (1907–1989) and much later Ella Marcus (1909–1982).

During 1937 to 1943 Constantin Popovici was appointed director of the Bucharest Observatory and worked at various studies on the effect of cosmic dust in the neighbourhood of stars, the effect of the solar radiation pressure upon planetary and cometary orbits and on equilibrium points of trajectories.

Another distinguished astronomer, Constantin Pârvulescu (1890–1945) performed most original studies (also at Bucharest Observatory) concerned with globular clusters. His work was referred to in W. M. Smart's book *Stellar Dynamics*.

Following WW II, Romanian Astronomy was given a new impetus. All of the observatories were considerably provided with updated equipment.

Bucharest Observatory, which had been managed by the University until 1951, was subsequently taken over by the Academy and headed by Gheorghe Demetrescu, 1943 to 1963, followed by Constantin Drâmbă, 1963 to 1977. In 1977 the Academy lost its institutions and the Observatory was integrated, along with other departments, into a Center of Astronomy and Space Research within the Central Institute of Physics.

The closing in of the International Geophysical Year, which began in 1957, brought a series of new instruments: in 1952 a transit instrument (100/1000 mm), in 1957 a solar refractor (130/1950 mm) for visual and photographic observations of the solar photosphere in integral light. A H-alpha filter (6563 Å) of Halle-Lyot-Öhman type, mounted on a special refrac-

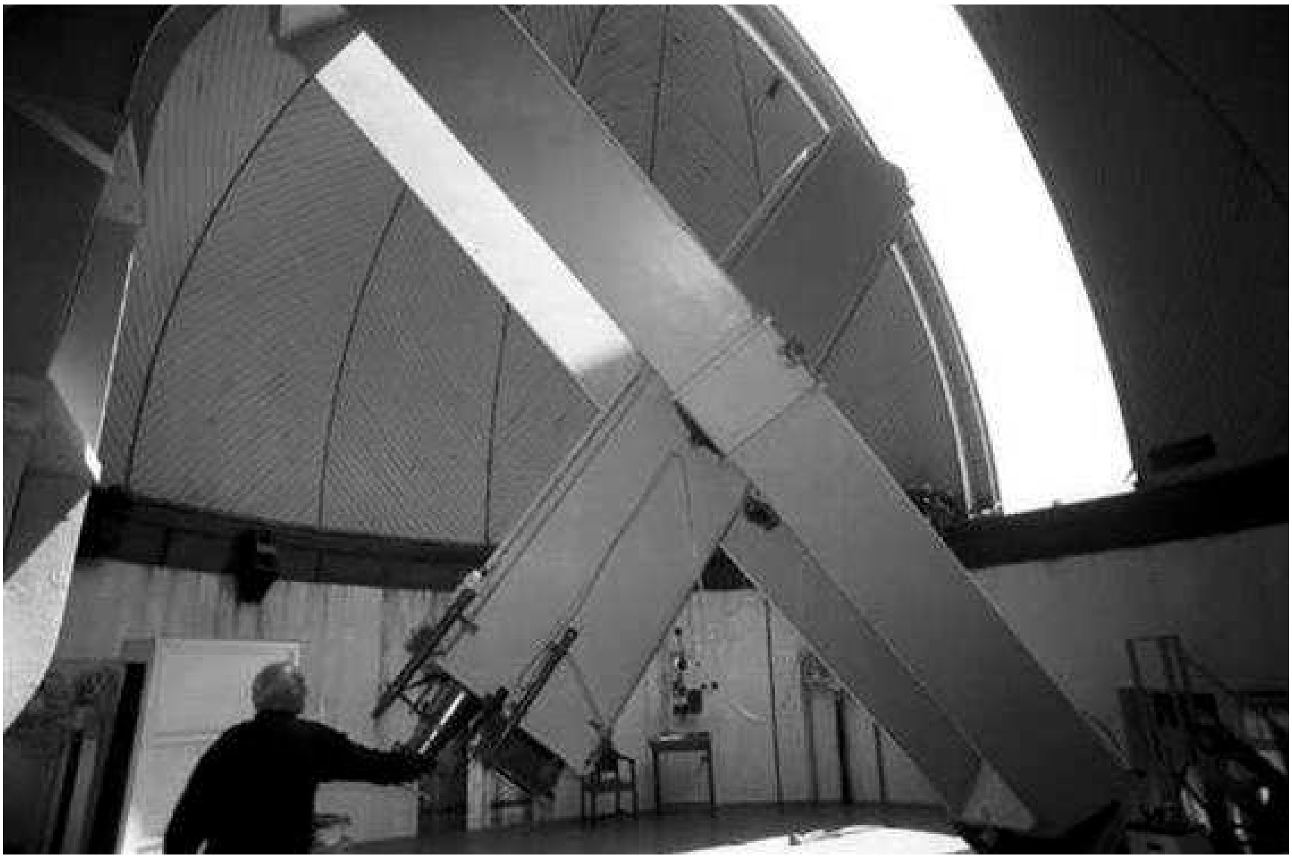

Figure 17.5: *Refracting Telescope of Bucharest Observatory*

tor (80/1200 mm), is used for photographic observations of chromospheric formations (filaments, prominences, flares) and in 1964 a Cassegrain telescope (500/7500 mm) was bought for the photometry of variable stars.

The time service was first endowed with Belin, then with Rohde & Schwarz quartz clocks. However, the 1980s brought a great recession, ranging from electric power or paper economies to the ceasing of the international relations, with the countries of the communist block included.

The publication of the Observatory's journal (*Studies and Researches in Astronomy and Seismology*, 1956–1962, then *Studies and Researches in Astronomy*) was stopped in 1974. The only publications which did not cease to be issued were those of tables, which did not raise any risk of interpretation, namely *Observations Solaires* and *Astronomical Yearbook*.

17.8 Development after 1990

Immediately after the events of December 1989, Romanian astronomy, as well as the entire society, took an extraordinary turn. On 8 January the Institute's board of administration was changed and on 1 April the Astronomical Institute was set up under the aegis of the recently re-established Romanian Academy; the Institute was made up of three observatories: Bucharest, Cluj and Timisoara. It was headed first by Magda Stavinschi (1990 to 2005) and then by Vasile Mioc (beginning with 2005).

The institute journal was immediately set up again, under the name of *Romanian Astronomical Journal*, with two annual issues.

Collaborations extended to very many countries. Important international meetings were organized by the Astronomical Institute, as, e.g., "CCD and photometric receptors applied to the Observations of the Saturnian satellites during the 1995–1996 opportunity" – PHESAT 95, 1994; NATO Advanced Research Workshop intended to prepare the 1999 total solar eclipse, 1996; International Seminar "Solar Researches in the South-Eastern European Countries: Present and Perspectives", 2001; Journées "Systèmes de référence spatio-temporels", 2002; IAU WG meeting "The Future Development of the Ground-Based Astrometry", 2002; and many others.

A remarkable event was the total solar eclipse of 11 August 1999, whose maximum was in Romania. On that occasion were organized the first international workshop before an eclipse and an Advanced Study Institute right in the period when the eclipse took place, both sponsored by NATO. In that period an International School for Young Astronomers under the aegis of IAU and UNESCO was also organized. The event was used also to obtain special funds from the government for the consolidation and restoration of Bucharest Observatory

Figure 17.6: *Bucharest Observatory ready for the total solar eclipse of 11 August 1999 – Mass media and the total solar eclipse*

buildings, and also for the construction of a special pavilion for a Planetarium (of 65 places and 8.5 m diameter), which is still without a projector.

Other important astronomical events involved the astronomers both in research programmes, as well as in those dedicated to astronomical education: Venus transit in 2004, mutual phenomena of the satellites of Jupiter, Saturn, or Uranus.

Romania was an important factor in the setting up of the South-Eastern European network, at first through the formation of the South-East Branch of European Astronomical Society, then through that of the Sub-Regional European Astronomical Committee – SREAC under the aegis of UNESCO-ROSTE and recently under that of UNESCO-BRESCE.

A special attention has been paid to astronomical education, especially in the conditions when the reduction of the school curricula led to the elimination of astronomy. At first it was the initiative of the resolution concerning the teaching of the astronomy (Sydney, Australia, 2003), Special sessions for Astronomy education in Europe during the JENAM meetings (starting in Budapest, 2003) were initiated, then the presidency of the IAU Commission 46 for 2006 to 2009.

Several young people, from the institute or from outside, obtained their doctoral degrees under the guidance of researchers of the institute. Some of them, at present, associated researchers of the Institute, work at important world research centers.

17.9 The Main Research Directions

Naturally, the scientific activity of Bucharest Observatory has continued in the first place the traditional one begun in 1908 and even before.

The presence of an instrument extremely good at the time, the meridian circle, has led to the development of a strong department of Meridian Astrometry.

In 1953 a collaboration agreement was concluded with the Soviet colleagues on "The Set-Up of the Inertial Reference System of Stars", a study concentrated on relating the positions and movements of stars to the distant extragalactic nebulae and the solar system.

Having gained experience in making up stellar catalogues the Meridian Group was invited to bring its own contribution by drawing up a catalogue for the FKSZ main faint stars (645 stars) and a KSZ faint star (4000 stars) catalogues, The Romanian Academy highly appreciated the work and awarded the Meridian astrometry group headed by Ella Marcus the prize "Gheorghe Lazar" – 1972. Many other catalogues followed.

In the recent times the studies for the acquisition of stellar images continued with the elaboration of software for image processing by means of the new Apogee 47p CCD camera mounted on our 6000/380 Prin-Merz astrograph. The project of building an interface to be used for areas around extragalactic radio-sources was accomplished. In order to include the accurate time coordinate in the computational process of CCD images, GPS time receivers were used. The studies concerning the reference stars to be used for extra-galactic radio-sources were continued. The Romanian contribution consists of the observation of the optical parts of ICRF sources and the elaboration of the intermediary reference catalogue.

Photographic astrometry was carried out many years. As far as the Solar system astrometry is concerned, the observations on Neptune and minor planets were completed. The computation program was build to improve orbital elements of the asteroids and an application of this program was finalized.

Lately, the collaboration with other observatories has been extended, especially with the Bulgarian colleagues, not only for the observation with other instruments, but also for the storing of the photographic plates gathered throughout the decades in Bucharest and Cluj.

Together with Jean Kovalevsky, the working group "Future Development of the Ground-Based Astrometry" (2000–2006) was organized, replaced now by the IAU Division I WG "Astrometry by Small Ground-Based Telescopes".

Naturally, the beginnings of Romanian astronomy marked by important thesis and studies in the field of celestial mechanics continued.

For several years, studies on terrestrial rotation were made. Under the supervision of C. Drâmbă, the rotation of the Earth was studied in the more general framework of elastic deformations. Thus, on the basis of the Euler generalized equations, the existence of the Chandler ellipse described by the instantaneous pole of the Earth's rotation was theoretically established and so was the analytical expression of the Chandler period. Starting from the elasticity differential equations in relation to a system of rotating driven axes converted into global equations and applied to the Earth (small inertia products), the differential equations for the trajectory of the instantaneous rotation pole were determined.

The Time Department participated in the MERIT international campaign (Monitoring of the Earth Rotation and Intercomparison of the Techniques and Methods), whose results actually led to the replacement of the classic ground-based techniques with modern space ones.

Starting from 1957, the studies about the motion of artificial Earth satellites (AES) gained a place of choice. Tracking stations were set up in Bucharest, Cluj, and Timisoara. Their observations were reported, along many years, to the data centers in Europe and USA. Paralelly, theoretical studies of the AES motion under various perturbing factors were developed. The perturbing influences of such factors were tackled analytically, in various approximations.

Another field of choice was the motion of celestial bodies in post-Newtonian fields (relativistic or not). Many results were obtained in the two-body or the (general or restricted) three-body problems associated to the models of Schwarzschild, Schwarzschild – de Sitter, Manev, Fock, zonal-satellite problem, etc. For most of these models the qualitative methods of the theory of dynam-

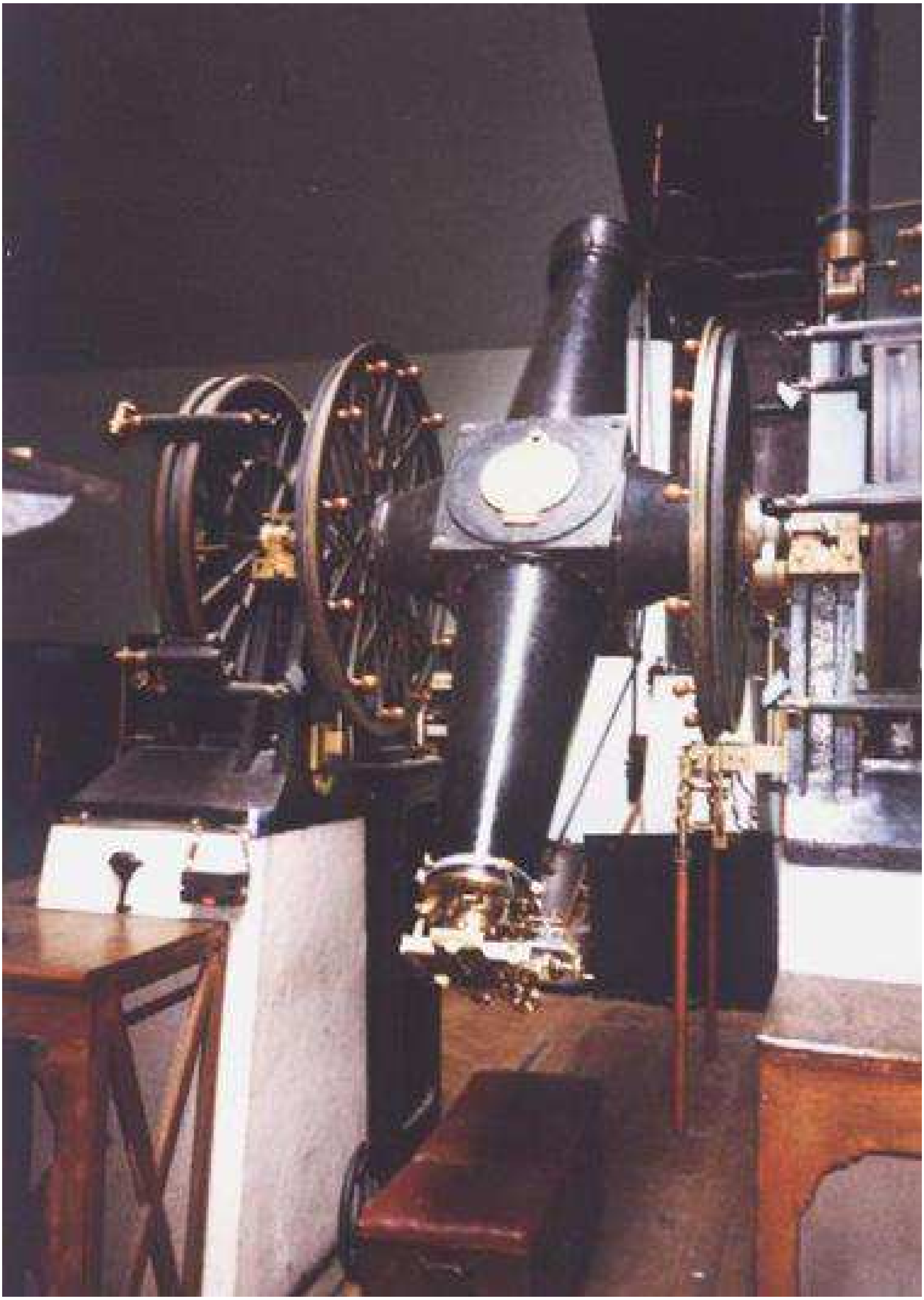

Figure 17.7: *Meridian circle of Bucharest Observatory*

ical systems were used. This led to a general geometric characterization of all the orbits. This worked also in more general problems, as, for instance, Maxwell's $(n + 1)$-body problem in Manev's or Schwarzschild's fields.

Lately an ever greater emphasis has been laid on studies of solar and stellar physics, as well as on extragalactic astronomy and cosmology.

As to solar physics, our research focuses on the data analysis and interpretation using ground based and space observations. We are interested in studying the active regions evolution and their implications in the chromospheric and coronal activity.

We search magnetic reconnections before and after flares or CMEs and the opening of the filed lines during these events in 3D extrapolation of the coronal magnetic field from MDI magnetograms. We also study filaments and prominences activity in connection with their end in coronal mass ejections. The magnetic topologies during the evolution of an event reveal a coronal dynamics that allows us understand the solar active phenomena.

Another topic of our interest is the follow up of a CMEs from the Sun to the interplanetary space. The halo CMEs from the solar source to the Earth's effects are also studied. The observational work is sustained by MHD 2D numerical simulations.

Our research framework belongs to the major scientific topics of the International Heliophysical Year.

Concerning the extragalactic astronomy and cosmology, at the Bucharest Observatory such studies begun in the early '80s, as a theoretical branch, directly related to the computational facilities available in our Observatory. Starting from a little Z8080 computer (early '80s) to a superscalar supercomputer of 44 processors (now), our cosmology team developed models, methods and techniques related to: the investigation of 2D and 3D catalogues of galaxies, clusters and superclusters; investigation of the log tails of the 2-points correlation functions; cosmological simulations (N-body + SPH) of the Large Scale Structure of the Universe (LSS); investigation of environmental effects in clusters of galaxies; application of neural methods in cosmology.

The use of such models and techniques allowed us to study problems related to: correlated signals in the long tail of the correlation functions for galaxies, clusters and superclusters (due to baryon oscillations); HD simulations of the LSS and of the evolution of the first and secondary Web structures; studies of the epochs of the formation of DM halos in a LCDM scenario (earlier than $z \sim 15$); studies of the evolution of halos and galaxies due to the parental merging phenomena; decelation of the Butcher-Oemler and Oemler-Butcher effects in far or nearby clusters; studies of E+A galaxies; study of the synthetic spectra of galaxies and of the chemo-spectro-photometrical evolution of galaxies (for $z<30$); photometric redshifts determination (for $z<10$).

The observational study of variable stars and their theoretical modeling represents the scientific framework for the three groups from Bucharest, Cluj-Napoca and Timisoara. The main directions of investigation are focused on the observation and the light-curve analysis of eclipsing binary stars and Delta Scuti, RR Lyrae and Delta Cephei type stars, in order to determine their elements and evolutionary status. It is also built up a relevant data base for several types of variable stars, including close binaries, eclipsing binaries, interacting binary stars, late-type active stars, early-type O-B stars. Other important directions of research are represented by the studies on stellar evolution, stellar pulsations, asteroseismology and searching of extrasolar planets, especially in the frame of the HELLAS and KASC Consortium and ESA/COROT, NASA/MOST, NASA/KEPLER space missions, in which we are actively involved. Important international collaborations in these fields were established with the Observatories of Paris-Meudon (France), Athens (Greece) and Belogradchik (Bulgaria).

Figure 18.1: *The Royal Observatory Greenwich in about 1900, showing the original building, Flamsteed House, on the right, and the Meridian Building in the centre. (Scan from a postcard in a private collection)*

18. The Royal Observatory, Greenwich, London: Presenting a Small Observatory Site to the Public

Gloria Clifton (Greenwich, UK)

When a working observatory is turned into a museum many potentially conflicting issues have to be addressed. The aim of this paper is to examine the problems which arose at the Royal Observatory, Greenwich, in London, and the various efforts made to resolve them. A brief historical introduction will set the scene, followed by an examination of the initial process of turning the Observatory into a museum, including the aims and criteria which guided the decisions made about what should be preserved and what was dispensable. The final section will deal with the challenges presented by growing visitor numbers and changing views about the purpose of scientific museums.

18.1 Historical Introduction

The Royal Observatory, Greenwich, was created in 1675 on the order of the king at that time, Charles II. Greenwich was chosen partly because it was royal land, and it remains a royal park to this day. The initial purpose of the Observatory was to provide more accurate methods of navigation and specifically to devise a practical way of finding longitude at sea from astronomical observations. Buildings and telescopes were added over the years and sometimes destroyed to make way for better ones. The original Observatory building was designed by one of the leading architects of the time, Sir Christopher Wren, who was also responsible for St Paul's Cathedral and many other churches in London, as well as the general oversight of the rebuilding of the City after the Great Fire of 1666. This first building later became known as Flamsteed House, after the first Astronomer Royal, John Flamsteed, who moved in when it was completed in 1676. However, his main observing instruments were in a separate small outhouse in the garden. This was added to by subsequent Astronomers Royal, until there was an extensive range of structures housing the telescopes, usually referred to now as the Meridian Building (see Fig. 18.1).[1]

The Observatory's original objective was achieved in 1766 when the fifth Astronomer Royal, Nevil Maskelyne, produced the first Nautical Almanac, with tables for 1767.[2] This provided all the information needed to find longitude by the so-called lunar distance method, which involved using a sextant to measure the angle between the Moon and a bright star or the Sun, and then undertaking a lengthy series of calculations to convert these measurements into longitude. Just a few years earlier, in 1764, another method of finding longitude had been successfully tested. It used a very accurate watch invented by the Englishman, John Harrison. This second method relied on the fact that longitude and time are interchangeable, since one hour's difference in local time is equivalent to 15 degrees of longitude. Harrison's marine timekeeper was intended to keep the time of the home port or other reference meridian, such as that at Greenwich, and this could then be compared with local time from the Sun to find the current longitude of a ship at sea. Eventually, after further development by other makers, these very accurate timekeepers for navigational use came to be called chronometers. However, both these methods of finding longitude at sea created a continuing need for the Observatory, to produce the tables published in the Nautical Almanac. It also took on new responsibilities such as the testing of chronometers for the Admiralty and checking their time-keeping against astronomical observations. In turn, this led the Observatory to become involved in the production of accurate time signals, represented most visibly by the time ball on the roof of the Observatory, installed in 1833. Also during the nineteenth century the seventh Astronomer Royal, George Biddell Airy, began to conduct regular magnetic and meteorological measurements, and further buildings were constructed to house the necessary instruments. His aim was to improve the accuracy of astronomical measurements by making appropriate allowances for the effects of variations in the earth's magnetic field and in atmospheric conditions.

Later in the nineteenth century the Royal Observatory at Greenwich acquired an international as well as a national significance. At a conference in Washington, USA, in 1884 the Greenwich Meridian was adopted as the prime meridian of the world, which has given the Observatory an iconic status as the place where east meets west, and the starting point for the World's system of time zones.[3] By this date the astronomers were becoming increasingly involved in research astronomy to discover the size and structure of the universe, alongside the more practical work of providing accurate time and compiling the nautical almanacs required for astronavigation. This kind of investigation soon became known as astrophysics, to distinguish it from the traditional positional astronomy, which had been the main work of most national observatories until the later nineteenth century. The possibilities for such scientific research had been greatly extended by the application to astronomy of two new techniques: photography and spectroscopy. But the new work required larger telescopes and led to the building of a number of new domes at Greenwich, including the Great Equatorial building at the eastern end of the meridian building, which housed a large equatorial telescope, based on designs by the then Astronomer Royal, George Airy (see Fig. 18.2).

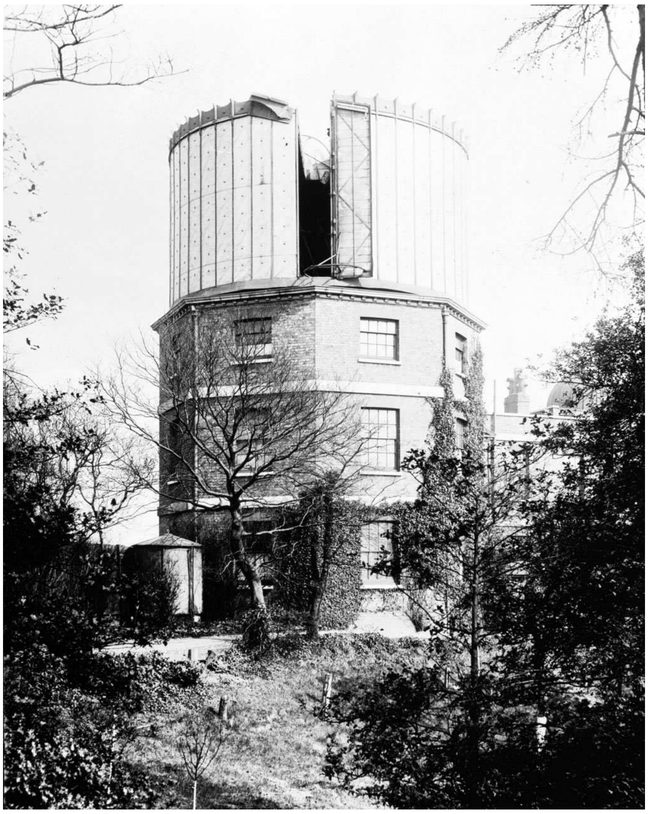

Figure 18.2: *The Great Equatorial Building, completed in 1857, showing the original drum-shaped dome (© National Maritime Museum, negative A9217)*

Astrophysics was enthusiastically taken up by Airy's successor, William Christie (1845–1922), who took up office in 1881.[4] He installed a larger refractor in the Great Equatorial Building to facilitate the Observatory's research work. The new instrument was designed by Howard Grubb of Dublin, with an objective lens 28 inches in diameter, or about 71 cm, much larger than that of the old telescope, made by Merz of Munich, which had an objective of 12.8 inches, or about 32.5 cm. The installation of the larger instrument meant replacing the old wooden drum-shaped dome by an onion shaped one, made of papier mâché by Thomas Cooke & Sons of York, to provide more space (the new dome can be seen on the left-hand side of Fig. 18.1). An additional dome was also added to the western end of the Meridian Building in 1890 to house a 13-inch (about 33 cm) astrographic telescope. The research work carried out in these new buildings had an international dimension, with the astronomers at Greenwich taking part in the 'Carte du Ciel' project, to provide a photographic map of the night sky.[5]

Christie then secured permission from the Admiralty to build a completely new Physical Observatory at the southern extremity of the site, consisting mainly of offices for the human computers who did the astronomical calculations, with a telescope dome on the top (Fig. 18.4). The new building incorporated a number of novel features; it was cruciform in shape with an iron framework and was designed by the architect, William Crisp, to be built in stages, so that the expense could be spread over several years. Work began in 1891 and was completed in 1899, the whole building being faced with decorative terracotta, incorporating the names of astronomers and telescope makers associated with Greenwich and a bust of Flamsteed above the main entrance. A small building in matching style was added a little to the north in 1899, to house a new altazimuth instrument, intended for the observation of the Moon, to support the Observatory's fundamental positional work.

One drawback of the construction of buildings with an iron framework was that the main Observatory grounds were no longer suitable for making magnetic observations, so Christie negotiated a new site within Greenwich Park, about 320 metres to the east, for a replacement magnetic pavilion. This became known as the Christie enclosure, but in 1923 it too became unsuitable for magnetic observations because of the electrification of the nearby Southern Railway. The magnetic work was then transferred to Abinger in Surrey, to the south-west of London, and the existing buildings in the Christie enclosure were demolished. In their place two new telescope domes were constructed to house a 36-inch Cassegrain reflector (91.4 cm) by Grubb & Parsons, installed in 1932, and a reversible transit circle by Cooke, Troughton and Simms, completed the following year.

However, during the first half of the twentieth century the observing conditions at Greenwich deteriorated markedly, with the expansion of London and its dust and smoke, the spread of electric street lighting and the construction of railway lines nearby. The decision was made in 1946 that the Royal Observatory should move from Greenwich to Herstmonceux Castle in rural Sussex, to the south of London, for clearer and darker skies away from the city. The astronomers left Greenwich in stages during the late 1940s and 1950s. In 1951 it was agreed that the old Observatory buildings would be transferred from the control of the Admiralty to the nearby National Maritime Museum, to become a historic site open to the public 'as an astronomical and navigational annexe'.[6] The Ministry of Works, a department of central government, took initial responsibility for the buildings, so that essential repairs could be made before they were handed over to the Maritime Museum, and decisions were made then about how to present the Observatory site as a

Figure 18.3: *Left: Flamsteed House in 1947. Right: Flamsteed House about 1957. (© National Maritime Museum, negative)*

Figure 18.4: *The new Physical Observatory at Greenwich, later known as the South Building (© National Maritime Museum, negative P39986)*

museum which would probably be more controversial today.

18.2 The Process of Turning the Observatory into a Museum

The first part of the Observatory opened to the public in 1953. This was the Octagon Room, the largest room in the Wren building of 1675–76, which still has the original decorative plasterwork on the ceiling. The rest of Flamsteed House followed in 1960, with a grand opening by the Queen, then the Meridian Building after the completion of repairs in 1967.

The philosophy which guided the refurbishment of the buildings for presentation to the public was that, as far as possible, they should be returned to the state they were in when used by the astronomers, and that the historical instruments should be restored to their original positions. None of Flamsteed's instruments could be traced; since he had provided them himself or been given them by patrons, they were considered to be his property, and they were sold by the family after his death. It was decided that a few of the most important examples would be represented by replicas, made using surviving drawings.[7] In addition, because the site was an awkward shape and had become cluttered with extra buildings and storerooms, some in a poor state of repair, it was decided to demolish many of the more recent and less important structures. The diagram in Fig. 18.5 shows these changes. The Ministry of Works was also keen to demolish the Physical Observatory, by then known as the South Building. The telescope formerly in the dome, the 30-inch equatorial, had been transferred to Herstmonceux in 1949 and the office accommodation was of no great historical interest. A senior Ministry official in 1957 described it as 'the ugliest of modern buildings' and added that demolishing it would be 'to the obvious benefit of the Park'.[8] However the National Maritime Museum started to use the building as a store and this ultimately preserved it as it was felt to be too useful to lose, as the museum was always short of storage space for reserve collections. A few years later the then Director of the National Maritime Museum, Frank Carr, inspired by a visit to the United States of America, decided to create a small planetarium, seating a maximum of 48 people, in the former telescope dome on the top of the South Building, and began offering shows to visitors in

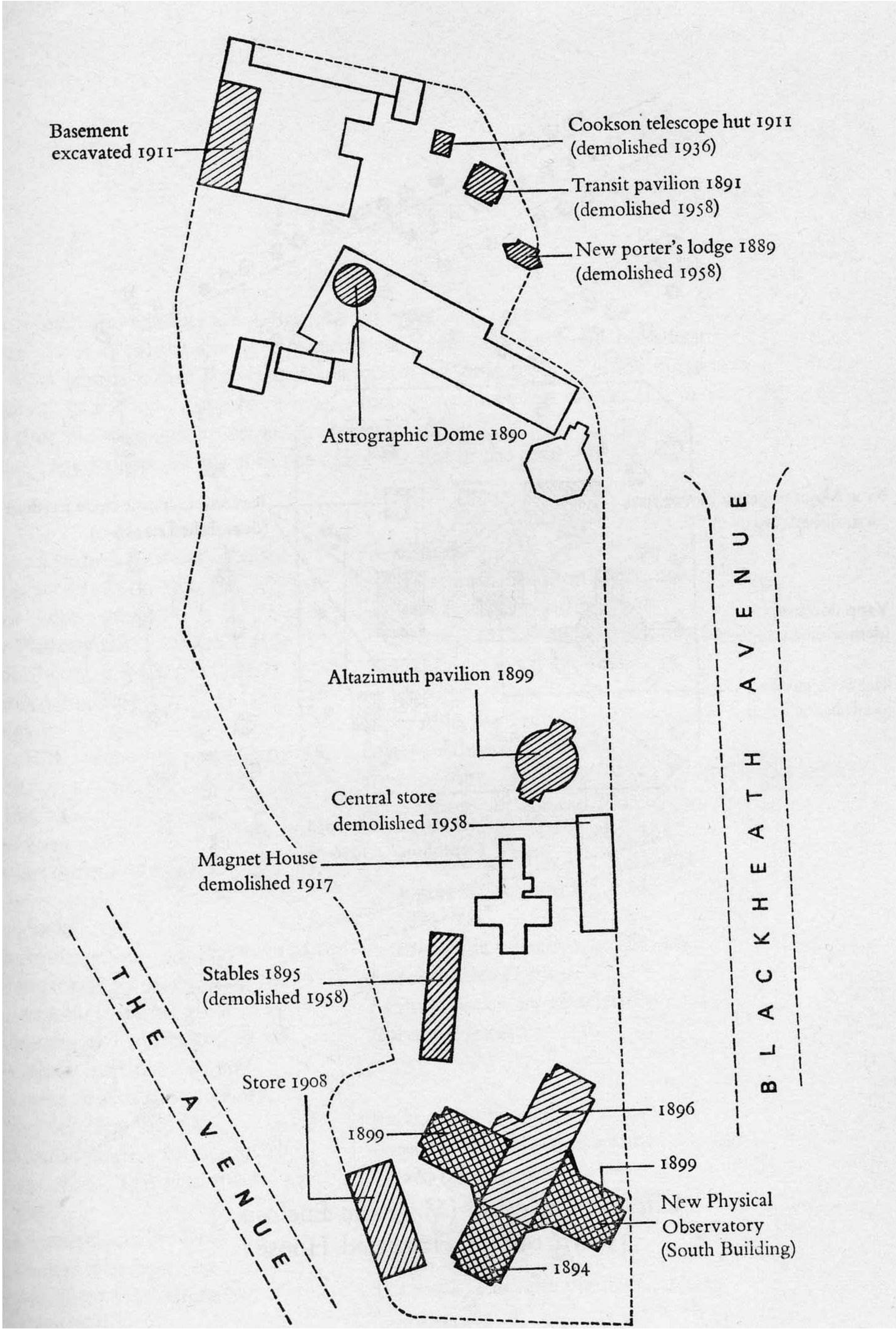

Figure 18.5: *Diagram showing the buildings demolished when the Royal Observatory, Greenwich, was turned into a museum (Source: Howse 1975, p. 165)*

1965.[9] In addition several of the rooms on the ground floor and in the basement were converted into picture restoration workshops.

Meanwhile work was proceeding slowly under the Ministry of Works to refurbish the old Observatory buildings and improve the site. Major repairs were needed because of damage during World War 2 caused by bombs falling nearby, although luckily there was no direct hit. However, general maintenance was also neglected during the war, when only a few staff remained and most Observatory functions had been transferred out of London for strategic reasons. The worst affected part was the Great Equatorial building, which had housed the 28-inch refractor. Fragments from a V2 rocket, which landed in Greenwich Park, set fire to the dome, which was especially vulnerable because of the papier-mâché from which it was made. Fortunately the telescope lens had been removed for safe keeping and eventually the whole instrument was moved to Herstmonceux and used there. The damaged dome was removed and a flat roof put in its place. Other essential repairs were carried out, especially to deal with dry rot, which had taken hold in the Meridian Building. There was also some disagreement between Carr, as museum director, and the Ministry of Public Building and Works (as it was then called), which was financing and directing the repairs. Carr wanted the Observatory to be a museum of astronomy, albeit with some emphasis on the links between astronomy and navigation, including retaining the historic telescopes which were no longer required by the astronomers and had been left in place during the move to Herstmonceux.[10] The Ministry took some effort to convince but it eventually agreed that the western part of the meridian building should be restored to its appearance in 1779, complete with the historic telescopes, and that the Airy transit circle, which defined the prime meridian, should be retained in its original position. Since the range of buildings housing the telescopes had developed piecemeal, it could not all be restored to the same date, so it was decided to return each part as closely as possible to its appearance at its principal period of use.[11]

A considerable amount of tidying also took place, removing many of the additions which had been made in the later nineteenth and twentieth centuries to Flamsteed House and the Meridian Building. Flamsteed House was largely restored to its late seventeenth century appearance, except that the eighteenth and early nineteenth century residential extensions were retained for use as galleries.[12] The external staircase, which had been added in 1849 to provide easier access to the meteorological instruments on the roof, was removed, as was the porch and covered way linking Flamsteed House and the Meridian Building (see Fig. 18.3.)[13]

However, in trying to turn back the clock in this way questions arose as to how far to go, and inevitably the final result was a site that appeared more architecturally coherent, but which did not actually look as it had done at any precise moment in its past. The focus on the earlier history of the Observatory meant that the physical evidence of some of the more recent work was completely removed. This obliteration of the recent past was further compounded by the fact that when the astronomers moved to Herstmonceux they took with them some of the late nineteenth and early twentieth century instruments. As well as the 28-inch refractor and 30-inch equatorial, both the 36-inch reflector and the reversible transit circle from the Christie enclosure were removed for use at the new observatory in Sussex, which was named the Royal Greenwich Observatory, with a change of word order to distinguish it from the original Royal Observatory, Greenwich. The historic buildings at Greenwich were renamed the Old Royal Observatory.[14] But all the structures in the Christie enclosure were completely demolished and the land once more became part of the park, leaving no physical trace of the aspects of the observatory's work once carried on there.

This more recent history was partly restored in the 1970s. By then the 28-inch telescope at Herstmonceux had been superseded by more up-to-date instruments and it was decided that it should be returned to its original home in the Old Royal Observatory at Greenwich. The telescope was placed back in its old position in the Great Equatorial Building in 1971 and a new dome was constructed over it, following the same design as the old one, but made of fibreglass rather than papier-mâché. The refurbished dome was opened to the public in 1975.

18.3 The Challenges Presented by Growing Visitor Numbers and Changing Views about the Purpose of Scientific Museums

It was found that growing numbers of visitors made many of the rooms very crowded at busy times and circulation around the site was increasingly difficult. In addition the old exhibits, with lots of historic instruments packed into showcases, were felt to lack appeal to a modern audiences, used to high standards of display in art galleries and even shops. Given that so many changes had been made to the Observatory, there were no strong objections when it was decided to undertake further alterations to the buildings in the early 1990s to improve access and to create spaces more suited to modern displays. The architects Stanton Williams were commissioned both to plan changes to the buildings to create a one-way flow around the site and to redesign the exhibition. They designed a new entrance area at the eastern end of the meridian building and a new shop on the ground floor of the Great Equatorial Building, which also formed the exit.

In 1997 World Heritage Site status was awarded to 'Maritime Greenwich' by UNESCO, including not only the Observatory and Maritime Museum, but also a large section of Greenwich town centre, including the Old

Figure 18.6: *Above: Aerial view of the Royal Observatory, Greenwich, in 2000. Below: Aerial view of the Royal Observatory, Greenwich, in 2007, showing the new planetarium building. (© National Maritime Museum, negative D9533–15-3, © National Maritime Museum, negative F7703-010)*

Royal Naval College, and Greenwich Park, which is still owned by the Crown. Since then the numbers of visitors to the Observatory have more than doubled, from about half a million to just over a million in 2007. This created new challenges in terms both of public expectation and of managing increased numbers of people on a small site.

The refurbishment of the early 1990s had originally been intended to include the South Building, and it had been suggested that it should become a space centre, featuring the exploration of space in the second half of the twentieth century. However the costs proved too great and that part of the project was abandoned for a while. It was revived in the late 1990s for a number of reasons. One was the growing demand from school groups for visits focusing on modern astronomy and space science. Another was the deteriorating state of the building itself, with a leaking roof, inefficient heating, and electrical and plumbing systems which needed renewal. A third reason for looking again at refurbishment of the building was recent legislation on disabled access. Both the Education room on the first floor and the planetarium in the dome at the top of the building could be reached only by a steep staircase.[15] Before undertaking any work on the South Building it was also decided to conduct some market research to discover what a range of visitors to the Observatory would most like to see. As well as simple questionnaires the research also made use of focus groups, including families, teachers and young adults.

This showed that there was a great interest in recent discoveries in astronomy and space missions, which strengthened the determination of the Museum's executive to combine repair of the South Building with the creation of a modern astronomy centre with interactive exhibits. The decision is principle was taken in 2001, subject to a satisfactory feasibility study.[16]

The government Department for Culture, Media and Sport provided a million pounds for the repair of the fabric of the building and a bid was made to the Heritage Lottery Fund for funding towards an astronomy centre with a new planetarium at ground level. This bid succeeded, backed up by the evidence from the market research, with the fund agreeing to provide £7.2 million. However, in discussions leading up to the submission, the managers of the Heritage Lottery Fund made it clear that they expected the whole site to present a coherent story, and so the bid included a plan to redisplay the galleries in the other buildings too. The Heritage Lottery Fund did not provide all the money and the museum also had to mount a general fund raising campaign to find the total sum of a little over £15.3 million.[17] Substantial amounts were granted by the Millennium Commission, Lloyd's Register Educational Trust, the Wolfson Foundation, and the Particle Physics and Astronomy Research Council. The planetarium equipment was financed by a private businessman, Peter Harrison, through his foundation, and the astronomy galleries were supported by the Weller Settlement Fund, along with many private individuals.[18]

Options for a new planetarium within the South Building were limited by the space available. Secondary schools often wanted to bring a whole year group, which would mean a planetarium which could seat at least a hundred people. In the end, after discussions with the architects appointed to oversee the project, Allies and Morrison, the decision was made to construct a completely new building in the garden. This had to be approved by English Heritage, which oversees alterations to buildings and sites which have been listed as being of historic importance. Given the many buildings which had come and gone over the years, a new structure could be seen as continuing this tradition, and English heritage was prepared to agree. The architects felt the new planetarium should be obviously modern, but in keeping with the older buildings. They were concerned that it should not overwhelm the historic site, so a substantial part of the new structure was out of sight below ground level; however it was felt that a shortened dome would look strange in the comparison with its neighbours, so the architects searched for an alternative but equally appropriate shape. It was eventually decided to give the structure a shape which has astronomical meaning, inspired by the ideas of the then Senior Astronomer at Greenwich, Dr Robin Catchpole. The building is basically an inclined cone shape, with the northern side cut off at an angle parallel to the celestial equator and covered by a mirror to reflect the northern half of the sky (Fig. 18.8). The angle of inclination is 51.5 degrees, the latitude of Greenwich. The overall effect is shown in the aerial views of the site before and after the construction of the planetarium building, Fig. 18.6.

At the same time there was a major internal rearrangement of the former South Building to create a new Astronomy Centre. The concrete pillar which had run up through the centre of the building to support the telescope in the dome at the top was removed, and replaced by a spiral staircase. The old stairwell was used to provide space for a lift. A café, shop and lavatories were built in the basement, and along with a lobby leading to the planetarium. On the first floor three new galleries were created to explain the most recent discoveries in astronomy. However, the curators were also keen to remind visitors that recent achievements have long roots, so examples of historical instruments and books, such as Isaac Newton's *Principia*, are displayed alongside the modern exhibits. The old telescope dome was turned into a library and seminar room.

18.4 Conclusions

Presenting a coherent story for a wide range of visitors in an institution which existed for nearly 300 years means choices have to be made about which parts of the story to tell. Much of the physical evidence for the twentieth century history of the Royal Observatory Greenwich was destroyed when the astronomers left, so this element of the story receives much less attention than

Figure 18.7: *The 28-inch telescope in use for a viewing session (© National Maritime Museum, image from Corporate Review 2004, p. 11)*

the important work carried out from the seventeenth to the nineteenth centuries. Providing a full chronological history may be easier in observatories where modern astronomical research continues on the same site, so that there is not the same physical separation between the historical telescopes and working astronomers.

Expectations of modern audiences and those providing funds inevitably shape the way the story is presented, and museums have to be ready to adapt as these demands change, if they are to interest large numbers of potential visitors and to secure funds to refurbish displays at regular intervals. In recent times the emphasis in the United Kingdom has been on encouraging young people to study science at university, so it has been easier to secure funds for displays and activities likely to interest them, rather than for purely historical exhibits. However, the new displays at Greenwich try to combine both, so that the dependence of today's scientists on the achievements of the past is made clear. Historical Observatories are well placed to provide this kind of balanced approach. Even though they are old, viewing the night sky though large telescopes is still an exciting experience (Fig. 18.7), which can capture the imagination of people of all ages.

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1. The account which follows is based largely on: Maunder 1900; Forbes, Meadows and Howse 1975; Howse 1997; Littlewood and Butler 1998, and Ronan 1975.
2. For Nevil Maskelyne see Howse 1989.
3. Smith 1976 p. 225–226.
4. William Christie became the eighth Astronomer Royal in 1881 and retired in 1910. See the Oxford Dictionary of National Biography 2004.
5. Forbes, Meadows and Howse 1975, Vol. 3, p. 11, 94–95.
6. Waters, Howse and Munday 1976, p. 253.
7. Howse 1966, p. 3–4.
8. Littlewood and Butler 1998, p. 177.
9. Littlewood and Butler 1998, p. 179–181.
10. Littlewood and Butler 1998, p. 155, 179–180. Carr 1957.
11. Waters, Howse and Munday 1976, p. 254.
12. Waters, Howse and Munday 1976, p. 253.
13. Howse 1975, p. 150–160, has a summary of the various changes made to buildings and instruments at Greenwich.
14. This name change was reversed after the abolition of the Royal Greenwich Observatory (RGO) in 1998, and the original site once again became known as the Royal Observatory Greenwich. In 1990 the RGO had moved from Herstmonceux to Cambridge. By then its main telescopes were in the Canary Islands, where observing conditions were so much better than in any part of the British Isles, and it was felt that its research work would benefit from closer collaboration with that being carried on in the universities. The ultimate logic of this was the integration of the researchers into the universities, which took place in 1998. The telescope domes at Herstmonceux have been taken over by a trust and are run as a science centre, and the remaining historic collections of books and artefacts were transferred to the National Maritime Museum. However the original archives remain in the University Library at Cambridge, partly because of they are part of a much broader scientific archive in that institution.
15. National Maritime Museum, documents submitted to the Heritage Lottery Fund, in folder GEN/21722.
16. National Maritime Museum Review 2001, p. 7.
17. National Maritime Museum file, NMM07/1448.
18. National Maritime Museum Review 2005 p. 11, 2006 p. 6, 32.

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Figure 18.8: *Detail of the new planetarium building by Allies and Morrison, 2007, and its position in relation to the South Building, housing the new Astronomy Centre (© National Maritime Museum, negative F6947–040)*

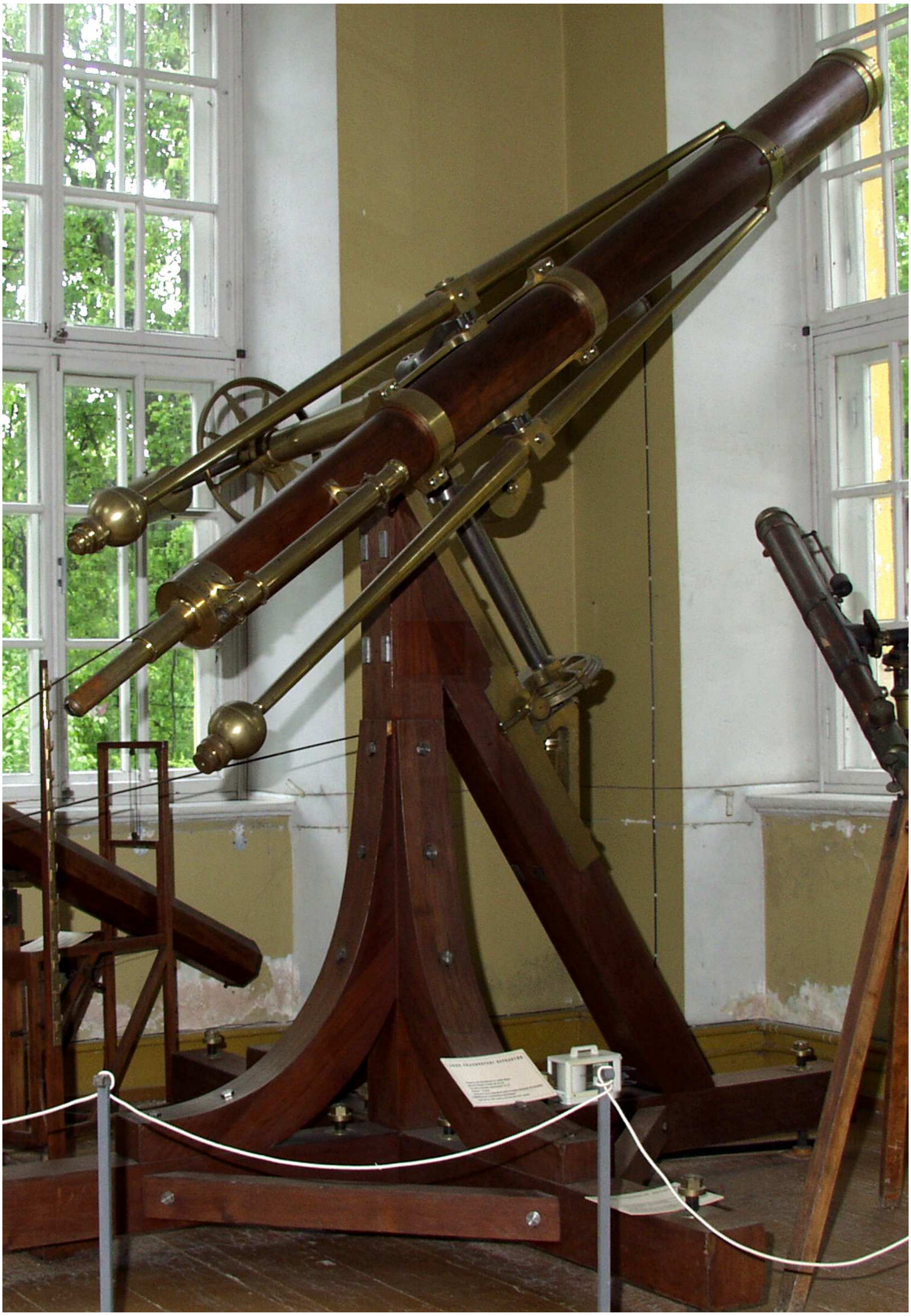

Figure 19.1: *The Fraunhofer refractor, Photo by Andres Tennus (University of Tartu)*

19. The Heritage of the 200-Year-Old University Observatory in Tartu

Reet Mägi (Tartu, Estonia)

Abstract

Tartu Observatory of the University of Tartu will soon celebrate its bicentenary. The observatory was completed in 1810 and soon became widely known as a research centre. In 1964, astronomers left it for a new location out of Tartu. Since then the main task of the old observatory has been to communicate information about astronomy and other sciences to the public. In 2005, the old observatory became a UNESCO World Heritage site as a point on Struve Geodetic Arc. Today, observatory buildings are in bad repair. Yet, a new era is about to dawn – plans have been completed to restore the observatory complex and to open it to the public as a museum. Indeed, the observatory is rich in heritage. The article at hand will give an overview of the material heritage of the Old Observatory of the University of Tartu in its historical context and describe its intended use as a museum. It will be a branch of the University of Tartu History Museum, a museum of science and of the history of the university that. The Museum holds a remarkable collection of historical scientific instruments used in the University of Tartu, including instruments of the observatory.[1] Although in the article the location of the observatory is referred by its current Estonian name of "Tartu", it should be mentioned that the observatory is internationally better known by its older German name – Dorpat Observatory – which was the official name of the observatory in the 19$^{\text{th}}$ century.

19.1 Observatory Buildings and the Observatory as an Institution – Development and Context

The design, construction and development of the ensemble of observatory buildings is closely linked to the history of the University of Tartu, and the history of science and society in general. The planned observatory museum will treat observatory buildings as a part of the overall heritage of the observatory.

The observatory was built in 1808–1810. It was part of a complex of university buildings. The observatory and the rest of the campus were built during the first decade of operation of the University of Tartu, which had just been reopened after having been closed for almost a century.[2] The buildings were designed by the university's architect Johann Wilhelm Krause. The ensemble has almost fully survived to the present day and most of its buildings have become symbolic of the city. The observatory was built on the Dome Hill not far from Town Hall in the city's central square. An anatomical theatre, a clinic and a library were erected in the vicinity of the observatory. The library was installed in the ruins of a medieval cathedral. Today, the same building houses the university's History Museum of which the observatory museum will be a branch. The main building of the university also forms part of this historical campus. All campus buildings share the same functional space – they are all linked by the park on the Dome Hill. The ensemble value of the campus has been stressed by historians of architecture as the reason for its powerful effect in the Tartu of today.[3]

The site where the observatory was erected is of special significance for the history of Tartu. Starting from the middle of the first millennium, that site had been occupied by a stronghold of ancient Estonians, which played an important role in the development of the town. The stronghold was conquered by the Kievan prince Yaroslav the Wise in 1030. Kievan troops were soon forced to leave Tartu, but mention of their conquest in a historical chronicle is considered the first reference to Tartu in historical records. Later, when German Brethren of the Sword captured Tartu in 1224, the bishop's castle was built on the site, and occupied it until the end of the 16$^{\text{th}}$ century.

The observatory complex consists of several buildings. The first building to be completed (by the end of 1810) was the observatory itself. The residence of the Head of the observatory was erected during 1819–1821. Later, the observatory was partly rebuilt and additional buildings were added to the complex. Each of these was dictated by the developments of science or the observatory's administrative or practical needs.

An important change in the observatory complex took place with the reconstruction of the main observation tower in 1825. The new shape was designed by Georg Friedrich Parrot, Rector of the university, and Friedrich Georg Wilhelm Struve, Head of the observatory. The

Figure 19.2: *The Observatory of Dorpat/Tartu (Lithography by W. Krüger, 1837) (University of Tartu Library)*

reason for the change was a Fraunhofer refractor that had been acquired by the observatory in 1824. The needs of the new instrument dictated a series of adjustments and structural changes in the tower. The original domed structure was replaced by a flat-top rotating tower with a balcony around it. The reconstructed observatory was quickly recognised as a model by its counterparts around Europe. Tartu Observatory served as one of the examples for designs for Helsinki University Observatory, which was completed in 1834. That observatory, in turn, provided the inspiration for Pulkovo Observatory (completed in 1839).[4] In addition to this indirect impact, the observatory of the University of Tartu can also be said to exerted an influence on Pulkovo Observatory through the person of F. G. W. Struve, Head of the observatory in Tartu, who was given the task of organising and launching the observatory in Pulkovo. The latter soon became world famous and came to serve as a model for a number of observatories in Europe and America.

In the end of the 19^{th} and in the beginning of the 20^{th} century, a smaller stone tower was added to the observatory complex, and two wooden observation pavilions were erected around the observatory. Thus, the trend towards a new type of observatory conceived as a complex of observation facilities can be seen taking shape on a modest scale in Tartu. After that, no more buildings were added to the complex and its later changes only concerned existing buildings.

Thus, in 1952, the observatory's West observation hall was rebuilt in two stories, and the old wooden staircase in the central part of the building was replaced by massive concrete one. The reconstruction resulted from the fact that more space was needed for observatory staff and that the meridian circle in the observatory's West Hall was not needed any longer. At that time the observatory was used by both astronomers and physicists, who at the time were affiliated to one and the same institute of the Academy of Sciences.[5]

Actually, the observatory had been considered too small already earlier, but plans to extend the complex, although they had been entertained as early as during Struve's days, had failed to be realized for one reason or another.

The need for additional office space and better conditions for observations resulted in the creation of a new observatory complex in the village of Tõravere, located 25 kilometers out of Tartu. In 1964, astronomers moved to the new location. The observatory archives and library was moved to the new location as well. From that time on, the observatory in Tartu is often called the 'old observatory' since the name "Tartu Observatory" was transferred to the new complex. With that, the main task of the observatory in Tartu changed from scientific research to that of presenting its heritage to the public.

19.2 Scientific Heritage – Achievements and Instruments

Several scientific discoveries made in the Old Observatory have remarkably broadened mankind's understanding of the physical universe. The work of Friedrich Wilhelm Struve, Johann Heinrich Mädler and Ernst Julius Öpik has been recorded in the history of world science[6] The generation of today's prominent astronomers exemplified by Dr. Jaan Einasto also started their careers in the old observatory.

The most famous person in the history of the observatory is Friedrich Georg Wilhelm Struve (born in 1793 in Altona, Denmark, today part of the German city of Hamburg) – died in 1864 in St. Petersburg, Russia). He started work in the observatory as an observer in 1813 after defending his doctoral thesis which was dedicated to determining the geographical coordinates of Tartu Observatory. In 1820 he became professor and was appointed Head of the observatory. Under his leadership, the observatory was equipped with state-of-the-art observation instruments. A most valuable piece of scientific equipment obtained during that period was a nine-inch Fraunhofer refractor, the largest and the most modern refractor in the world at the time. It was used in the tower until 1908, when it was replaced by a Zeiss refractor, and continued in use for a short time afterwards as well.

Figure 19.3: *Portrait of Friedrich Georg Wilhelm Struve, Lithography by G. F. Schlater (after E. Hauu), 1837 (University of Tartu Library)*

The Fraunhofer refractor, one of the most famous instruments in the history of astronomy, has been preserved in Tartu to date.

Struve used the Fraunhofer refractor with considerable success. He was able to compile a catalogue of double and multiple stars that is used to these days. He was also the first astronomer to measure the distance from the Earth to a star (the Vega) using the parallax method. The same was accomplished almost simultaneously by F. W. Bessel in Königsberg. This achievement of Struve's has been referred to as the apex in the scientific history of Tartu Observatory.[7] Struve also did some pioneering work in geodesy, arranging and carrying out the survey of a segment of a meridian arc stretching from Northern Norway to the Black Sea which today appears in UNESCO's World Heritage list as Struve Geodetic Arc.

Other large instruments that have been preserved from Struve's period include a transit instrument (Dollond, London, 1807) and a meridian circle (Reichenbach & Ertel Munich, 1822). The optical parts of both have been removed for use in other instruments. Tracing the story of these instruments is a good way of following scientific developments of the day and learning about the conditions that existed for scientific work during that period in Tartu.

Struve left Tartu for the new Imperial Observatory of Pulkovo in 1839. His departure was soon reflected in the observatory's equipment, which would never be as modern as during Struve's days. Nevertheless, the next Head of the observatory, Johann Heinrich Mädler (born in 1794 in Berlin, Prussia – died in 1874 in Hannover, Prussia) also holds an outstanding position in the history of science. Although his main achievements in selenography were made earlier in Berlin, where he published a large map of the surface of the Moon, it was in Tartu that he laid the foundations of what would later become known as stellar dynamics.[8] Collections of the History Museum of the University of Tartu include sixteen gypsum models of surface forms of the Moon from the Mädler's period as Head of the observatory in Tartu.

During the first period of the Estonian Republic (between World War I and World War II), the research at the observatory was galvanized by another pioneer of astronomy – Ernst Julius Öpik (born in 1895 in Kunda, Estonia – died in 1985 in Banor, Northern Ireland). His theories of stellar structure and evolution proved a decade ahead of generally accepted views held by astronomers.[9]

The history of the old observatory in Tartu has also experienced its failures and its periods of decline. The planned museum will tell these stories as well.

19.3 The Observatory as a Museum

In 1971, seven years after astronomers had moved out to their new facilities, the old observatory was opened

Figure 19.4: *Visitors in the observation tower of Tartu Observatory in 1963, University of Tartu Observatory in 2008, Photo by Andres Tennus (Tartu City Museum, University of Tartu)*

as a museum of astronomy. It was affiliated to Tartu City Museum. The museum's exhibition was located in the East Hall of the observatory building, which had escaped reconstruction and still preserved in its original layout. The most important object on display was the Fraunhofer refractor. During this period, astronomers performed supervised demonstration observations in the tower with a Zeiss refractor.

In 1996 the observatory was returned to the university and the astronomy museum was closed. In the same year, the Astronomy Club of the observatory was officially founded and continued organising observations, lectures and other events for those interested in astronomy as well as for the general public. Four years later, the Science Centre *Ahhaa* was accommodated on observatory premises and in the former residence of the Head of the observatory. The Science Centre was founded by the university[10] with the aim of raising awareness of science among the public and has been remarkably successful in its work. The Astronomy Club has continued its activities as well. In 2009, the Science Centre is expected to move to new facilities.

The buildings of the observatory complex have to date fallen into disrepair. The university has prepared a renovation project that foresees turning the complex into a museum. An application for financial support to carry out the project has been submitted to a programme financed from the Regional Development Fund of the European Union. In fact, a definitive approval has just come through in January 2009 in respect of the application, and work can now begin on the project. According to project schedule, the renovated observatory complex and the new museum will be opened in the beginning of 2011. The University and the University Museum will carry out the project in co-operation with the Astronomy Club, Tartu Observatory (the science institution in Tõravere), Tartu City Government and the Science Centre *Ahhaa*.

The underpinning concept of the museum is preservation of the heritage of the observatory, including its historical ambience, to the greatest extent possible. In the rooms that have been preserved in their original layout, traditional museum solutions will be avoided. The museum will tell a series of stories of which those about the period of the 19$^{\text{th}}$ century will be in the foreground. The stories will link facts about the building and the instruments and other objects in it to the history of scientific disciplines practiced in the observatory. This approach is similar to the one that has been outlined and advised for the musealization of Tapada da Ajuda, the Astronomical Observatory of Lisbon by a group of museum experts of which the author of this article has the privilege to be a member. In 2007, a meeting of UNIVERSEUM, the European university museums network was held in Lisbon, and some of the meeting's participants of which were invited to a workshop to discuss the possibilities of turning the Tapada da Ajuda observatory into a museum. The opinions of the participants were then developed further and published as an article.[11]

The museum in the old observatory in Tartu will show the history of the disciplines that have been practiced here – astronomy, geodesy, seismology and determination of time. Old furniture will be restored and used for storing and displaying instruments and books as they were stored and displayed in the heyday of the observatory. Small instruments that have been held in various storage facilities of the University History Museum because of inadequate security measures in the observatory, will be brought back to the observatory and exhibited. The most important instrument of the old observatory, the Fraunhofer refractor, will be exhibited, too. It is in rather good condition but still needs careful cleaning and slight restoration. The refractor was previously restored in 1993. The restoration was carried out under the supervision of Enno Ruusalepp who works in the new observatory in Tõravere. Restoration was considerably assisted by the international contacts of the astronomer and historian of astronomy Heino Eelsalu from the same institution. Indeed, support by colleagues from Germany was very important – for instance, Mr. Ruusalepp was trained at the *Deutsches Museum* (German Museum) in Munich. Special thanks for their kind help and cooperation are also due to Professor Dr. Gudrun Wolfschmidt and Mr. Ernst Ellinger, master technician of the *Deutches Museum*. Both Eelsalu and Ruusalepp have written about the restoration process, the former about its general background and the latter about particular restoration operations.[12]

A suitable microclimate must be ensured for historical instruments in the restored observatory. The most complicated problems that have to be tackled concern the Fraunhofer refractor. The current situation, in which considerable temperature and humidity swings take place in the observatory rooms daily, threatens the preservation of the instrument over a longer period of time. There are plans to start heating the room of the refractor so as to keep its climatic parameters constant. Architects and technical designers are faced with a difficult task of ensuring suitable conditions for the refractor, while avoiding the introduction of complicated technological solutions into the historical building.

19.4 Struve Geodetic Arc as World Heritage

The old observatory in Tartu belongs to UNESCO's list of world heritage as part of Struve Geodetic Arc. The arc runs through the observatory and a point on the arc is marked in the floor of the entrance hall of the observatory. The arc is a chain of triangulation survey points stretching from Northern Norway to the Black Sea. The survey was carried out in 1816–1855 under the leadership of F. G. W. Struve and Carl Tenner. The survey was of considerable importance for determining the shape and size of the Earth and represented an important step in the development of astronomy, geodesy and cartography. The arc was inscribed in UNESCO's

Figure 19.5: *The Fraunhofer refractor in the 1970s, Photo by E. Sakk (University of Tartu History Museum)*

list of world heritage in July 2005. There are two more points of the arc in Estonia, both of which are also on the world heritage list. A total of 34 preserved sites on Struve Geodetic Arc have been marked as world heritage. The survey actually involved 265 main points.

Struve Geodetic Arc has given rise to the first series of World Heritage nominations shared by a considerable number of countries – according to contemporary geography, the arc passes through ten countries (Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Belarus, Moldova, Ukraine). The national surveying agencies of these countries have cooperated since the beginning of the nomination process in 1994. The leading role in the process was played by the National Land Survey of Finland. Now, the countries have assumed principal responsibility for the points of the arc in their territory, but they still need to continue cooperation. The goal is to develop common rules and good practice in protecting, presenting and promoting the arc to the public.

The fact that the old observatory of the University of Tartu is included in the world heritage list is a great recognition to the heritage of the observatory. It adds both responsibility and motivation to preserve that heritage and keep the observatory open to the public.

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1. The other highlights of the collection are that of physics, chermistry and medicine. The Museum was founded in 1976. It is one of the three museums of the University of Tartu. The other museums – the Natural History Museum (1802) and the Art Museum (1803) are the oldest museums in Estonia.
2. The University of Tartu is the oldest and the only *universitas-type* university in Estonia. It was founded in 1632 as a Swedish university. The operation of the university was supended in 1710 due to the Great Northern War. The university was reopened in 1802, soon becoming a Russian imperial university, although for the most part of the 19$^{\text{th}}$ century it remained intellectually a German institution.
3. Maiste, Polli, Raisma 2003, p. 177.
4. Markkanen, Linnaluoto, Poutanen 1984, p. 49 and pp. 58–60.
5. In the Soviet system, research and higher education were regarded as separate fields – institutes of the Adacemy of Sciences were expected to be leading in research, while universities had to act as providers of higher education as their primary task. In 1948, the old observatory of the University of Tartu was taken from the university and affiliated to the Academy of Sciences of the Estonian SSR.
6. Eelsalu 1999, p. 111.
7. Eelsalu 1999, pp. 116–117.
8. Eelsalu 1999, p. 116.
9. Einasto 2004, p. 64.
10. Since 2004, the Science Centre Ahhaa works as a foundation established by the University of Tartu, the City of Tartu and the Ministry for Education and Reseach.
11. Clercq et al. 2008.
12. Eelsalu 1999, p. 120; Ruusalepp and Pehk 1994.

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Figure 20.1: *Repsold meridian circle (La Plata Astronomical Observatory)*

20. La Plata Astronomical Observatory

Juan Carlos Forte and Sofia A. Cora (La Plata, Argentina)

Abstract

La Plata, the current capital city of the province of Buenos Aires, was founded on 19^{th} November 1882 by governor Dardo Rocha, and built on a very innovative design giving emphasis to the quality of the public space, official and educational buildings. The Astronomical Observatory was one of the first inhabitants of the main park of the city; its construction started in 1883 including two telescopes that ranked among the largest in the southern hemisphere at that time and also several instruments devoted to positional astronomy (e. g. a meridian circle and a zenith telescope). A dedicated effort has being invested during the last 15 years in order to recover some of the original instrumentation (kept in a small museum) as well as the distinctive architectural values. In 1905, the Observatory, the School of Agriculture and the Museum of Natural Sciences (one of the most important museums in South America) became part of the backbone of La Plata National University, an institution with a strong and distinctive profile in exact and natural sciences. The First School for Astronomy and Related Sciences had been harboured by the Observatory since 1935, and became the current Faculty of Astronomical and Geophysical Sciences in 1983. This last institution carries PhDs programs and also a number of teaching activities at different levels. These activities are the roots of a strong connection of the Observatory with the city.

20.1 Astronomical Observatory as one of the Founding Institutions of La Plata National University

La Plata National University (Universidad Nacional de La Plata) was created in 1905 by Joaquín V. González, who was Minister of Justice and National Public Education at that time. The *Astronomical Observatory* together with the Natural Sciences Museum and the Veterinary and Agronomy Faculty became the pillars of the National University. These relevant institutions gave the scientific profile, more oriented to natural and exact sciences. The institution began operations on 18^{th} April 1897 as the La Plata Provincial University (Universidad Provincial de La Plata) with Dr. Dardo Rocha as its Rector. In 1906, and after becoming a national university, Joaquín V. González, was appointed as the first Rector.

The university coat of arms was adopted at the first university assembly on 14^{th} February 1897. It represents the City of La Plata holding up the "Light of Science". The constellation of the Southern Cross is also featured as well as the coat of arms of the Province of Buenos Aires which is held in the hands of the woman who represents the city. The university emblem is the oak leaf, and its motto "Pro Scientia et Patria" is a Latin phrase meaning "For Science and the Motherland".

In chronological order, La Plata University is the third after Buenos Aires and Córdoba and is considered as one of the most prestigious of the country. Currently, it has fourteen colleges: Agrarian Sciences, Engineering, Liberal Arts, Law and Social Sciences, Veterinary, Exact Sciences, Medicine, Economic Sciences, Natural Sciences, Astronomical Sciences, Dentistry, Fine Arts, Architecture and Journalism.

The story tells that Joaquín V. González was impressed by the great comet that became very bright in September 1982 leading him to choose the Astronomical Observatory as one of the founding institutions of La Plata National University. In turn, La Plata, the capital city of the province of Buenos Aires, was founded by Governor Dardo Rocha (1838–1921) on 19^{th} November 1882. The construction of the Observatory was scheduled in a decree passed by on 7^{th} May 1881. In this decree, the Engineering Department was ordered to set up plans and a budget for several public buildings, including an Astronomical Observatory, relevant for the cartographic survey of the province.

La Plata city is widely known as the one of the best planned urban system of the 19^{th} century. Urban planner Pedro Benoit designed a city layout based on a rationalist conception of urban centers. The city has been conceived on three fundamental axes on which most public buildings are located. One is limited by 51^{st} and 53^{rd} avenues and the other two cross it in 7^{th} and 13^{th} avenues. The House of Government, the Provincial Legislature, the Municipal Palace and the Cathedral rank among the main buildings. The House of Government was projected by the Belgian architect Julio Doral. It has typical Renaissance style and is located opposite the Provincial Legislature on the other side of San Martín Square. The Provincial Legislature emerges on the inter-

Figure 20.2: *Areal view of the Observatory at the beginning of 20th century*

section of two of those axes on Plaza San Martín. It was designed by the German architects Gustav Heine and George H'agemann, from Hannover, who won the contest called by the provincial government in 1881. Carlos Nordman was the architect who directed the construction. The Municipal Palace is one of the most beautiful buildings in the city. It has German Renaissance style and it was designed by the German Architect Uberto Stier from Hannover School. The Cathedral of the Immaculate Conception, is one of the most characteristics symbols of La Plata. The style is Neogothic, with French influence. It was inspired by the cathedrals of Amiens (France) and Cologne (Germany), though smaller. The project was elaborated by the Department of Engineers led by Pedro Benoit.

The city Park is a great "lung" which still keeps a considerable area. The buildings that constitute a relevant part of this traditional park are the open air Martín Fierro theatre, the Zoo, The Natural Sciences Museum, and the Astronomical Observatory. As it already mentioned, the Natural Sciences Museum was one of the pillars of the National University. It is a great Greek-Romanic building, founded by Francisco P. Moreno in 1884. Moreno was the director for 20 years and placed it in the top international level, with about two million of classified pieces, a collection he contributed to gather in a significant way. It holds one of the most important paleontological and anthropological collections in South America.

20.2 The First Instrument

The 1882 transit of Venus in front of the Sun had influence in the decision of constructing an astronomical observatory and stimulated considerable efforts by astronomers from countries all around the world. 1st November 1881, a local commitee was designed to collaborate with the French mission from Paris Astronomical Observatory that would observe the phenomenon from our latitudes. With the aim of observing this event of worldwide attraction, the provincial government ordered an equatorial refracting telescope with 21.6 cm of aperture and 3.1 m of focal length made by Gautier House. This first instrument, acquired as part of the activities that promoted the creation of the Observatory, has been kept at the observatory of the amateur Argentinian Association of Astronomy Friends (Asociación Argentina de Amigos de la Astronomía) since 1942.

The budget for the construction of the public buildings, including the astronomical observatory, was accepted 18th October 1882. Thirteen months later, 22th November 1883, Francisco Beuf was designated *Director of the construction of the building*, thus becoming the first Director of the Institution. He was a lieutenant of the French army and director of the Naval Observatory of Toulon. Astronomers at La Plata, in fact, celebrate the creation of the Observatory on 22th November.

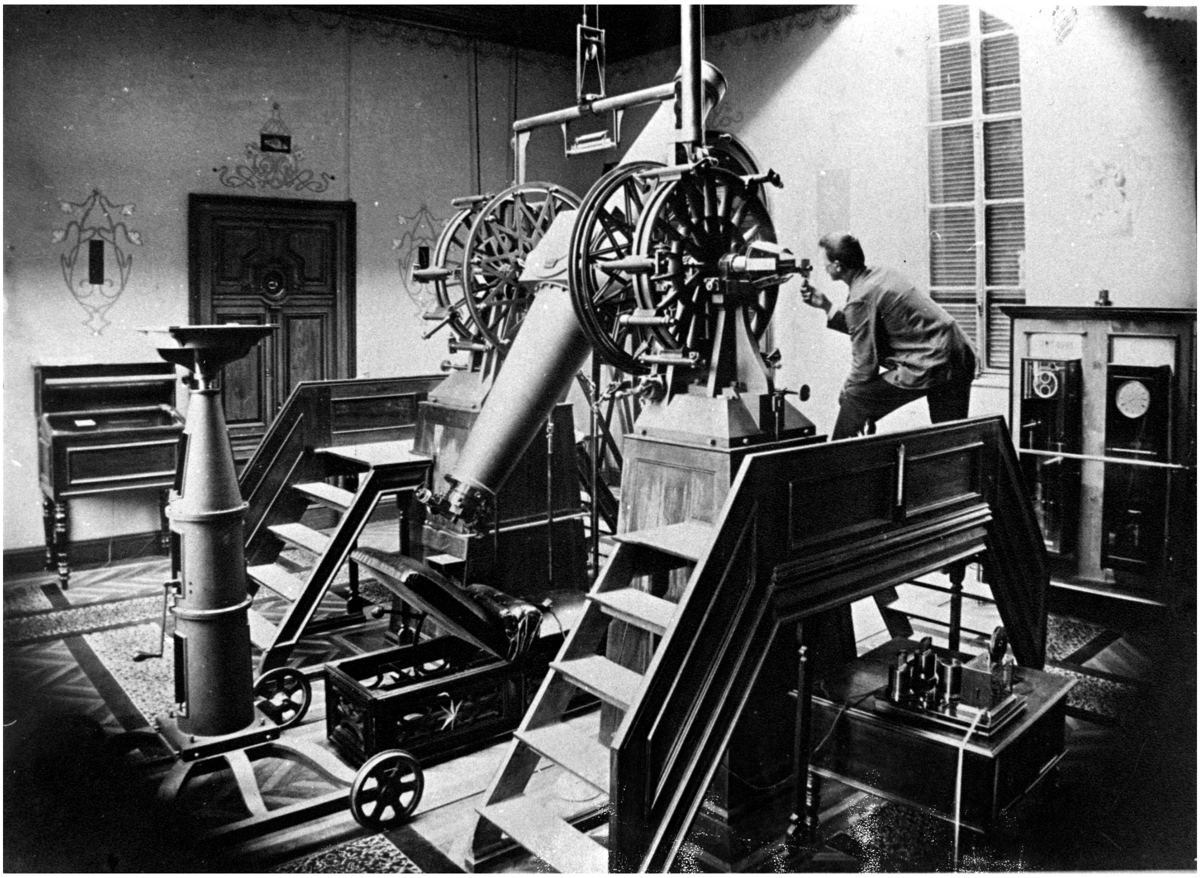

Figure 20.3: *Large Gautier meridian circle*

20.3 Instruments in the Period 1884–1890

In the period 1884–1890, during the Direction of Francisco Beuf (1883–1889), several telescopes were acquired: a Gautier zenith telescope, an astrograph, a Zeiss-Gautier reflector, a large Gautier equatorial refractor and a Gautier meridian circle. In the following, we describe the main characteristics of these instruments and their evolution, making a link to the different directors of the Observatory that contributed to build up its history and the development of Astrophysics in La Plata.

One of the purposes of the Observatory was the determination, by astronomical and geodetical observations, of the geographical positions of a sufficient number of places for the construction of an accurate map of the Province of Buenos Aires. By resolution of 17th March 1884, Director Beuf purchased two zenith telescopes of 8 cm of aperture and 80 cm of focal length from Paul Gautier of Paris. These instruments were installed in 1887 and 1888.

In April 1886, the purchase of a photographic refractor of 15 cm of aperture was intrusted to the care of Admiral Mouchez, Director of Paris Observatory. Admiral Mouchez suggested to buy a larger instrument, similar to others designed to carry out an important catalogue of stars covering practically the whole sky, known as *Cart du Ciel*.

The astrographic telescope arrived in August of 1890. During the administration of Director Francisco Porro Di Somenzi (1906–1910), a new objective from Carl Zeiss firm was acquired. It was set on the instrument in August 1913, thus obtaining the first astronomical pictures with this telescope. The objective has 34.2 cm of aperture and 3.42 m of focal length. Since then, photographic observations of asteroids and comets had been taking place at La Plata Observatory. This telescope worked till 1986, providing a large number of photographic plates. During those years, the observatory contributed made significant contributions to the accurate determination of positions of asteroids and comets. Several asteroids were discovered in that period, such as (965) Angélica, (1029) La Plata and (1254) Erfodia.

In April 1886, a reflector telescope of 80 cm of aperture was ordered from Paris Observatory. The instrument was assembled by Gautier and finished in 1887. The optical devices were provided by Paul and Prosper Henry. The original large mirror was finished in 1889. Several modifications have been introduced since 1921 such as a new mirror provided by the firm Zeiss of Jena, Germany, in 1930, changing from a Newtonian to a Cassegrain system. These improvements were done by Dr. Johannes Hartmann, a German Director of the Observatory in the period comprised between

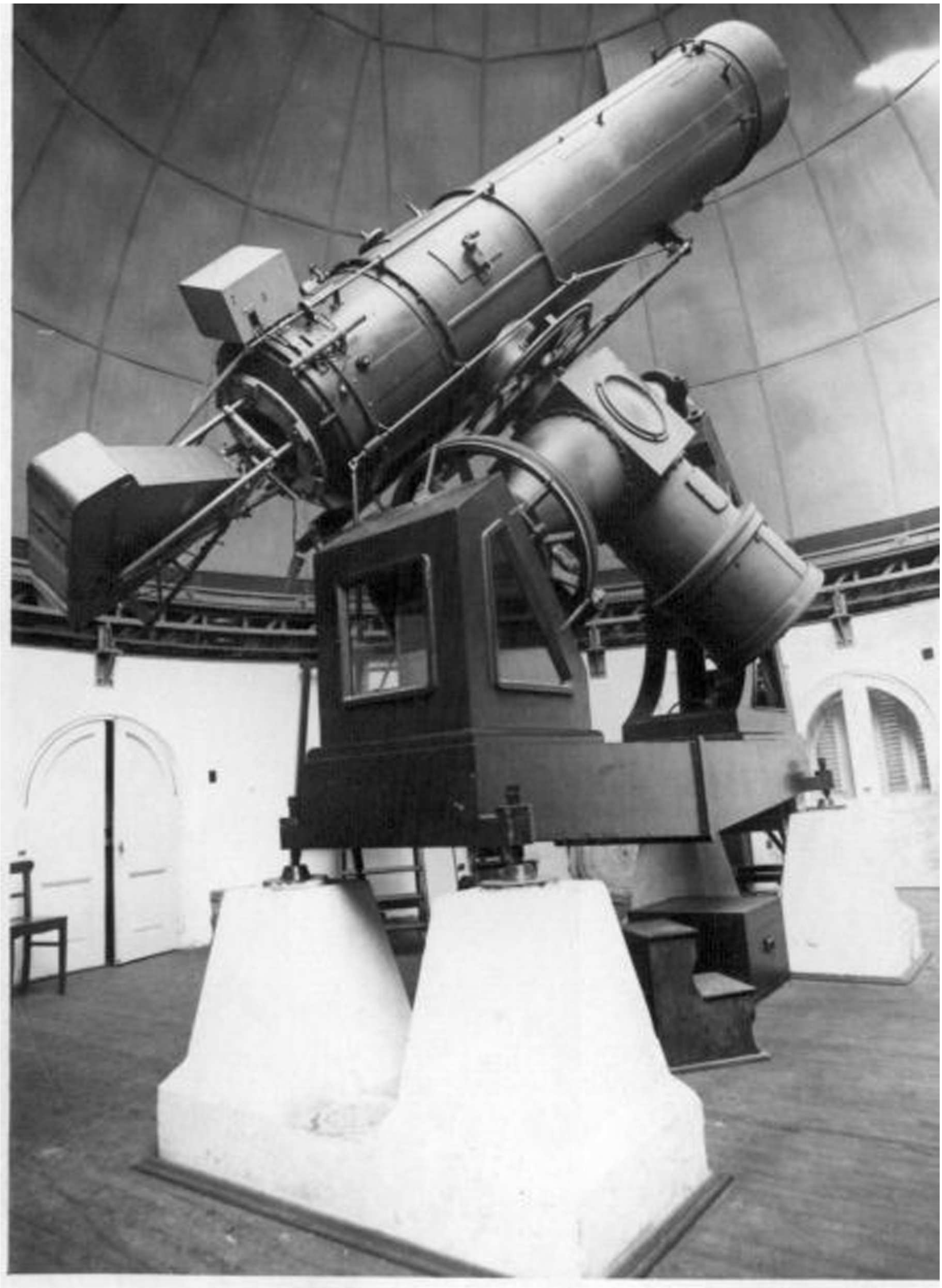

Figure 20.4: *Zeiss-Gautier reflector telescope*

1921 and 1934, who tried to promote the astrophysic and astrographic research activities. During this period, the asteroids Angélica, La Plata and Erfordia, already mentioned, were discovered and the programmes and observations of Eros and the Nova Pictoris were started. However, the instrument was not much used during this period. In 1954, several improvements were made by the mechanic Herbert Glinschert under the indications of Dr. Livio Gratton and during the direction of Guillermo O. Wallbrecher (1947–1955).

In April 1887, the acquisition of a refractor telescope of 43.3 cm of diameter and 9.6 m of focal length was approved. The assembly of this instrument was done by Gautier and finished in 1894. The optical devices of this large Gautier equatorial telescope were manufactured by Paul and Prosper Henry. Scientific research carried out with this instrument includes the observation of binary stars and asteroids and Mars opposition of 1956.

That same year, by resolution of 4$^{\text{th}}$ May 1887, the acquisition of a meridian circle refractor telescope was authorized. This instrument was designed by P. Gautier with the aim of being one of the largest and best telescopes of this kind in the world. The objective of this large meridian circle has 21.3 cm of aperture and 2.8 m of focal length (from the firm Henry Brothers). This telescope reached Buenos Aires in April 1890.

20.4 Instruments around 1906

In January, 1906, Dr. Francisco Porro di Somenzi was appointed Director of the Observatory and also became the first Dean of the Faculty of the Mathematical, Physical, and Astronomical Sciences that was created within the Observatory. Among the instruments obtained on Dr. Porro's initiative, was a Repsold meridian circle, a Zeiss comet-seeker, two Repsold transit instruments and Wanschaff zenith telescopes. We present now a brief description of the acquisition and main features of these instruments.

In October 1906, Director Porro placed an order with the celebrated firm A. Repsold & Son of Hamburg, for the construction of a large meridian circle. This instrument has a two-lens objective by Carl Zeiss, having 19 cm of aperture and 2.8 m of focal length. It was received in La Plata in May 1908. In 1932, the Director Johannes Hartmann lent the instrument to the Córdoba Astronomical Observatory, after having keeping it in its packing during a quarter of century. In 1934, during the Direction of Ing. Félix Aguilar (1934–1943), specialist in geodesy, the instrument returned to La Plata, replacing the large Gautier meridian circle in 1938.

While in Europe, and also in 1906, Director Porro ordered a comet-seeker to the well-known firm Carl Zeiss. The telescope has 20 cm of aperture and 1.38 m of focal length. It was with this instrument that astronomer Pablo T. Delavan on 26$^{\text{th}}$ September 1913, discovered the comet 1913d, an interesting discovery since it was the second apparition of Westphal's comet, 1852.

Two astronomical transit instruments were constructed by the house A. Repsold & Son of Hamburg, one of which was received in 1906 and the other in 1907. The objectives were made by Steinheil of Munich of 7.5 cm of aperture and 75 cm of focal length.

The zenith telescope was constructed by Julius Wanschaff, from Berlin. It is like all the zenith telescopes furnished by this maker for latitude observatories of the International Geodetical Association.

In 1945, Félix Aguilar proposed the construction of an astrometric station to better determine the position of circumpolar stars. It was established in Santa Cruz, in the south of the town Paso del Río La Leona, being the southernmost observatory at that time. The observations were done with the Repsold meridian circle.

20.5 Other Instruments

Among the instruments acquired in the two above mentioned periods, only the Zeiss-Gautier reflector telescope, the large Gautier equatorial refractor telescope and the Zeiss comet-seeker are currently in use, mainly for teaching activities aimed to the general public. The Zeiss-Gautier reflector telescope is also used with academic purposes, and some astronomical projects are carried out by both astronomers and undergraduate students. There is, however, a bigger reflector telescope of 2.15 m that was bought during the sixties thanks to the efforts of Dr. Jorge Sahade. It was installed in San Juan in 1986 and is currently used as a national facility.

A Mainka seismograph, a GPS system part a worldwide net, and a meteorological tower are also within the current equipment of the Observatory. Since the beginning of the 20$^{\text{th}}$ century, the institution has also had several clocks systems designed to provide accurate time to a number of different observing instruments.

20.6 Main Buildings Today

The Observatory extends over 7 ha area with 18 buildings, including domes and the small shelter for the Wanschaff telescope. The construction of these buildings started in 1885 and finished a decade later. Between 1885 and 1886, the small equatorial building and the east and west pavilions were built, and are used today as the Electronic and Astrometric Department, respectively. In 1889, the main building and the one hosting the Repsold meridian circle, that is currently used as a conference room, were finished. In 1891, the construction of the domes for the Zeiss-Gautier reflector telescope and the astrographic telescope were carried out. In turn, the building that host the Gautier equatorial refractor telescope was finished in 1895. The ground floor of this building became the Museum of Astronomy and Geophysics. This museum was created in May 1997 by the Astronomical and Geophysical Faculty (Facultad de Ciencias Astronómicas y Geofísicas), within the Web of Museums of La Plata National University. The main

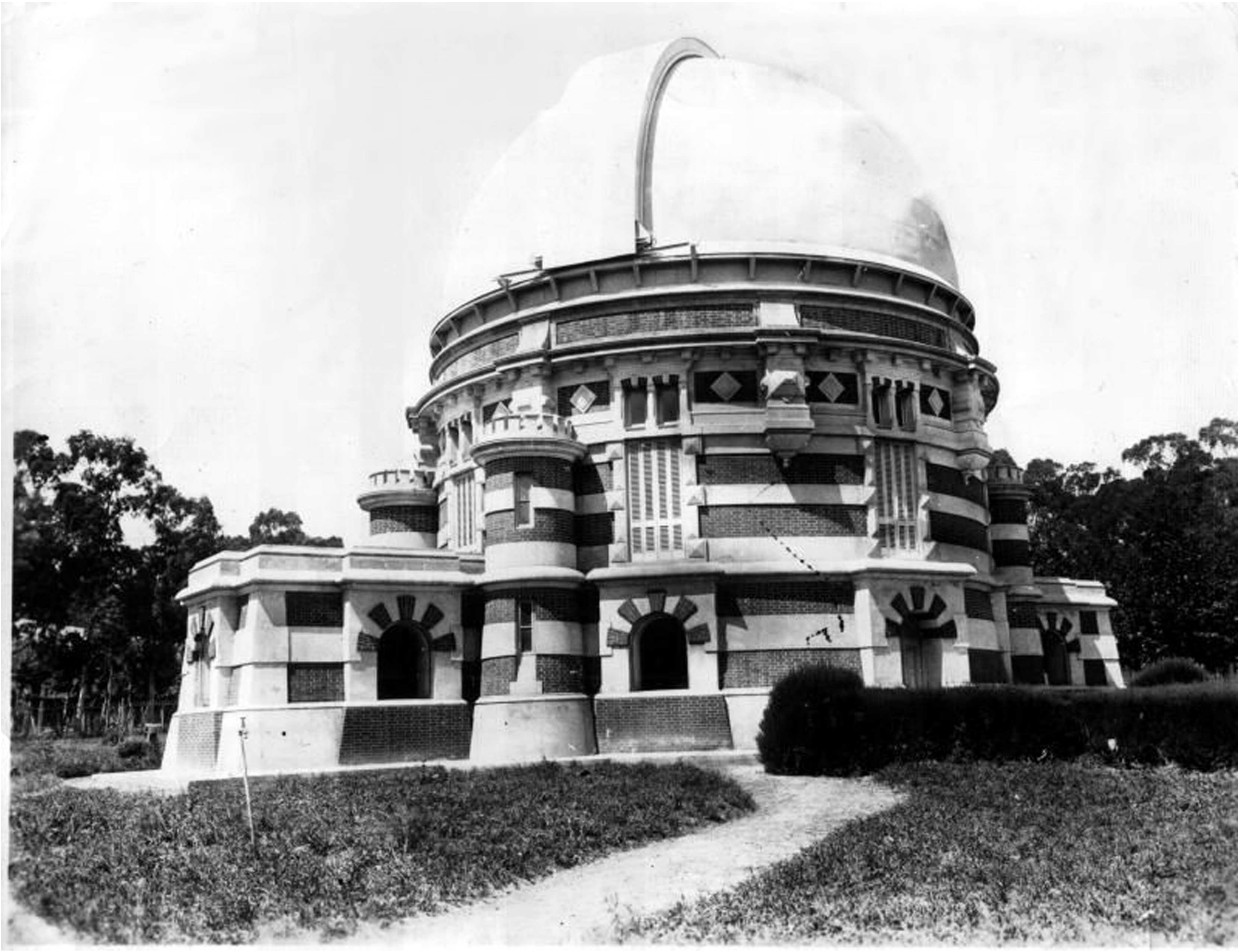

Figure 20.5: *Building that hosts the Gautier equatorial refractor telescope, where the Museum of Astronomy and Geophysics currently operates*

purposes of this museum are the restauration and conservation of the historical patrimony of the Observatory, mainly composed by the instruments acquired at the beginning of 20$^{\text{th}}$ century. For example, a Zeiss "blink microscope" for asteroids and variable stars research, as well as parts of the Repsold meridian circle and a photometric camera, among others.

The architectural style of these buildings are the same as those characterizing the main public buildings of La Plata city at the end of 19$^{\text{th}}$ century, most of them created by the Ingeneering Department, directed by Pedro Benoit.

20.7 Brief Description of the Main Building

The main building was originally used in part as the House of Directors. Contiguous to the current main entrance corridor, there is another one, that leads to the library, one of the most beautiful rooms of the observatory. The floor is made of heart pine and the room is equipped with a large size table. One of the objectives of the observatory, at the time of its foundation, was to make a cartographic survey of the Province of Buenos Aires and that table was used for spreading and unfolding the large charts the experts had to draw. Since the table is wider that the door of the library, it is believed that it was assembled inside this room. There is also an antique cast brass gas chandelier. There is not much information about the origins of this lamp that maintains its original shape. It has several ornate arms with etched lampshades. In the 1880s, there was no electrical wiring in La Plata, so this chandelier ran on gas, which circulated down from the ceiling through the pipe into the arms. The ceiling of the library is ornamented with carvings and a central rosette. In the corners, there are paintings of different telescopes that still remain at the Observatory. Important meetings took place at this library, like the Symposium on Stellar Evolution in 1960, organized by Dr. Jorge Sahade. Outstanding astronomers, like Carlos Jaschek, Maarten Schmidt, Allan Sandage, Margaret and Geoffrey Burbidge, Olin J. Eggen, Alex Feinstein and José Luis Sérsic attended that remarkable meeting. Currently, the library is frequently used for special events connected with the institutional life of the observatory.

Figure 20.6: *Current view of the main building*

Connected to the library is the Dean's office, where meetings of the Academic Board take place. Just outside of this room, in the external part of the building, there is a gallery with missing statues corresponding to famous astronomers, like Newton, Kepler and Galileo. The story tells that the statues were lost with the sinking of the ship that was bringing them to La Plata. In fact, and as recently found in old recovered documents, these statues were never bought because of budget reductions.

Many of the original rooms of the original building are currently offices occupied by scientists, engineers and the Observatory administration.

20.8 Concluding Remarks

The most significant restauration works that have been done include the buildings that host the Gautier refractor telescope and the Zeiss-Gautier reflector telescope, and the ceiling of the library. They were carried out by the architect Leonforte, and specialist of Fine Arts.

On the other hand, future projects involve the construction of a Planetarium within the park of the Observatory, that will contribute to enhance the profile of the City Park as a scientific and cultural circuit that will also include the Zoo and the Museum of Natural Sciences.

Regarding the academic aspects, Félix Aguilar promoted the creation of the Superior School on Astronomical and Related Sciences (Escuela Superior de Ciencias Astronómicas y Conexas) between 1934 and 1935. In 1948, the graduate course of Geophysics was created. Later, in 1983, these Schools merged into the current Faculty of Astronomical and Geophysical Sciences, being Ing. Pastor Sierra its first Dean. Both students and professors keep a deep connection with the historical past of the Observatory and there is a strong commitment to preserve the value of this unique cultural heritage.

Acknowledgements

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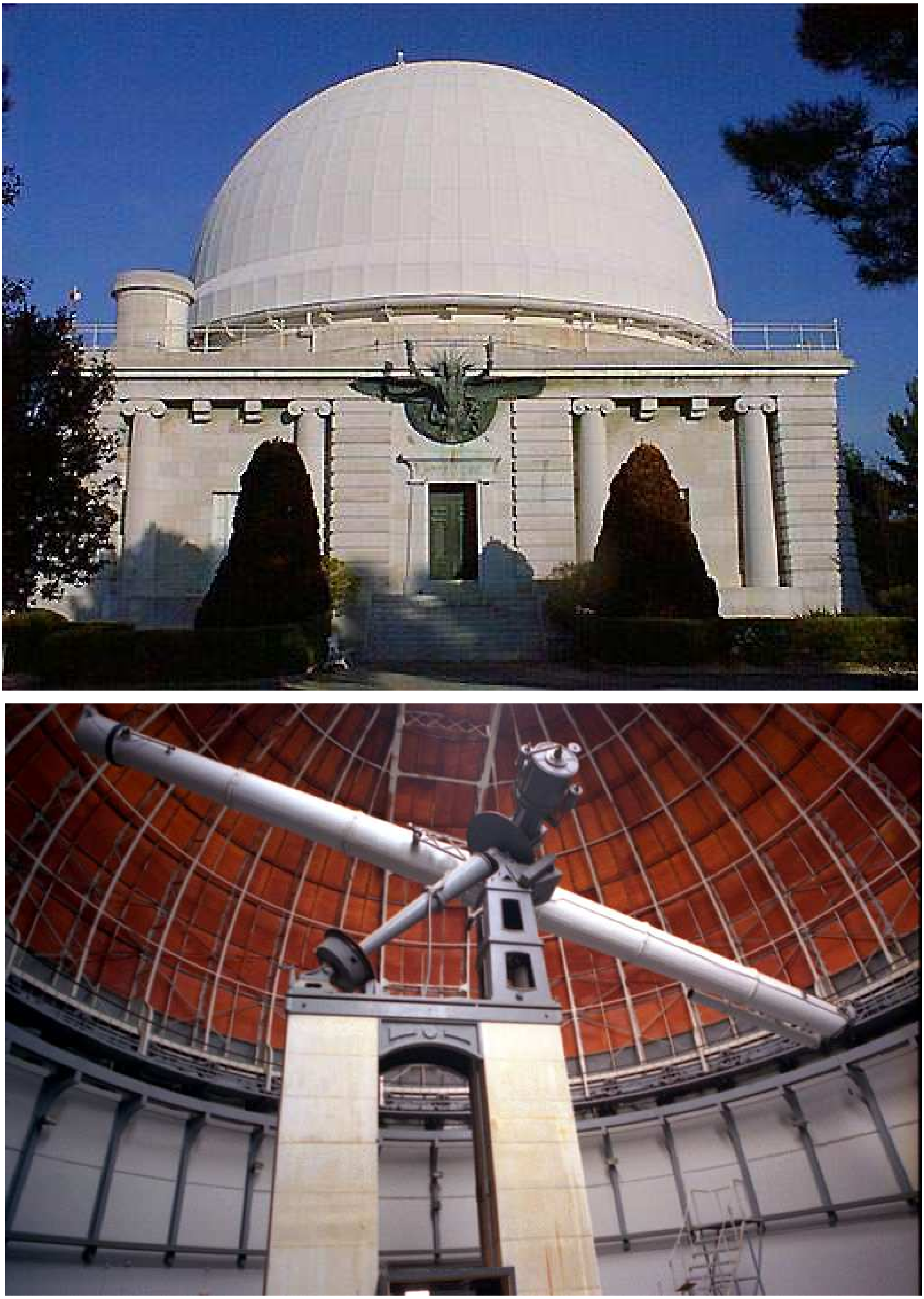

Figure 21.1: *Large refractor, Observatoire de Nice, donated by Raphaël Bischoffsheim (1823–1906) in 1887*

21. Astronomical Heritage Sites: Two Early "Mountain" Observatories on the Mediterranean Coast

Françoise Le Guet Tully (Nice, France) and Hamid Sadsaoud (Alger, Algeria)

Abstract

The number of French observatories increased significantly during the 1880s. Among the ten establishments in activity at that time, eight were on sites chosen because of their proximity with a faculté des sciences or with Paris, while the remaining two, Nice and Algiers, were installed on hills carefully chosen for their quality as astronomical sites.

We shall compare the scientific and political environments leading to the creation of these two observatories and describe their astronomical equipment and architectural designs. Since in both cases the original astronomical sites are still in activity as research institutes, we shall also evoke the present use of their astronomical heritage.

21.1 French Institutional Astronomy around 1880

At the death of Urbain Leverrier in 1877, French institutional astronomy consisted of only four establishments. Erected in 1667 at a small elevation just south of the city, the Paris observatory's monumental building had been criticised for its inconvenience by Cassini, its first director. Two centuries later, the surrounding land had been progressively built upon and observations were menaced by the industrial development of the city. The observatory of Marseilles, installed just above the port, had been officially founded in 1702. When in 1863 Paris Observatory received the first large mirror glass telescope ever made, the famous 80 cm Foucault telescope, Leverrier decided to install it under better skies and had it transferred to Marseilles after moving the old observatory from the port to a 7 m high flat hill called "plateau Longchamp". In 1841, the old Toulouse observatory had been reorganised by Arago and installed outside the city at an isolated place called Jolimont. In 1875 Jules Janssen had finally obtained from the government the creation of an observatory dedicated to astrophysics, which in 1879 was to be officially set up on a 180 m high hill at Meudon, in an ancient *château* burnt down in 1870 during the war with Prussia.

Soon after Leverrier's death, French institutional astronomy underwent important changes including an efficient policy of decentralisation: in 1878 new observatories were created in three cities having faculties of science – Besançon, Bordeaux and Lyons – bringing the number of institutional French observatories to seven.

A year later a private observatory, owned by the "grand amateur" astronomer Antoine d'Abbadie, was founded in Hendaye, and in the same year another private observatory was programmed on the French Mediterranean coast. For the first time in Europe a search for a site was organised in order to implement this new astronomical observatory. It led to the choice of a 375 m high "mountain" near the city of Nice. A tenth French observatory appeared in the early 1880s in Algiers when the outstation created by Leverrier in 1856 was installed in an excellent site overlooking the city very similar to the one of Nice and equipped with very good instruments.

In order to investigate the foundation of these two early "mountain" observatories, we shall first describe the context of the creation in 1846 of the Algiers meteorological outstation.

21.2 From the Crimean War to an Observatory in Algiers

Invented by Morse in 1838 in the USA, the electric telegraph was introduced in France in 1844. First of all it was reserved for the state, until in March 1851 the Prince-President Louis Napoléon Bonaparte, soon to become Emperor Napoléon III, allowed its public use. In November 1854, the shipwreck of the Henri-IV, one of his majesty's best war ships, occurred during a hurricane while fighting against the Imperial Russian fleet in the Black Sea. This led Leverrier, a friend of the Minister of War, Vaillant, to collect data about this disastrous meteorological phenomenon in order to study it. On February 16, 1855 – a day after another French war ship sank during a terrible storm between Corsica and Sardinia – Leverrier, who had become the director of Paris observatory in 1854, proposed to the Emperor the setting up a meteorological network based on the use of the telegraph for collecting data. Less than a year later, in January 1856, Leverrier decided to extend his network by creating a meteorological station in the *Lycée* at Algiers. Placed under the responsibility of Charles Simon (1825–1880), professor of mathematics and graduate from the *École normale supérieure*, this annex of Paris observatory was enlarged in December 1858 to include an astronomical station. However, its development was prevented by a few events that occurred between 1859 and 1861, among which the arrival of Charles Bulard (*1825) with a 33 cm Foucault telescope, the origin of which is unclear. Several changes in the Algerian administration led to no decision being taken regarding the choice of an astronomical site for installing the telescope and to the departure of Simon, who did not accept being placed under Bulard's authority. Although in 1861 Bulard obtained a second Foucault telescope, this time a 50 cm one, the French administration never acquired a proper site in Algiers nor did it really fund the astronomical station. As a result, from 1859 onwards Bulard did not achieve much apart from meteorological observations. Changes first occurred after the war with Prussia and the end of Napoleon III's regime. In 1872 a report recommended a professional astronomer to be sent to Algiers and a year later the observatory became administratively a State observatory similar to those of Marseilles and Toulouse.

In 1879, within the frame of the decentralisation of institutional astronomy set up after the death of Leverrier, the Ministry of Education agreed to fund a Southern observatory in order to benefit from a better climate than in Paris and in the other state observatories and also to challenge the British observatory that had been installed in Capetown as early as 1820. In the same year the French State created an *École supérieure des Sciences* at Algiers to which the observatory was attached. So that when in 1880 Charles Trépied (1845–1907), an astronomer trained in Paris by the *Bureau des longitudes*, was sent to Algiers, he became director of the observatory and taught astronomy at the newly founded *École supérieure*. With the help of a just one assistant, Charlemagne Rambaud (1857–1955), Trépied quickly moved Bulard's instruments from *"a hole next to a gasworks"* to a temporary 130 m high site called Kouba, situated North-East of the harbour, where he and Rambaud soon started to observe very actively. Awaiting for a definite site to be chosen and acquired.[1]

21.3 Towards Mountain Observatories

In the winter of 1852–1853, the grand British amateur astronomer William Lassell (1799–1880), discoverer in 1846 of Triton, the first satellite of Neptune, transferred his excellent self-built 24-inch (61 cm) reflecting telescope from Liverpool to Malta. As Allan Chapman puts it "Lassell's Malta expedition not only demonstrated the lavishness with which the Grand Amateurs went about their astronomy, but also opened the eyes of north European astronomers to what we now call 'prime sky locations' for big telescopes."[2] In 1856 Charles Piazzi-Smyth (1819–1900), Astronomer Royal for Scotland, made experimental observations with a 71-inch telescope on the Peak of Tenerife in order to test the astronomical advantages of a mountain station. The upshot of the expedition was to verify Newton's surmise, that "a serene and quiet air, pre-eminently-fit for astronomical observations, exist[ed] on the tops of the highest mountains above the grosser clouds."[3] Although Smyth did show the importance of suitable mountain sites for large instruments, his experiment was not followed up until 1868 when the AAAS meeting in Chicago took a resolution *"On the establishment of an Observatory on the Line of the Union Pacific Railroad"* which recommended *"to the attention of those who would make intelligent and munificent endowments of scientific institutions, the importance of an Astronomical Observatory at some point on the Pacific Railroad between Nebraska and the Pacific Coast, and at as high an altitude as possible, where the clearness of the atmosphere, and the great number of cloudless days, would ensure remarkable and unsurpassed opportunities for astronomical observations"*.[4] The first concrete attempt to follow the AAAS recommendations – the search for mountain sites with a clear atmosphere and many cloudless days – took place in the early 1870s when the Italian astronomer Pietro Tacchini (1838–1905), director of Palermo observatory and great observer of the Sun, suggested erecting an observatory on Mount Etna. Decided upon in 1876 and completed in 1882, the 2942 m high Mount Etna observatory could not however be used during the winter.[5]

The second attempt to follow these recommendations took place in 1875, when the summit of Mount Hamilton (1280 m) near San José (California) was recommended to James Lick (1796–1876) for implementing what was going to be the first permanent mountain observatory. Constructed between 1876 and 1887, it was also going to be equipped with *"the largest refractor in the world"*, superseding the one installed a few months earlier in Nice.

21.4 "Mountain" Observatories on the Mediterranean Coast

When at the beginning of 1879 Raphaël Bischoffsheim (1823–1906) let the *Bureau des longitudes* know about his wish to offer an astronomical observatory to French science, he mentioned immediately that it was to be installed on the Mediterranean coast, but did not say anything about altitude. Although not a scientist himself but the son of a successful banker, Bischoffsheim had during the previous years become acquainted with many scientists, especially with astronomers at Paris observatory and *Bureau des longitudes*. This was probably the result of his own tastes – born in Amsterdam in 1839, he had been sent to Paris to attend the *École Supérieure*

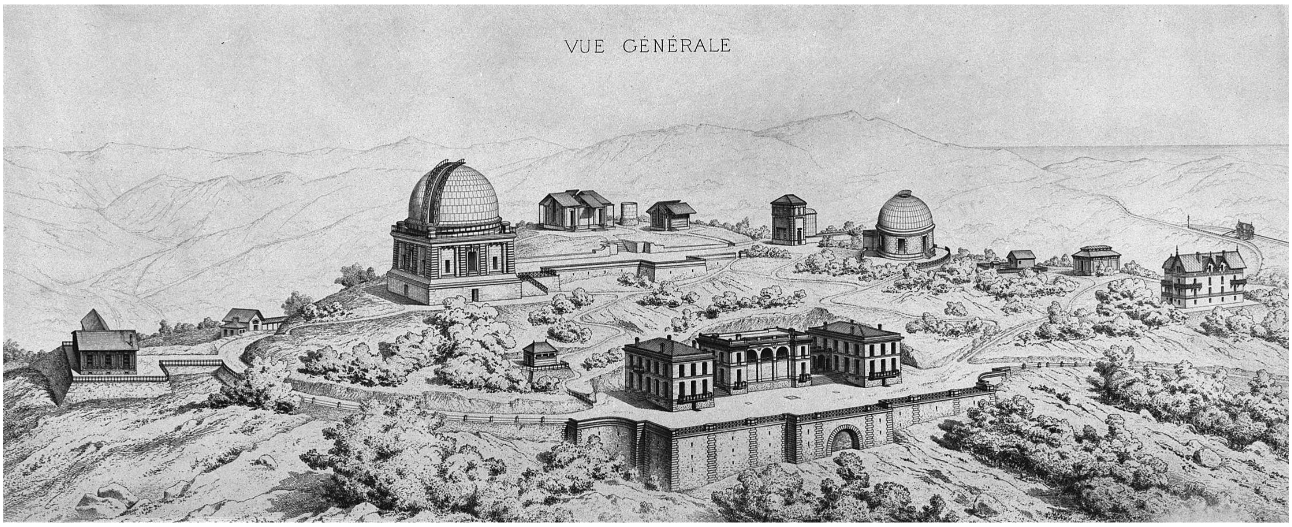

Figure 21.2: *Nice mountain observatory (1888) with the large dome by Gustave Eiffel. (Garnier, Charles: Monographie de l'Observatoire de Nice, 1892)*

des Arts et Métiers – and of the death of his father which occurred in 1872 and made him an extremely wealthy man. Already a patron for the observatories of Paris and Lyons, in 1879 Bischoffsheim was well aware of the situation of French astronomy and knew of the Lick project at Mount Hamilton.

Although the French State owned three historical observatories (Paris, Marseilles, Toulouse) as well as three new ones (Besançon, Bordeaux, Lyons), none of these was located under particularly clear skies. Furthermore, Janssen's astrophysical observatory, hardly out of limbo, was to be installed in Meudon in the vicinity of Paris and the new d'Abbadie's private observatory, intended for meridian observations only, in Hendaye on the Atlantic Coast, suffered from a fairly wet climate. As for the Southern observatory solicited from the Minister in Algiers, it still had no funding, no site and no astronomers.

Not only did French astronomy remain without good astronomical sites, but it also lacked large instruments, even at Paris observatory, which instrument-wise could no longer be considered a first class observatory. Despite Leverrier's long lasting efforts, the 74 cm (29-inch) refractor programmed as early as 1855 was far from being ready (it was going to be definitely abandoned in 1884)[6] and the 120 cm Foucault telescope that was installed in 1875 had a defective glass mirror.[7] The only large operational instrument was an excellent Eichens-Martin meridian circle, funded with Bischoffsheim's support, that had been installed in 1877 in the observatory gardens.

Meanwhile, in Europe and in the USA, a race to build *"the largest refractor in the world"* had begun. In 1869, Robert Newall (1812–1889), a Scottish manufacturer who successfully developed transatlantic telegraph cables, ordered from the York instrument maker Thomas Cooke (1807–1868) a 25-inch refractor which he installed in 1869 in his property at Gateshead (Durham). Not used very much by Newall, this magnificent instrument was given by his son to Cambridge university in 1889 and from then to Athens observatory in the 1955. In 1873 the US national observatory (USNO), settled in Foggy Bottom district near the Potomac river in 1844, installed the *"largest refractor in the world"*, a 26-inch (66 cm) by Clark that was moved to the USNO new location on Massachusetts Avenue in 1893 and is still in use today.[8] In 1875 the Austro-Hungarian Government ordered from Grubb in Dublin a 27-inch refractor (69 cm): completed in 1881 it was to be installed at the new Vienna observatory in 1882. Meanwhile, in 1879, the new Strasbourg German observatory installed a 19-inch refractor ordered from Repsold (Hamburg) and Merz (Munich) that, though not the largest in the world, was the largest in the German Empire.

When in February 1879 Bischoffsheim made his offer to the *Bureau des longitudes*, he knew that the new observatory he proposed was to be installed under clear skies and equipped with an instrument at least as powerful as the largest ones just mentioned.[9] Once the three scientists who were quickly sent by the *Bureau des longitudes* to search for a site on the Mediterranean coast had proposed the top of a 375 m high hill near Nice called Mont-Gros, Bischoffsheim's observatory would be the first permanent " mountain" observatory in Europe. And when in the early 1880s, Trépied looked for a permanent place in Algiers for setting up the French Southern observatory, he led the Ministry of Education to acquire the top of an almost 400 m high "mountain" west of the city.

21.5 The Nice Astronomical Adventure

Although the new observatory would never have existed had it not been for its rich patron Bischoffsheim, son of a banker and friend of scientists, another person played a very important role in its creation: Bischoffsheim's "messenger", the French-Austrian astronomer Maurice Lœwy (1833–1907), who was born in Vienna and studied at the Polytechnisches Institut before taking a position in 1856 as assistant at the Imperial observatory. Brilliant but prevented from entering an academic career in Vienna because of the regulations applied to Jewish people at that time, he accepted the invitation from the Paris observatory director, Leverrier. He arrived in 1860, acquired French nationality in 1867 and spent the rest of his life at Paris observatory, where he ended his career as its director. Having invented a new instrument in 1871 – the coudé refractor – he had obtained Bischoffsheim's financial support to build a prototype, but due to extreme turmoil within the national observatory, the making of this first coudé had been postponed. When, after the death of Leverrier, Mouchez (1821–1892) became director with Lœwy as *directeur-adjoint* and official representative of astronomy with the Ministry, scientific projects with Bischoffsheim's support were (re)activated: the patron offered the new Lyons observatory its first instrument, a good Eichens meridian circle similar to the Parisian one although with a slightly smaller objective lens, and the making of the coudé prototype was finally launched. At the same time Bischoffsheim asked Lœwy to be his messenger at the Bureau des longitudes where it is recorded that on 12 February 1879:

"Mr Lœwy informs the Board that Mr Bischoffsheim intends to found an observatory on the border of France near Menton and that he wishes this establishment to be put under the patronage of the Board of Longitudes."[10]

Meant to be a model, the new French observatory was to be directly inspired by the observatory that the famous German astronomer Wilhelm Struve (1793–1864) had set up for the Russian tsar Nicholas I forty years earlier. As in Pulkovo, an elevated and isolated site was to be carefully chosen, the commission for a monumental architecture was to be given to a famous architect, the scientific and the non scientific buildings were to be organised separately, the best available instruments were to be ordered, the library was to be richly funded and the new observatory was to be equipped with *"the largest refractor in the world"*. While Struve had had a very limited choice of elevated places in the vicinity of Saint-Petersburg – the Pulkovo 75 m high hill was the only one in the South of the city – Lœwy and his Parisian colleagues launched a real astronomical site search on the Mediterranean coast before selecting an excellent 375 m high "mountain" in the vicinity of Nice, a city with clear skies annexed to France in 1860.

As regards the architect, Bischoffsheim chose Charles Garnier (1825–1898), whose Opera house in Paris had been inaugurated in 1875 and from whom Bischoffsheim had ordered a prestigious house in Bordighera.[11] Famous since 1861, the year he won the competition for the new Paris Opera house, Garnier received from Bischoffsheim the exceptional commission of conceiving and realizing a model observatory for French astronomers[12].

As regards the instruments, their specifications were established by the Parisian astronomers and Henri Perrotin (1845–1904) – an astronomer trained at Toulouse observatory under the young and brilliant Félix Tisserand (1845–1896) who, after having passed his PhD in Paris in 1879, had accepted to become Nice observatory first director – and Bischoffsheim ordered them from the best makers of the time: the Henry brothers for the optical parts, Paul Gautier and the Brunners for the mechanical parts.

21.6 A Twin Observatory at Algiers

Work on the Mont-Gros started in 1881, the year the Algiers observatory – mainly devoted to observations because placed under more Southern skies and a more favourable climate than any other French observatory – started to be funded by the Ministry of Education. Naturally, this second "mountain" observatory was greatly inspired by the "model" observatory being erected at the same time on the northern side of the Mediterranean Sea. Although it was funded by the State and not by a rich patron, not only was it situatd like the one at Nice in an excellent "mountain"-like site, but its was commissioned to Jules Voinot (∼1855–1913), architect for the Government, who with Trépied visited several times the Garnier building site in Nice. No wonder that the design of the astronomical site and the architecture of the main building – hosting a rich library and accommodation for the director – are very similar on both sides of the Mediterranean coast.

As regards the astronomical instruments, Algiers observatory was better endowed than any of the other French State observatories and – apart from a giant refractor – it had no need to envy any of Nice's equipment. While Nice was to be equipped with a large meridian circle, a portable one, a 15-inch refractor, a coudé (Lœwy system) refractor, Algiers was to going to acquire a large meridian circle, a coudé refractor, a *Carte du ciel* astrograph, as well as a horizontal refractor for spectroscopy. Moreover, not only did Trépied move from the previous setting a small portable meridian circle, but also the famous 50 cm Foucault telescope that Bulard had obtained. This most powerful instrument was going to be housed under an elegant dome built at the centre of the domain while in Nice the *"largest refractor in the world"* was to be sheltered within Garnier's monumental Egyptian base, on top of which was placed a 24 m floating dome – *"the largest rotating dome that had ever been constructed"*.[13] – conceived by Gustave Eiffel (1832–1823) a few years before his famous tower was erected.[14]

1. See Le Guet Tully, Sadsaoud and Heller: "La création de l'observatoire d'Alger." In: *La Revue, Musée des Arts et Métiers* n° 38 (2003), p. 26–35.
2. `http://www.mikeoates.org/lassell/lassell\_by\_a\_chapman.htm` (Nov. 2009).
3. `http://books.google.fr/books?id=TmsPAAAAYAAJ\&printsec=frontcover\&dq=piazzi+smyth+t\`

'{e}n\'{e}riffe\#v=onepage\&q=newton\&f=false, p. 436.

4. http://archives.aaas.org/docs/resolutions.php?doc_id=444.
5. This led to the creation in 1880 in Catania of a *succursale cittadina* that, due to the working difficulties on Mount Etna and the bad choice of its location near the central crater, became within a few years the main station and the first Italian astrophysical observatory.
6. Firstly its construction suffered from a succession of delays, then it was found out that Paris observatory had been built on ancient careers that prevented the installation of the solid foundations necessitated by such a large instrument.
7. Foucault had not been able to achieve it before his premature death at 48 in 1868.
8. Built by Alvan Clark & Sons, an establishment founded in 1846.
9. That same year, Otto Struve (1819–1905) ordered a 30-inch lens from Clark in order to equip for Pulkovo observatory once again with the *"largest refractor in the world"*. As a result, Nice large instrument was to be also a 30-inch, but a with a focal length of 18 m instead of the 16 m of the Pulkovo objective lens.
10. "M. Lœwy fait part au Bureau que M. Bischoffsheim a l'intention de fonder un observatoire sur la frontière de France près de Menton et témoigne le désir que cet établissement soit mis sous les auspices du Bureau des Longitudes."
11. A small village on the Italian Riviera, not far from the French border, where Garnier himself spent part of the winters with his family and artist friends in a villa he had built in 1873.
12. State or private observatories were usually commissioned to renowned architects: in the 1860s, Henri Espérandieu at Marseilles, in the 1870s, Hermann Eggert at Strasbourg (Germany), Abraham Hirsch at Lyons, Eugène Viollet-le-Duc (1814–1879) at Hendaye (for d'Abbadie), Léon Ferrand at Bordeaux, in the 1880s, Etienne-Bernard Saint-Ginest at Besançon, Jules Voinot at Algiers, Thomas Fitte at Toulouse.
13. http://adsabs.harvard.edu/full/1886AReg...24..279.
14. Garnier, who sat on many official committees, took part at the beginning of the 1880s in the one examining the competitive tenders made for the making of an unusually large dome for housing the large refractor planned at Paris observatory. He got to know about the very original proposition of the not yet famous engineer Gustave Eiffel: to house the instrument under a dome made to float in order to ease its rotation. Eiffel's proposition was rejected by the Parisian committee, but Garnier, who had been in favour of it, suggested Bischoffsheim to adopt it for housing the Nice 30-inch refractor.

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Figure 22.1: *Google image of Royal Observatory, Cape of Good Hope. The H-shaped main building was completed in 1828*

22. The Royal Observatory, Cape of Good Hope, a Valuable Cultural Property

Ian S. Glass (Cape of Good Hope, South Africa)

22.1 Geographical Position

The **Royal Observatory, Cape of Good Hope** is the original name for the headquarters of the present-day South African Astronomical Observatory. It is situated in the suburb of Observatory, a part of Cape Town, Western Cape Province, Republic of South Africa. The entire property of 9 hectares occupies a small hill 3 km east of central Cape Town, within the **Two Rivers Urban Park**. The location was chosen to be within view of the City's harbour to permit the visual signalling of time to visiting ships. The property is one of the last remaining places close to the city centre where the original ecology of the area is preserved.

22.2 Longitude and Latitude

The Observatory is situated at longitude 01h 13m 54s.6 E; latitude 33° 56′ 03″.5 S; elevation 15m. This is the precise place occupied by the Airy Transit Circle, upon which all South African geographical positions were formerly based.

22.3 General Description and World Cultural Importance

The Royal Observatory, Cape of Good Hope, was created on 20 October 1820 by an Order of King George IV of the United Kingdom, a colony of which the Cape then was. The first building was completed in 1828.

For most of its existence it was the major contributor to positional astronomy in the southern hemisphere. Among its most noteworthy achievements are: the first successful measurements of the distance of a star (α Centauri) by Thomas Henderson in 1832/33 and the first use of photography to make a systematic sky survey (Gill, 1885 on). Gill was one of the leaders of the *Astrophotographic Congress*, the precursor of the *International Astronomical Union.*

22.4 Partial Inventory of Extant Items

22.4.1 Buildings

- The main building of the Observatory (see fig. 22.1, p. 210) was completed in 1828. The central part comprised observing chambers for a transit telescope and a mural circle as well as an entrance hall and two small computing rooms. The west wing comprised quarters for the Astronomer and the east for two assistants. It was designed by the noted naval architect John Rennie, Chief Engineer to the Admiralty.
- Other early structures include the south meridian mark for the mural circle (ca. 1828) and a dome running on cannon balls dating from 1849 (for the 7-inch Merz telescope).
- The 18-inch dome (former heliometer observatory), 1888.
- The McClean (Victoria) dome of 1897; an early work by the internationally famous architect Herbert Baker.

22.4.2 Some Movable Artefacts Surviving

- A repeating transit by Dollond, described in a publication of 1820. (used by the first astronomer before the completion of the main building).
- 7-inch telescope by Merz (1849). Used for Transit of Venus 1882. Used also by RTA Innes, the discoverer of Proxima Cen, for double star work.
- A speculum mirror by W. Herschel (1811).
- Time signal pistol 1833.
- Regulator clocks by Molyneux, Hardy, Dent and Riefler. The Hardy clock, which dates from the 1820s or slightly earlier, was in the Transit Room and was used by Henderson in his α Cen work; the Molyneux clocks (one each sidereal and mean) date from a similar time.
- Ross lens used by Gill for his epoch-making photography of Great Comet of 1882

- Large Dallmeyer portrait lens used for *Cape Photographic Durchmusterung* – the first photographic sky survey
- Eyepiece and lens of Airy Transit circle (installed 1854).
- "Kew Pattern" Heliograph by Dallmeyer (1878).
- 6-inch Grubb telescope (1882).
- Astrographic telescope (Grubb, 1889).
- McClean (Victoria) telescope (Grubb, 1897).
- Gill transit circle (1905), the precursor of all modern transit circles.
- 18-inch telescope (1955) on Heliometer mount by Repsold (1885).

In addition, the library, which is the National Library of Astronomy, is one of the most comprehensive astronomical libraries in the world, both for antique and contemporary material.

22.5 Brief Survey of the History of the Site and its Uses

In pre-colonial times the property was probably used for grazing by the indigenous San pastoralists. Later, but before it was acquired for the Observatory, the area was farmland, though rocky, treeless and windswept. It nevertheless supported a remarkable variety of seasonal grasses and bulbs. It is underlaid by greywacke, quartzitic limestone and shale. Although it is the habitat of many interesting flora and fauna, it is particularly noted for being the last remaining natural habitat of a rare Iris *Moraea aristata* and the northern limit of the Western Leopard Toad *Bufo pantherinus*, an endangered species.

From *ca* 1820 the property has been in use as an observatory. In 1971, it became part of the South African Astronomical Observatory.

No longer barren, over the nearly two centuries of its existence the site has been planted extensively with shrubs and trees to act as windbreaks.

22.6 Authenticity and Integrity

We are fortunate in having a number of photographs of the Observatory dating from ∼1842 (see fig. 22.2, p. 213). These are the oldest photographs taken in South African and the oldest of any observatory anywhere (excepting JFW Herschel's photograph of his father's 48-inch telescope).

Many of the buildings on the site are original structures. The Main Building, commenced in 1825 and completed in 1828, is still extant and has been modified only marginally. Two copper domes, shown in the 1842 photograph, were removed in 1883 and the central lantern structure was removed in 1961.

The Royal Observatory, as a living institution, has evolved continuously since its foundation. The original instruments, consisting of a transit and a mural circle, were located in the Main Building. By 1855, these had been replaced by a transit circle designed by Airy. In 1849 a 7-inch Merz telescope with dome was added. A magnetic observatory, comprising several buildings, was established in 1841 but none of these survive today.

Still within the 19$^{\text{th}}$ century, a photo-heliograph designed by Warren de la Rue was installed in 1876.

During the regime of David Gill, one of the greatest astronomers of the 19$^{\text{th}}$ century, activity on the site reached its zenith. Numerous buildings from Gill's time are extant, including the Astrographic dome (1888), the Heliometer dome (1888), the McClean dome (1895) and the Gill Transit Circle (1905).

The 20$^{\text{th}}$ century saw the New Offices (*ca* 1920), the WW II Optical Workshop (now lecture theatre), the Lyot coronagraph (1958) and the Technical Building (*ca* 1988).

Numerous other small buildings have come and gone during this period, including the Franklin-Adams telescope (ca 1909), the 40-inch (Elizabeth) Telescope (1964) and the Astrolabe Hut (ca 1960s).

22.7 Cultural and Symbolic Dimension of the Site

The Royal Observatory was the first major scientific institution to be erected on the continent of Africa, so far as is known.

For much of the 19$^{\text{th}}$ century it occupied an important position in the Cape Colonial hierarchy, His or Her Majesty's Astronomer being called upon to give advice and to serve on the boards of cultural and educational institutions.

To the general public it was known as the supplier of time services, operating a noonday cannon (as it still does) and time balls at various places in the Cape Colony. It was also the repository of standard weights and measures for the colony. The weather records are the longest-running in South Africa.

Today it forms the headquarters of the South African Astronomical Observatory, where astronomers have their offices, data reductions are carried out and instruments are constructed. The current observational activities of the SAAO are centred in Sutherland, about 400kms into the interior.

22.8 Documentation and Archives

All phases of the existence of the Royal Observatory are well-documented. Large amounts of material exist in the following archives: Hydrographic Office of the Royal Navy (UK), Royal Greenwich Observatory Archives (now in Cambridge University Library), the

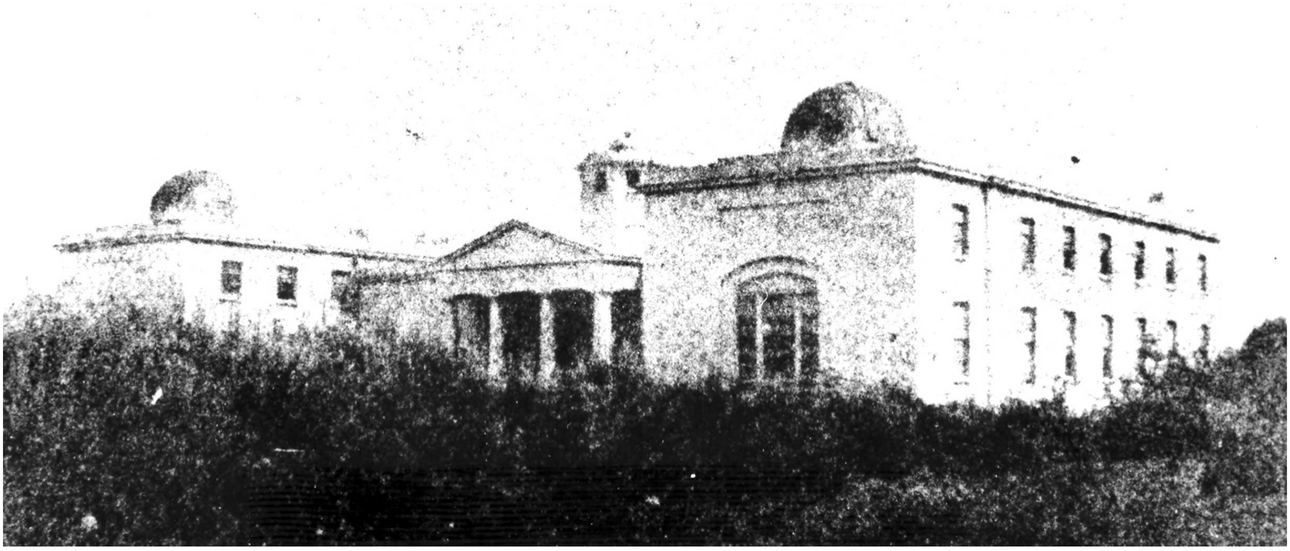

Figure 22.2: *Photograph of Royal Observatory ca. 1842*

South African Government Archives and, of course, the SAAO Archives, kept on the Royal Observatory site.

22.9 Present Site Management

The property is owned at present by the National Research Foundation (NRF), the umbrella agency of which the SAAO and a number of other scientific institutes form part. It is used exclusively for astronomical purposes.

Protection: The property is central to the Two Rivers Urban Park, a conservation area established by the City of Cape Town. It is bordered to the East and North by wetlands. As such, it is protected from encroachment.

22.9.1 State of Conservation of Buildings, Instruments and Archives

Most of the buildings are regularly maintained but certain of those not in use for current astronomical projects require restoration. In particular, the Gill Reversible Transit Circle building of iron and steel is in poor condition. The archives and retired instruments are generally well-protected from environmental damage.

22.9.2 Restoration and/or Maintenance of the Site and Instruments

Certain of the old instruments have recently been restored. These include the Merz 7-inch telescope and the de la Rue photoheliograph.

A museum in the former McClean laboratory contains a selection of the smaller antique instruments no longer in use, ranging from a Dollond Repeating Transit used by Fallows to the photometry equipment of A.W.J. Cousins.

22.10 Buffer Zone

The Royal Observatory site is partly flanked by preserved wetlands and the lower parts of the site itself are subject to occasional flooding, making them unsuitable for development.

22.10.1 Context and Environment, Landscape

The site is no longer dark and rural. Beyond the boundaries of the Two Rivers Urban Park it is surrounded by freeways and major roads, office buildings etc.

22.10.2 Archaeological/Historical/Heritage Research

The Royal Observatory is well documented historically in books by Gill and Brian Warner and by many articles in books and journals. Research on historical matters by various interested parties is fairly continuous. There is a keen interest in the history of the site and recently an independent "Friends of the Observatory" group has been organised, with restoration of old instruments and domes as a major theme.

An application to the South African National Heritage Agency is currently in progress. If approved it would be the first South African cultural site to be so designated for its scientific research history.

22.11 Main Threats or Potential Threats to the Site

The main threat to the Royal Observatory site lies in the ever-increasing pressure on open urban land from real-estate developers.

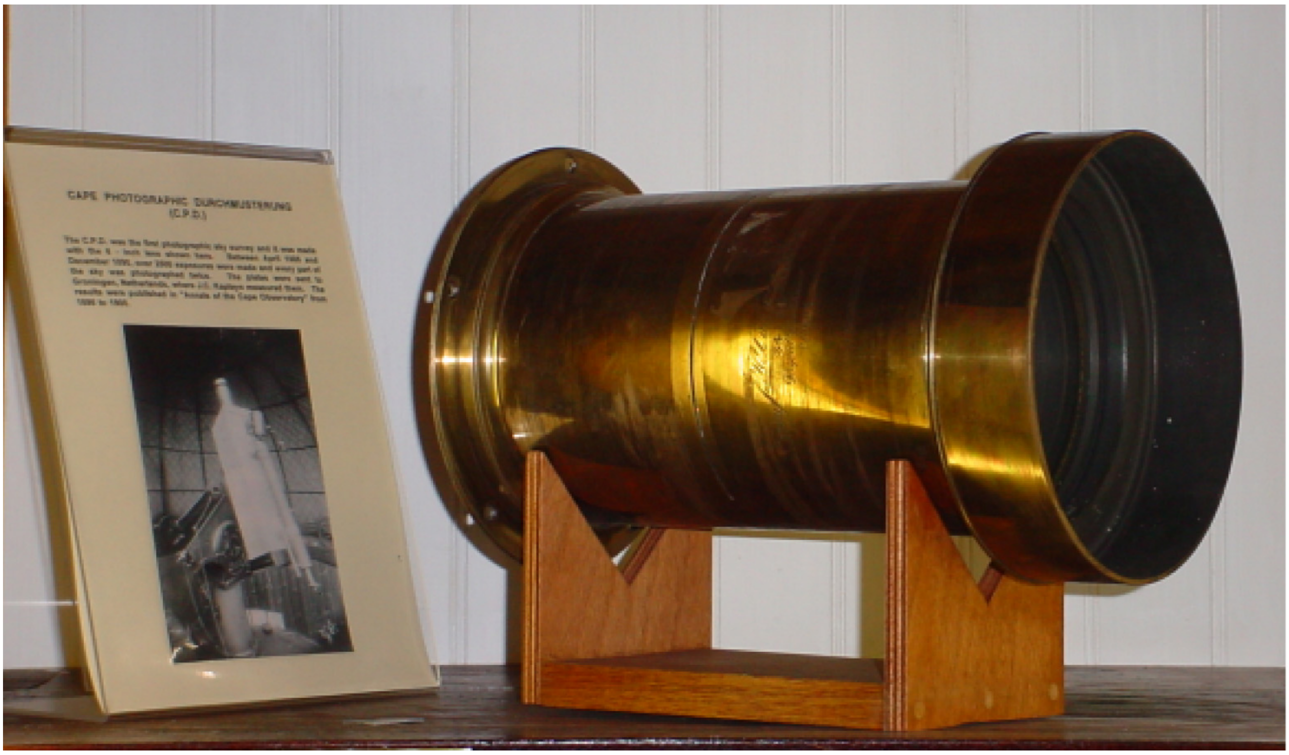

Figure 22.3: *6-inch (15 cm) Dallmeyer portrait lens, around 1884, used by Gill to produce the Cape Photographic Durchmusterung*

22.12 Environmental Study

Currently, an *Observatory Baseline Information Study* has been commissioned to better analyse the natural and urban environment of the site and better characterise its unique properties, with a view to preserving them.

22.13 Outreach

For many decades there has been a public outreach programme. Open nights are held monthly or more often, in which members of the public are given free of charge an introduction to the Observatory, a lecture on an astronomical topic and sky-viewing opportunities. In addition, many school and other groups tour the establishment during the daytime.

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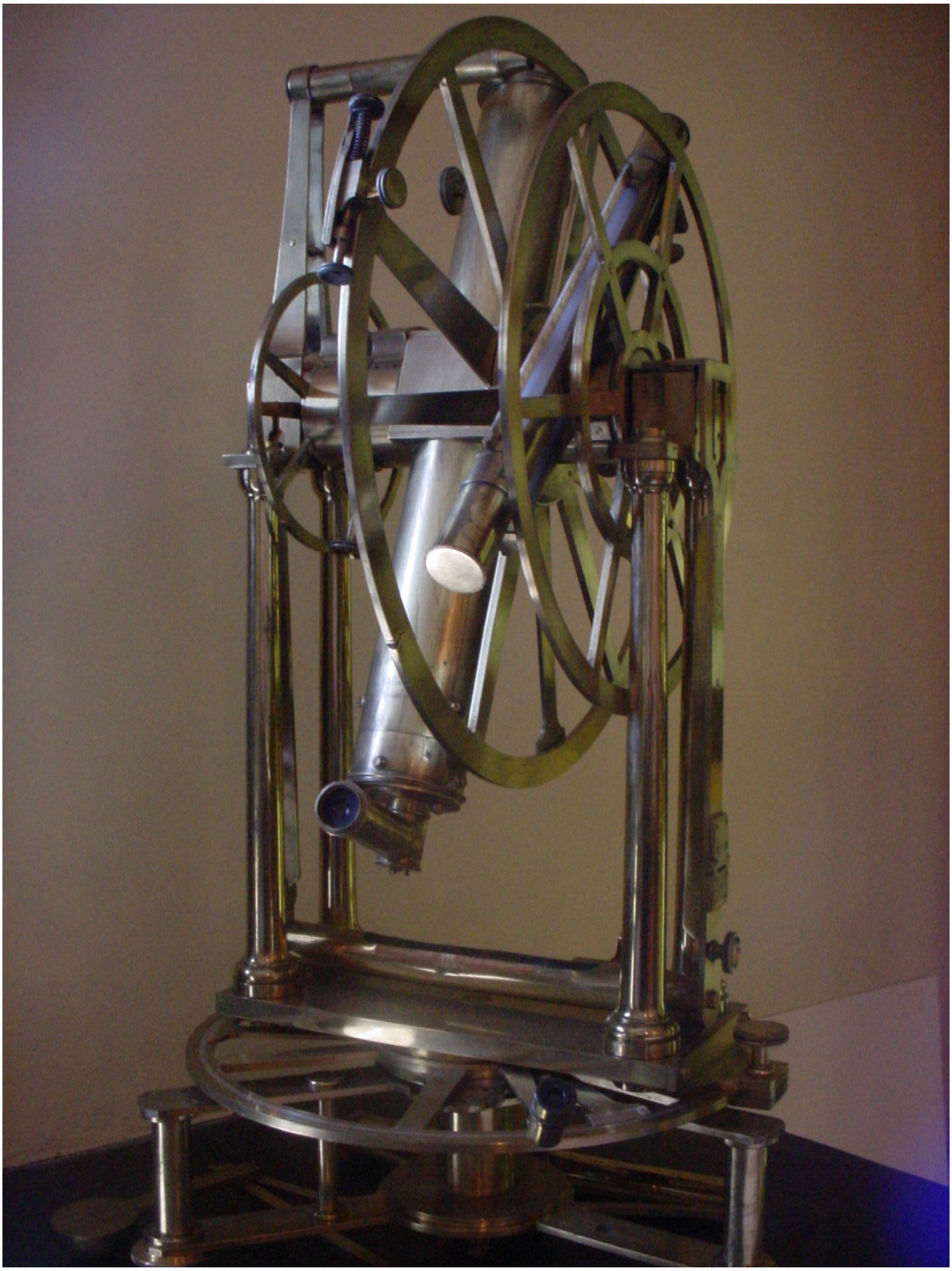


Figure 22.4: *Repeating Circle by George Dollond that was completed in January 1819 and was used by the director of the Royal Observatory before the main observatory was ready. (It is described in a paper "The Description of a Repeating Instrument upon a new construction" by G. Dollond. In: Memoirs of the Astronomical Society of London* **1** *(1822), p. 55–58)*

Figure 23.1: *A "bird's eye" view of the US Naval Observatory. In the middle at center is the administration building and the dome of the 12″ refractor. To its right is the dome of the 26″ refractor. The 1000 foot diameter grounds of the USNO were established in 1890 to protect sensitive instruments from the vibrations caused by carriage wheels along nearby roads. (U. S. Naval Observatory)*

23. U. S. Naval Observatory: The Move to Georgetown Heights and Double Star Work (1850–1950)

Brian Mason (Washington, D.C., USA)

Abstract

Founded in 1830 as the Depot of Charts and Instruments, the U. S. Naval Observatory (USNO) is one of the oldest continuously operational scientific institutions in the United States. Among its first tasks were testing, rating and evaluation of various US Navy equipment (such as ships' chronometers) as well as the dissemination of time, first through its historic time ball and later through direct input via the Western Union telegraph. Fundamental Astrometry and maintenance of the Fundamental Reference Frame were among its earliest charters. There have been two main USNO campus locations since 1844; the first was a region of Washington still known as "Foggy Bottom", which it occupied until 1893, when the USNO moved to its current location at "Georgetown Heights". The activities and history of the USNO from approximately 1850 to 1950 are briefly described with special attention to double star work done from then to now.

23.1 Early Years of the Observatory

The foundation of a National Observatory was proposed by U. S. President John Quincy Adams in 1825[1] but due primarily to his unpopularity was never initiated. The Navy, especially after the War of 1812, recognized the value of a facility to support navigation and founded the Depot of Charts and Instruments in 1830. An observatory in all but name, its capabilities in those areas were severely restricted due to staff shortages and frequent changes of temporary housing in the early part of the 19$^{\text{th}}$ Century. In the early years frequent trips to Europe were made by James Gilliss for the purchase of books and instruments, among them a 9.6″ Fraunhofer refractor and a 5.3″ Ertel transit from Merz & Mahler.

Finally the US Naval Observatory (USNO) was given a more permanent home in 1844 at a location in Washington with the astronomically ominous name of Foggy Bottom. Bordered on three sides by the Potomac River, a swamp (fed by a sewer) and a coal-gas conversion facility, the location, while substandard astronomically, was well-placed for ship captains to set their chronometers with the dropping at noon of the time ball from the mast above the dome at the top of the Observatory. Despite purchasing much of the equipment of the observatory, being the last officer in charge of the Depot, and designing the observatory, James Gilliss was not selected as the first superintendent of the USNO. Instead, that distinction went to Matthew Fontaine Maury. While Maury learned the observational work of the USNO, he is most well known as the father of the new science of Oceanography.

In 1861, when Maury resigned his Navy Commission to fight with the Confederacy in the American Civil War, Gilliss was finally named superintendent of the USNO. Coming on board with an ambitious observing program, Gilliss' plans were placed on hold because of the Civil War need to supply charts and instruments for the greatly expanded navy. After having to wait seventeen years before coming to the helm of the USNO, and then not having time to engage in astronomy, were not the end of Gilliss' run of bad luck as he, like other USNO astronomers, died as a result of complications due to malaria carried by the indigenous Anopheles mosquito.[2] Fortunately before this, as a concession from Welles, Gilliss was allowed to hire two "professors of mathematics" to engage in astronomical work, and his choices were quite good ones: Asaph Hall and Simon Newcomb.

Hall, Newcomb and other staff members made frequent trips for the recording of solar eclipses and participated in the two transits of Venus that occurred in the 19$^{\text{th}}$ Century but their most significant contributions were in other areas. Newcomb, for his part, was a much better mathematician than observer, and while bad observing conditions were prevalent in Foggy Bottom, it wasn't the only reason for not observing, as Newcomb recalled in his memoirs:

When either Hubbard or myself got tired, we could "vote it cloudy" and go out for a plate of oysters at a neighboring restaurant.[3]

Meanwhile, despite early instrumentation being of primarily German or English origin, a domestic instrumentation source was soon available. Alvan Clark & Sons of Cambridge, Massachusetts, began work in optics. After the quality of their telescopes was praised by English astronomer William Dawes, they began to get work worldwide building large telescopes, including in 1873, the 26″ refractor of the U.S. Naval Observatory. During a close approach of the planet Mars in 1877, while Newcomb and his assistant Edward Holden were away from the USNO, Hall observed Mars and discovered Phobos and Deimos. But, in what should have been the most productive years of the 26″, then the largest telescope in the world, its capabilities were severely compromised due to the poor observing conditions in Foggy Bottom. Shortly after the discovery of Phobos and Deimos, Admiral Rodgers set in motion the process that would eventually lead to the USNO moving to Georgetown Heights. Land was purchased in 1881, funds allocated from 1886 to 1891 and in 1893 the USNO moved to its current location in a rural, high point above Georgetown.[4]

In the half century between the establishment of the USNO at Foggy Bottom and that of the new USNO at Georgetown Heights, the design of large observatories changed rather dramatically. Gone was the single monolithic building (exemplified by the Paris Observatory) which housed all instruments and offices. Instead, observatories started resembling parks, with discrete buildings dedicated separately for daytime office work and nightime observing.

In addition to compartmentalizing work done on the campus this had the additional benefit of isolating the observing from noise, light and vibrations associated with work done in the daytime. The Georgetown Heights campus of the USNO followed this "observatory park" motif, as seen in fig. 23.1, p. 216. In addition to the administrative building was a dome for a 12″ refractor, a spacious library, a large dome for the 26″, several transit houses, a clock vault, and other structures.

In keeping with the overall change in the design philosophy of observatories, the Dean of American Architects,[5] William Morris Hunt was selected to design the USNO. Hunt is probably most well known as the architect who designed the pedestal of the Statue of Liberty. It somehow seems fitting that he is well known for providing a solid base for that iconic statue just as astrometry, the principal astronomical activity of the USNO, serves as the foundation of the "astronomical pyramid".[6]

At a more remote location, Georgetown Heights certainly had fewer distinguished visitors than visited Foggy Bottom,[7] and astronomers were supplied housing on the grounds due to its remote location. Today, these former astronomical staff houses are occupied by Flag Officers of the US Navy and other high officers of the government, most recently the Vice President of the United States.[8]

The 26″ telescope can still be used today whenever conditions allow (typically 200 nights per year) and is now exclusively used for the observation of bright ($V < 11$) double stars.

The astrometric workhorse of the USNO, the 6″ transit circle was built in 1898 by Warner & Swasey and was used continuously by at least two shifts of observers per night making positional measurements until 1995. Astrometric catalogs derived from these positions were produced on a regular basis. It remained the most reliable and accurate of the transit circles used with single measurement errors in the neighborhood of 0.4″.

The pole-to-pole program would have been the best celestial reference frame if the Hipparcos satellite had failed. With the demonstrated success of space-based wide-field astrometry the transit circle program was terminated. Shortly after the centennial observation with the 6″ transit circle, the telescope was moved to the main lobby of the USNO's Administrative Building for display and educational purposes. The foundation and piers of the building and telescope remain, and will form part of an interpretive courtyard presently under design review. Currently, the USNO is leading the development of a small satellite dedicated to absolute astrometry.[9]

The history and architecture of the USNO are well-recognized and the site was nominated for designation as a National Historic Landmark.[10]

23.2 Double Star Work

The U.S. Naval Observatory has, for well over a hundred years, been involved in various programs related to the observation of double stars. One of the first orders of the superintendent of the USNO, Matthew Fontaine Maury to Sears Walker discusses what parameters should be observed:

Sir: I wish you to take charge of the equatorial for the present, and to prepare for a regular series of observations of double stars, clusters, nebulae, and lunar occultations.

The observations of double (and multiple) stars will embrace distance, angle of position, color, magnitude, and appearance ...

Let your observations embrace every double star of which the larger is of the 10th magnitude or under.

Three observing techniques have been used at the USNO: visual micrometry, photography, and speckle interferometry.

23.2.1 Visual Micrometry

Visual micrometery is the most often used (59%) technique for long-focus (pointed) double star work, and is, fortunately and unfortunately, the one most influenced by the skill of a particular observer. The earliest work in micrometry was done at the Foggy Bottom site in the midst of the Civil War with the 9.6″ refractor by Hall, Newcomb and James Ferguson. Later work in the late 19th and early 20th century was done by these and Hall, Jr., Holden and others, primarily with the 26″ refractor. In the early years, the 26″ was visited by the leading double star astronomers of the time. The first double stars discovered at the USNO were discovered

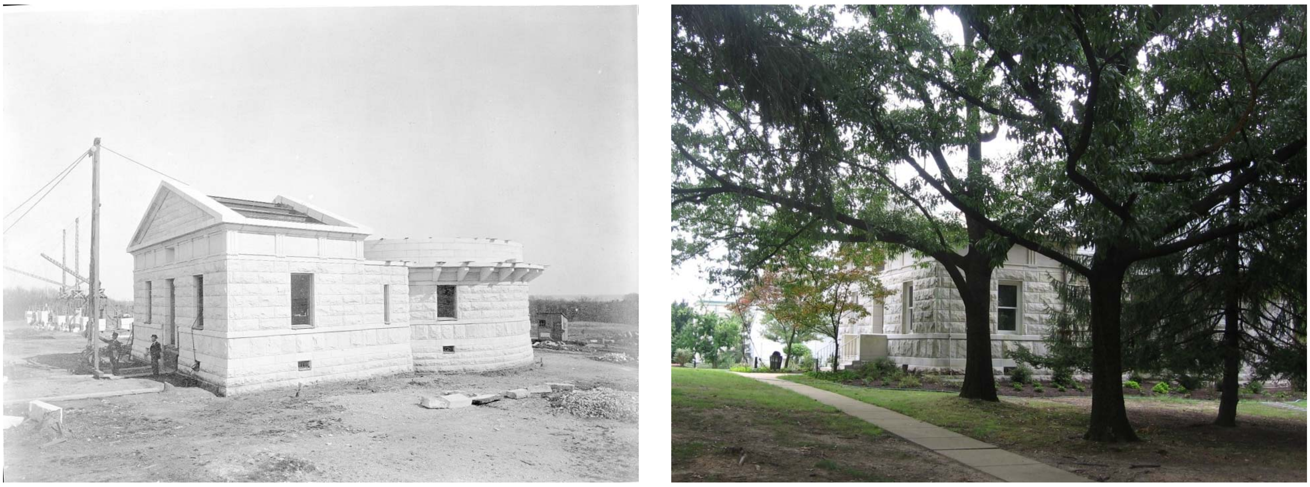


Figure 23.2: *The Hunt designed building to house the 26″ refractor in 1890 in the midst of construction and today. In the 1890 image at left rear are seen the initial work on the foundations of the main administrative building. Despite the rather significant change in local foliage, these are kept at a managable height and about 200 nights per year are suitable for obtaining observations. (U. S. Naval Observatory)*

by a visiting astronomer: Sherburne Wesley Burnham. This prolific double star astronomer visited the USNO in August 1874:

Passing through Washington, I spent a few days there, and through the courtesy of Admiral Davis, Superintendent of the United States Naval Observatory, I had the pleasure of using the magnificent 26″ recently erected by the Messrs. Clark and Sons. I had only one good night, and the 14 double stars in the following pages were all observed on that occasion …
For double star work this instrument seemed to be perfect. I looked up many of the closest double stars I could think of without finding anything that at all approached the limit of the power of the telescope. In fact these objects were almost too easy to be interesting.[11]

On that evening Burnham was hosted by a contemporary mentioned in the log book, Edward Holden, long before the founding of Lick Observatory or the Astronomical Society of the Pacific, then on the staff of the USNO. Burnham found the objects numbered 286 to 300 in his list that night.

While Hall is well known for his discovery of Phobos and Deimos, from 1875 to 1891 he made nearly five thousand measures of close or faint stellar companions. These were ideal targets for the large telescope and Burnham[12] includes Hall as one of the "leading observers" in his double star catalog. About 5% of all double star micrometry measures made from 1875–1900 were made at the USNO.

While Simon Newcomb also observed double stars with the 26″, his primary target and the focus of his and Holden's work turned out to be undetectable. Newcomb and Holden were the first 26″ observing team and wanted to make a significant discovery with the largest telescope in the world. Following the Clark discovery of the white dwarf companion to Sirius, Newcomb and Holden spent most of their time trying to resolve the suspected close pair to Procyon[13] and failing to do so. It would not be resolved until Schaeberle turned the 36″ refractor at Lick, also a Clark refractor, on it in 1896.

In 1883 the USNO was host to the Director of the Imperial Observatory at Pulkovo, Otto Wilhelm von Struve and his son Hermann. The primary purpose of this visit was instrument evaluation preparatory to testing the 30″ objective made by Alvan Clark & Sons for the Pulkovo Observatory. It is easy to imagine these two double star experts desiring to put the 26″ through its paces by observing some close doubles. However, as the 26″ log indicated, conditions were not favorable.

Following Hall's retirement there was a flury of activity related to double stars led by the "Astronomical Director" Stimson Brown and assisted by T. J. J. See. Another well known double star observer, William Hussey, observed with Brown the night of June 20, 1899 at Georgetown Heights.[14] However, many of these staff members departed in the wake of an attempt to place the USNO under civilian control.

In the early 20$^{\text{th}}$ century some micrometry of double stars was done by Burton, Wylie, Lyons and Markowitz, but the combination of redirected priorities and limited staff at the USNO as well as productive programs elsewhere led to it producing less than 1% of all double star measures in the first half of the 20$^{\text{th}}$ century.

When Kai Strand joined the staff of the USNO, the double star program began to re-emerge. Strand recruited Charles Worley, who came to the USNO from Lick in 1961. Shortly thereafter the recognized standard double star catalog, the *Index Catalogue of Visual Double Stars*, or IDS, was transferred from Lick to Washington and re-designated the *Washington Double Star Catalog*, or WDS. The WDS was by then the *International Astronomical Union* (IAU) official catalog,[15] with the "Double Star Centre" [sic] at the USNO having the responsibility to maintain and deliver copies of the catalog, now done via internet. The USNO and the double star program have continued to have very

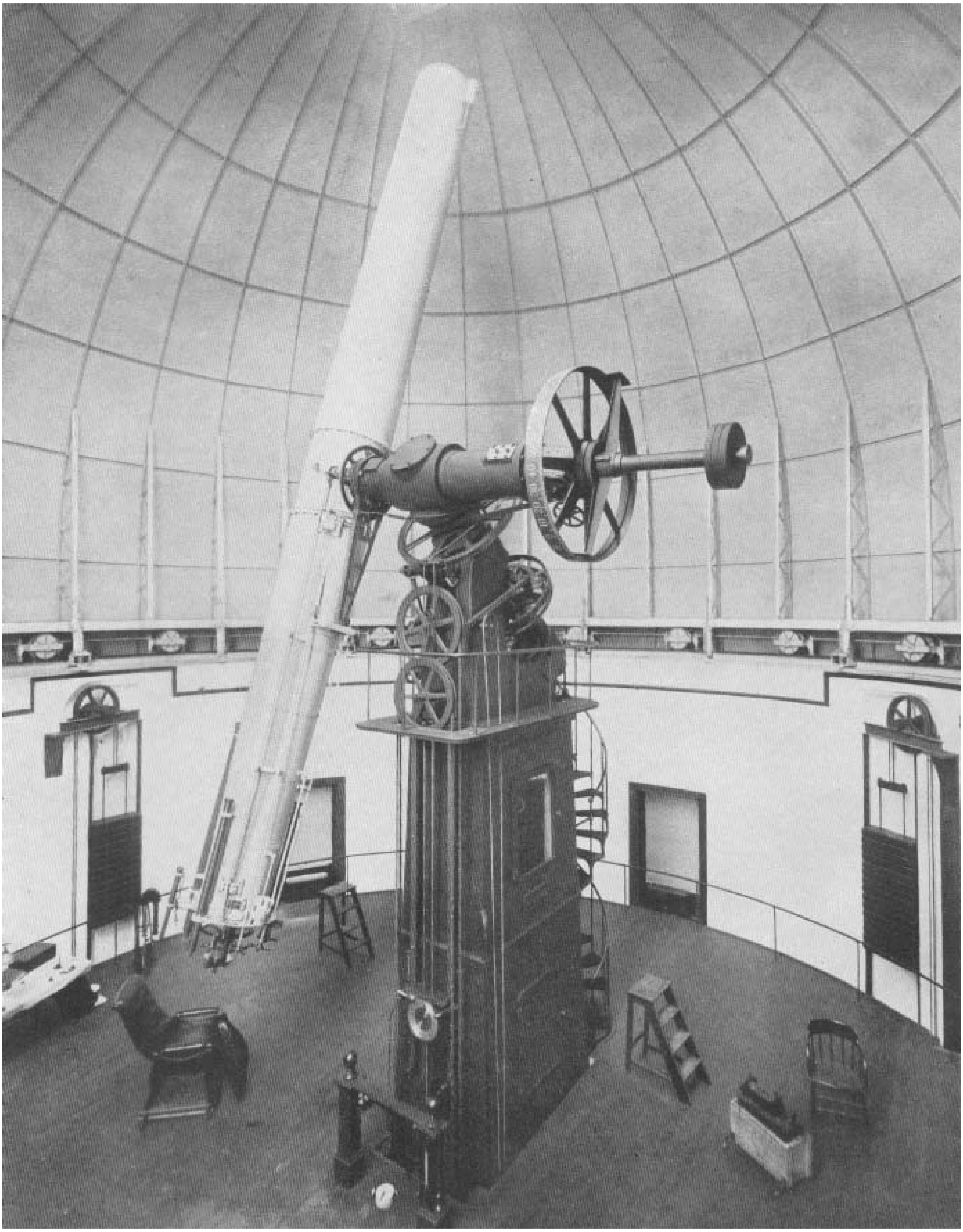


Figure 23.3: *The 26″ telescope in 1911. At the time it was still among the world's largest refractors, but with the Mt. Wilson 60″ complete and work on the 100″ progressing, the time of large refractors was passing. (U. S. Naval Observatory)*

close ties with the IAU in general and Commission 26 (Double and Multiple Stars) in particular: at one time or other, USNO astronomers have been president of this Commission four times.

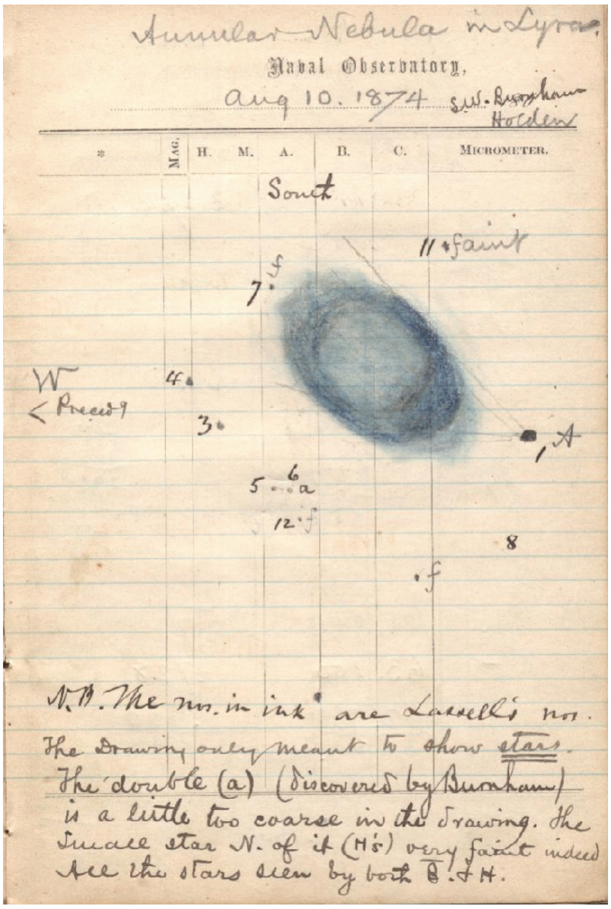
Worley began collaborations, first with William Finsen[16] and later Wulff Heintz,[17] in the production of catalogs of the orbits of binary stars. As an observer, Worley concentrated on obtaining very accurate measures of the closest, and most astrophysically significant, orbit pairs and to this day remains the third most prolific observer of double stars. From 1960 to 1990 over 20% of the total number of measures of doubles were done at the USNO. Micrometry ceased at USNO in 1990.

23.2.2 Photography

Observing double stars with the technique of multiple exposures with coarse gratings to reduce the magnitude error problem was developed by Ejnar Hertzsprung at Potsdam around 1914. Using this method, Strand initiated this program at the USNO in 1958. Utilizing cameras on the 24″ Clark refractor at Lowell Observatory in Flagstaff, Arizona (led by Otto Franz) as well as the 26″ in Washington (led by Jerry Josties) this program obtained over 10,000 very accurate measures of wider pairs before its termination in 1982. About 80% of these measurement were made with the 26″. For a select group of wide pairs this method provided an objective technique for extremely accurate and precise measurements. This technique was most effective on pairs with a separation of at least a few arcseconds, allowing it some overlap with visual micrometry, although the core observing of these contemporary programs were non-overlapping. This relatively short activity period represented over 30% of all photographic measures of double stars ever made.

23.2.3 Double Star Observing Today

It is a credit to Charles Worley that, in the autumn of his scientific career and after making tremendous contributions in micrometery, he abruptly switched fields and embraced speckle interferometry for its abilities to resolve the closest and most astrophysically interesting pairs: his passion. This program was well suited for systems with separations as close as the Rayleigh limit of the telescope and as wide as the isoplanatic patch. For the 26″ telescope this means that separations greater than 0.2″ are resolvable. For closer pairs the speckle camera can, and has, been shipped to larger telescopes elsewhere in the US and overseas. In addition to continued measurement of close, orbit pairs, speckle is quite effective at confirming pairs discovered by satellite observation (Hipparcos, Tycho, HST-FGS), at a fraction of the cost of followup space observation.



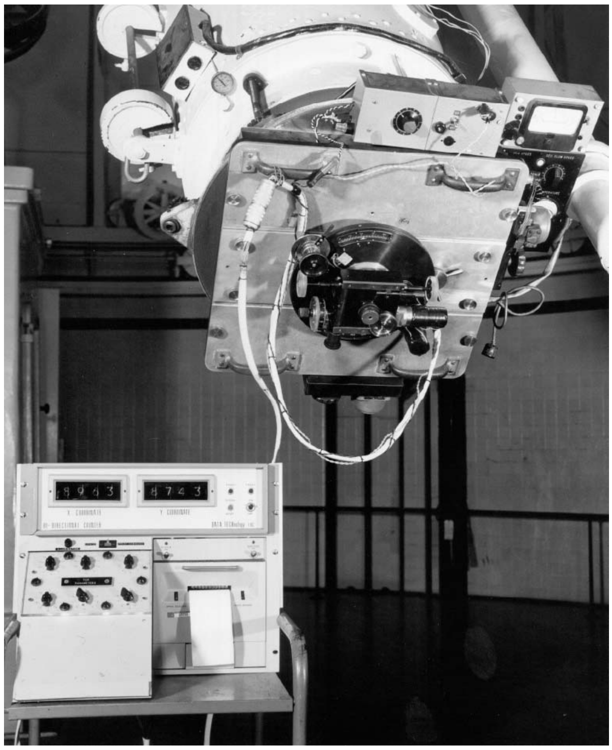


Figure 23.4: *Discovery of the multiple system BU 293 in the observing logs of the 26″ telescope in Washington; The semi-automatic micrometer. The eye was still used to judge positions, but digital encoders read out positions. Attached to the backend of the 26″ refractor. (U. S. Naval Observatory)*

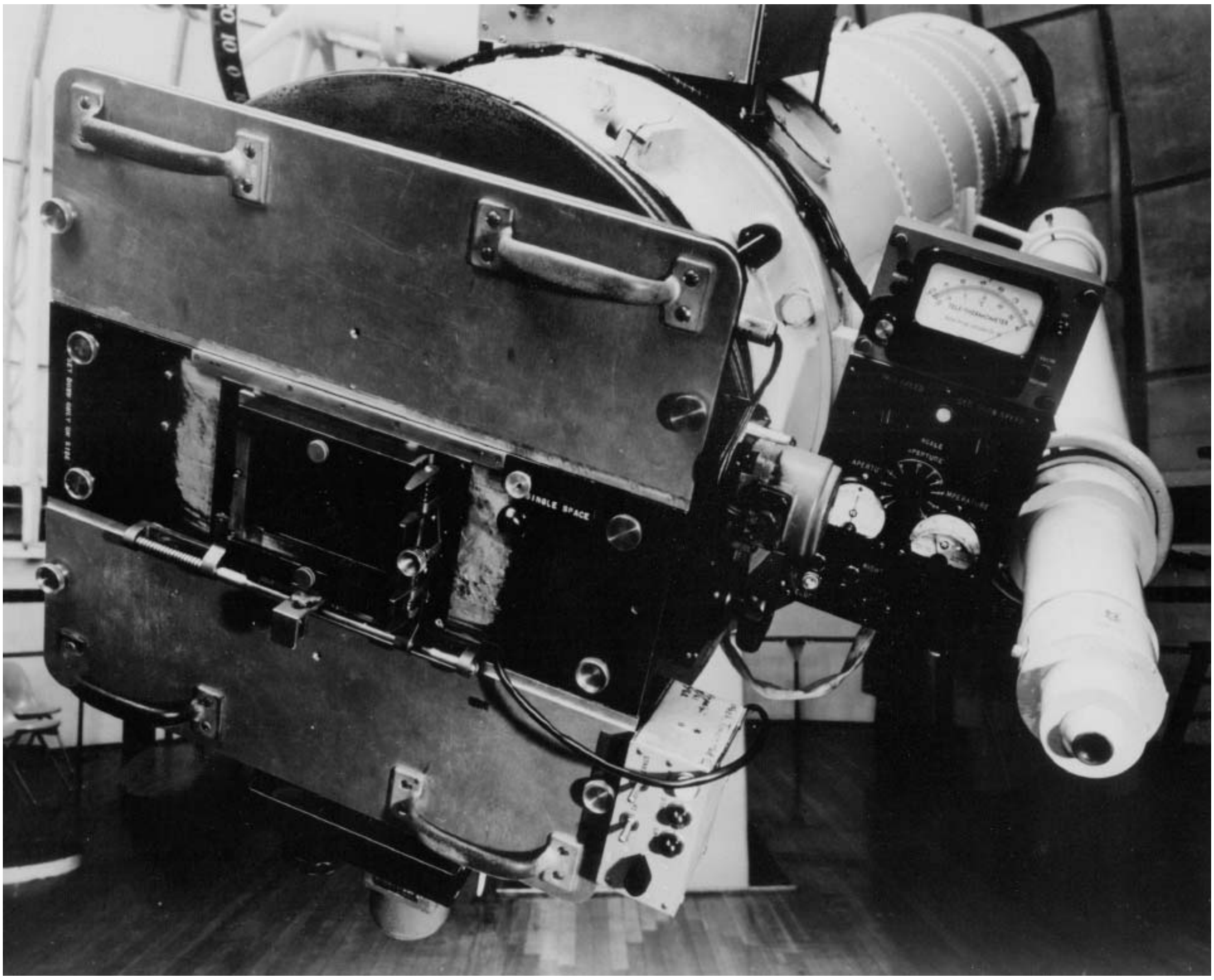


Figure 23.5: *The photographic double star camera attached to the back end of the 26″ refractor. (U. S. Naval Observatory)*

Another important facet of USNO double star work is that the leadership of the USNO in wide-field astrometry ensures that when these techniques measure separately the components of double stars they can be identified and added to the WDS.[18] This process is ongoing.

The long history of the USNO's work in double star astronomy, the suitability of speckle interferometry for an urban setting, and the applicability of speckle to bright stars (which are the ones most often used for navigation) makes the long-term future of the program (and the continued use of the 26″ Clark refractor) quite bright.

Acknowledgments

The USNO speckle interferometry program has been supported by the National Aeronautics and Space Administration under reimburseable #NNH06AD70I, issued through the Terrestrial Planet Finder Foundation Science program. Thanks are also extended to Ken Johnston and the U. S. Naval Observatory for their continued support of the Double Star Program.

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1. Dick 2003, pp. 5.
2. Herman 1996, pp. 52. His apoplexy may have been due to overdosing with Quinine, a malaria treatment.
3. Newcomb 1903, pp. 102.
4. Dick 2003, pp. 298.
5. Dick 2003, pp. 311.
6. See Figure 1 of `http://www.scholarpedia.org/\\article/Astrometry`
7. Burlingame 1997, pp. 75.
8. Cleere 1989.
9. Gaume et al. 2009.
10. Butowsky 1989, pp. 15.
11. Burnham 1874.
12. Burnham 1906.
13. Davis 1876.
14. Brown 1900.
15. Pecker 1966, pp. 267.
16. Finsen & Worley 1970.
17. Worley & Heintz 1983.
18. e.g., Wycoff et al. 2006.

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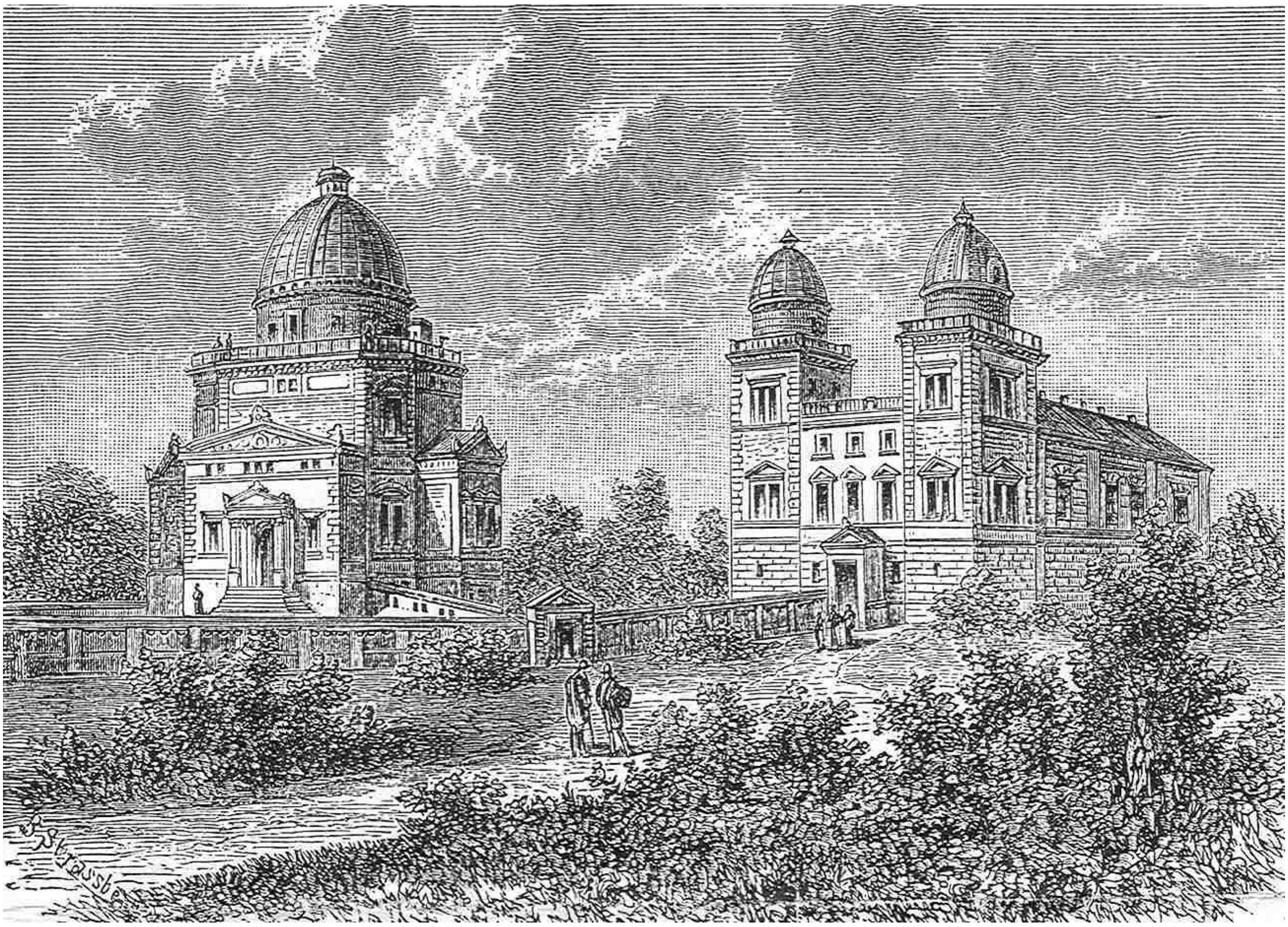

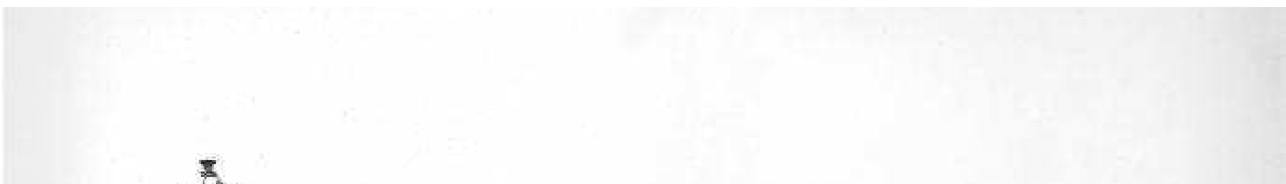

Figure 24.1: *Above: Strasbourg Observatory, 1876–1880; Below: General view of the University of Strasbourg: around the new botanical garden, the 'Great Dome' of the Observatory, the greenhouses and the buildings of the institutes of botanics and physics. (Above: Ule, Otto: Die Wunder der Sternenwelt. Berlin, Leipzig: Otto Spamer 1884, p. 411. Below: Glass plate photography of about 1880 – Strasbourg University Archives)*

24. The Architectural and Instrumental Heritage of the Strasbourg University Observatory

Jean Davoigneau (Strasbourg, France)

Abstract

When, in 1872, Alsace was handed over to Germany, Emperor Wilhelm I decided to make Strasbourg the showcase of his empire, and in particular to build a prestigious university and an observatory.

The construction of the observatory was entrusted to the astronomer August Winnecke (1835–1897), former director of the Pulkovo observatory, and to the *Baumeister* Hermann Eggert. Begun in 1876, the work was completed in 1880. The astronomical instruments, ordered from German makers, were installed during the winter of 1880–1881, and the observatory was inaugurated on September 22, 1881 at the general assembly of the *Astronomische Gesellschaft*, the international association of astronomers, whose secretary was Winnecke.

Marking the south-eastern extremity of the 'imperial axis', the architecture of the university observatory harmonizes perfectly with the new German city built on the former French parade grounds. The astronomical heritage operation conducted at the beginning of the present decade provides a richly documented and illustrated inventory of both the architecture and instruments of this institution. This work has also highlighted the unique quality of the collection of instruments, befitting the long and complex history of this institution.

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L'Observatoire astronomique de Strasbourg, Inventaire du patrimoine astronomique: `http://www.hp-physique.org/OBSERVATOIRE/`

Figure 25.1: *Geographical distribution of the Italian Astronomical Observatories*

25. Italian Astronomical Observatories and their Historical Instruments Collections

Ileana Chinnici (Palermo, Italy)

25.1 A Brief Historical Introduction

Italy has a high number of astronomical observatories in comparison with its territorial extension. This is due to historical reasons, as Italy results from a political process of unification and annexation of several small states into which the country was divided – a process (the Risorgimento) which was carried out mainly around the half of 19th century.

The first "institutional" Observatories in Italy were established in the 18th century, as in the majority of the other European nations. At that time, Italy was composed by seven states and since 1711 to 1819 each of these states established one or two Observatories in its territory.

After the political unity of Italy, a reform was planned[1] and in 1876 some small observatories were declassed as simple meteorological stations (it is the case for Modena and Parma). Three more observatories were established at the end of the 19th century, and after the World Wars, with the annexing of the last ex-Austrian territories (Bozen, Trento and Trieste), the total number of the Italian Observatories was twelve – which is the current number.

It is also to be mentioned the existence of the Vatican Observatory, which keep a collection of 19th and 20th century instruments – but it is out of the purposes of this paper, as the Vatican State is politically independent from Italy.

25.2 Buildings and Collections

The consequence of above-depicted situation is a peerless Italian astronomical heritage consisting of historical buildings, instruments, books and archival materials.[2]

About the eighty per cent of this heritage is kept in the astronomical observatories, but also some Universities (such as Bologna and Palermo), some prestigious museums (such as the Istituto e Museo di Storia della Scienza in Florence), and some private institutions (such as the Luxottica Museum in Agordo, near Belluno) possess or keep historical astronomical collections. Concerning observatories, the most ancient ones keep many beautiful and well-preserved 18th century instruments, made by famous instruments-makers of that time, such as Ramsden, Short, Sisson, etc. while the typical equipment of an Italian observatory in the middle of the 19th century consisted of astronomical instruments made by Reichenbach, Fraunhofer, Repsold, Merz and others.

The ancient observatories, built upon towers or palaces in the middle of the cities, have mostly preserved their original building and their historical architecture; a special mention is to be deserved to the Naples Observatory, located on the hill of the Capodimonte: it was the first architectural complex in Italy specially planned and built to be an astronomical observatory; it dates back to 1819, thus preceding the Pulkovo Observatory, established in 1839, which will serve later as architectural model for many observatories all over the world.

Many of the observatories established in 19th century have been moved to other sites – and the collections have been moved too. For example: the Turin Observatory collection is now kept at Pino Torinese; the instruments of the Arcetri Observatory are displayed at the Istituto e Museo di Storia della Scienza (IMSS) in Florence; the important collections of the two main Observatories in Rome (Collegio Romano and Campidoglio) is now splitted into the two current sites of the Rome Observatory at Monte Mario (which hosts also the remarkable collection of the Museo Astronomico e Copernicano) and Monte Porzio. It is to be mentioned the Catania Observatory, established in 1880, which was the first Italian astrophysical observatory, built on a mountain site (the Aetna).

The most recent Observatories possess instruments dating back to late 19th or early 20th centuries. Unfortunately, sometimes in the past, these instruments has not been considered as historical materials and a number of them has not been preserved, suffering loss or destruction.

25.3 Conservation and Preservation Activities

Since the 1980s an important effort has been made in preserving the collections kept in Universities and Ob-

Figure 25.2: *Italian observatories: Above: Brera Observatory Museum Milan (1764), Middle left: Palermo Observatory (1799), Lower left: Naples Observatory (1819), Middle right: Padua Observatory (1767), Lower right: Teramo Observatory (1882) (Courtesy of INAF, Istituto Nazionale di Astrofisica, Photo (Padua): Gudrun Wolfschmidt)*

servatories, thanks to a growing interest in the field of the history of science.

Following the example of the Brera Observatory in Milan, the first Italian Observatory to pay attention to its historical heritage, other Observatories decided to make inventories of their collections. In 1989 and in 1993, two national meetings were promoted by the History of Astronomy Working Group of the Società Astronomica Italiana to discuss the problems of the conservation of the historical astronomical heritage and in 1994 a proposal of classification for historical astronomical instrumentation was defined and presented at the Leiden SIC Symposium. Thereafter, the historical instruments in all the Observatories started to be inventoried and catalogued.

In 1999, the National Institute for Astrophysics (INAF) has been established with a unique central administration for the Italian astronomical research. INAF embodies all the astronomical Observatories and, since 2002, also the astronomical institutes of the National Research Council (CNR).

INAF Department 1 (Dipartimento Strutture) has been created to coordinate the activities of all the embodied institutions; it has activated four Services and one of them, established in 2005, is devoted to the INAF Museums. The INAF Museums Service has a Coordinator and a Working Group; it is aimed at: a) supervising the preservation of the historical instruments and buildings of INAF; b) promoting the making of inventories of the INAF historical collections; c) stimulating the Observatories in rendering accessible to the public their instruments heritage; d) if requested, advising the Directors of the Observatories in matter of historical instruments.

Once defined the aims of the Service, in June 2006, the Working Group promoted a workshop on the INAF Historical Instruments Heritage, held in Florence, thanks to the welcome of the IMSS. Representatives of all the INAF Observatories (except for Cagliari) attended the workshop and participated to the discussion, exposing problems and perspectives.

The map of the different local contexts has been updated in the workshop. The results have been encouraging: only four observatories had their collections not on exhibition; the others had museums accessible from the public. Two of them (Bologna and Palermo) keep instruments belonging to the University, while the instruments of the Observatory of Arcetri, near Florence, are on exhibition at the IMSS. The instruments of the Brera Observatory are merged with those of the University of Milan while, unfortunately, the astronomical museum in Rome is closed at present, because of space problems - its renovation and reopening is one of the most important steps to move for INAF. From 2006 to 2008, three more observatories have made efforts to exhibit their collections (this is the case for Catane, Turin and Trieste), and the situation has furtherly improved: by now, all the collections are fully or partially accessible from the public (see Table 25.1, p. 231).

Concerning instrument catalogues, the situation is encouraging too: almost the totality of the Observatories have produced both printed and online catalogues (see Appendix). This fact forms the evidence of a spread attention and sensibility to preserving and inventorying the historical instruments. Of course, the situation shows also several problems, both general and local. The main general problems are related to the lack of qualified staff – there is only one curator (in Padua) and two ex-curators, now researchers (in Palermo and in Rome) – as well as to the lack of adequate spaces, especially for the most recent observatories. Moreover, the inventory cards, where existing, are not homogeneous. From 2006 to 2008, two more collections have been catalogued (Turin and Trieste – these catalogues are not yet available), some collections need to be set on adequate exhibition (this is the case for Turin, where work is in progress – and Cagliari), and, above all, the astronomical museum of Rome needs to be re-opened and renewed.

Fortunately, there are also some resources: INAF has an annual budget for the restoration and the urgent interventions on his historical heritage (100.000 euros in 2008) and, at present, many museums are supported by local associations or by local government furnishing temporary staff.

25.4 From Specola 2000 to Astrum 2009

In 1999 the Ufficio Centrale Beni Archivistici of the Italian Ministry for the Cultural Heritage and Activities and the Società Astronomica Italiana launched Specola 2000, a project for the inventorying and preservation of the Observatories archives.[3] Specola 2000 started at the end of 1999 and is currently well-advanced on the whole: the arrangement of seven from the twelve archives of the Observatories has been financed either partially or totally; the general skeleton of the archives has been identified; the inventory of five archives is entirely or partially on line.

In order to carry on and to coordinate the efforts for the conservation of the historical astronomical heritage of the Italian Observatories, the INAF Museums Service Working Group intended to follow the outlines of Specola 2000 and in 2006 presented to the Ministry MuSA 2009, a project for the preservation and cataloguing of the historical instruments kept in the museums and collections of the Italian astronomical Observatories. Musa 2009 consisted of three phases:

1. To obtain homogeneous inventorying of all the instruments according to the "PST Catalogue Card" standards recently proposed by the IMSS and the Centro Universitario per la Tutela e la Valorizzazione del Patrimonio of Sienna (CUTVAP), and officially accepted by the Italian Ministry for the Cultural Heritage and Activities, and by the Central Institute for Cataloguing and Documentation (ICCD). The latter should have solicited the local

superintendents for sending specialized technical staff for compiling the cards, with the assistance of a local scientific supervisor.

2. To publish a printed and online catalogue of all the historical astronomical instruments kept in the Observatories.
3. To set a great central exhibition on the history of Italian astronomy, to be held in Rome in 2009, International Year of Astronomy, with historical materials taken from all the Italian Observatories. The exhibition would have summarized the main scientific achievements obtained in all the Observatories, or, at least, in the most important of them from a historical point of view. Unfortunately, the Ministry did not give support to Musa 2009 project and this hampered phase 1 from starting; phase 2 was consequently abandoned, while phase 3 was the only part of the project which did not depend from the carrying out of the other two phases.

Therefore, the project Musa 2009 was aborted, while the phase 3 of the project has developed into a new project: Astrum 2009, an exhibition of the Italian historical heritage in astronomy (instruments, books, archives), which will be held at the Vatican Museums from October 2009 to January 2010, thanks to the collaboration with the Vatican Observatory.

A second INAF workshop has been held in 2007 in order to coordinate the project. Actually, instruments from the major collections of the INAF Observatories will be on exhibition, together with items coming from other institutions. Except for the Museo della Specola in Bologna, also Universities collections such as those belonging to the Dept. of Astronomy in Palermo and Dept. of Physics in Bologna and Pavia, will lend some instruments, as well as private collections, such as Luxottica. In Astrum 2009, therefore, all kinds of institutions possessing astronomical instruments will be represented. The main aim of this initiative is that of giving visibility to the historical scientific collections in the Observatories and hopefully improving the current efforts in preserving the Italian astronomical heritage.

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Table 25.1: *The situation of the Italian Observatories' historical heritage in 2008*

Observatory	Year	Collection site	Museum	Catalogue	Current owner	Notes
Bologna	1711	Original building (Palazzo Poggi)	Yes	Printed and online	Uni-versity	The Observatory is currently located at the University Campus
Turin	1759	Moved from Turin (Palazzo Madama) to Pino Torinese	Collection partially on exhibition	Printed as internal Report)	INAF	A project for displaying the collection in the Morais dome is in preparation.
Rome	1760	Two current sites at Monte Mario and Monte Porzio	Yes (to be re-opened)	Printed	INAF	The Rome Observatory keeps the collections of the Collegio Romano and the Capitol Observatories
Brera-Milan	1764	Original building (Palazzo Brera)	Yes	Printed and online	INAF	A second site of the Observatory is located at Merate; some instruments are kept at the Museo Nazionale di Scienza e Tecnica
Padua	1767	Original building (Castel Vecchio)	Yes	Printed and online	INAF	A second site of the Observatory is located at Asiago
Palermo	1790	Original building (Palazzo Reale o dei Normanni)	Yes	Printed and online	Uni-versity	An agreement exists between INAF Palermo University; the conservation and the preservation of the collections is entrusted to INAF
Naples	1819	Original building	Yes	Printed and online	INAF	This is the first building expressly conceived to be an astronomical observatory
Arcetri-Florence	1872	Moved from the Observatory to IMSS	-	Printed and online	INAF	The collection has been donated to the Institute and Museum of History of Science (IMSS); only a few items are extant in Arcetri
Catania	1880	Moved from the ex-Benedictin monastery to the University Campus	Collection partially on exhibition	Online	INAF	This is the first astrophysical Italian observatory, conceived as a mountain observatory (with a station on Mount Aetna); the Observatory is currently located at University Campus; an observational station is located at Serra La Nave
Teramo-Collurania	1882	Original building	Yes	Printed and online	INAF	It was a private observatory, donated to the Italian Government by the owner V. Cerulli
Trieste	1898	Moved from Trieste to Basovizza	Collection partially on exhibition	No	INAF	The Observatory is still located in his original site (Castello Basevi); a second site, hosting the exhibition, is located at Basovizza
Cagliari	1899	Moved from Carloforte to Poggio dei Pini	(Virtual)	online	INAF	It was originally intended as a station for the International Latitude Service; the Observatory is now located at Poggio dei Pini

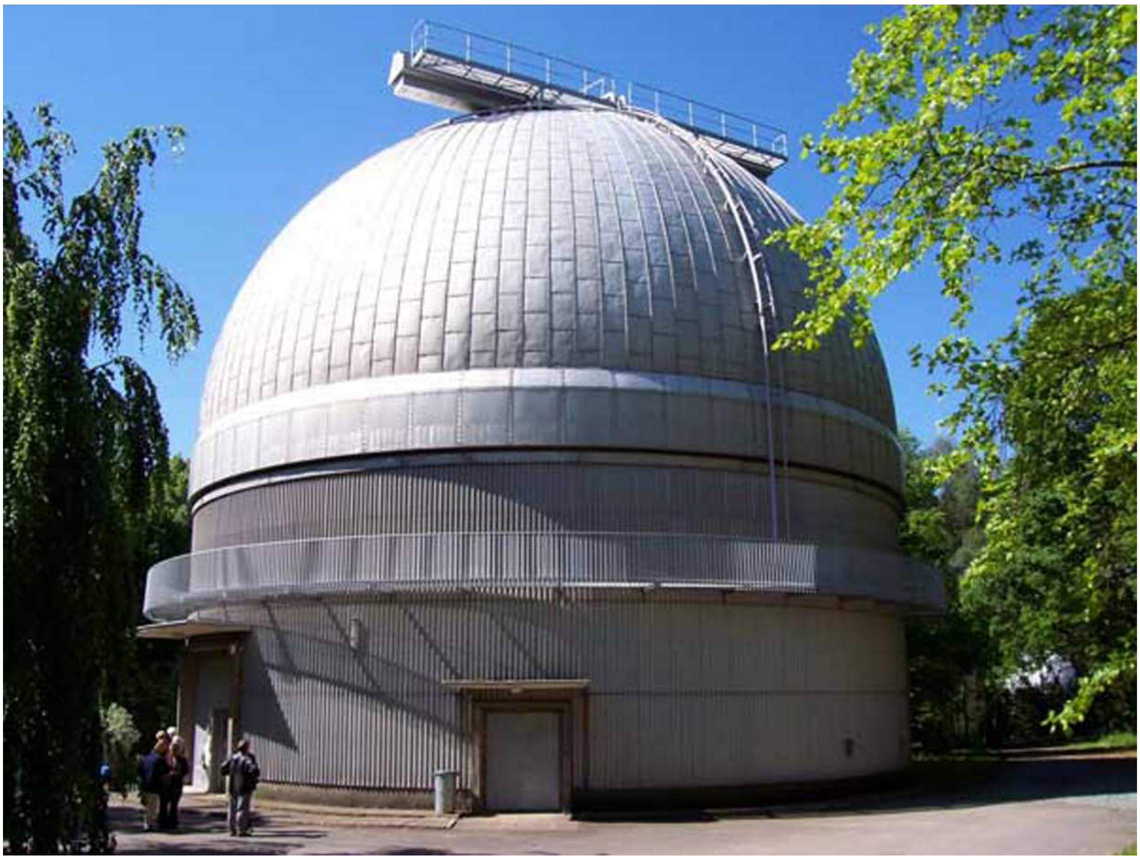

Figure 26.1: *Ondřejov Observatory, built in 1898–1925 by Josef Fanta; Below: Dome of the Schmidt telescope*

26. Prague and Ondřejov Observatory

Martin Šolc (Prague, Czech Republic)

Before 1900, only few astronomical observatories existed in Bohemia:

(1) The Astronomical Tower of Clementinum College in Prague was built by Jesuits in 1722, for daily observations reconstructed and equipped in ca. 1751–1755. After suppression of Jesuit order in 1773 it belonged to the state and its director became "Astronomer Royal". The main tasks were timekeeping, positional astronomy and education of university students. After split of the university onto national parts in 1882, the observatory was incorporated into the German part.

(2) Astronomical tower of Jesuit college in Komotau (now Chomutov). It served later to the town gymnasium, that is housed in the buildings of the former college.

(3) The private observatory of Baron John Parish von Senftenberg was situated in garden of his castle in Senftenberg (Žamberk). For scientific work, Parish invited Danish astronomer Theodor Ambders Brorsen. This well equipped observatory consisted of two domes, one intended for an equatoreal telescope and other for a meridian circle and geomagnetic and meteorological instruments. Unfortunatelly, the observatory existed only in 1846–1859.

(4) The observatory pavilion of the Czech part of the Prague university was built in the garden of the Czech Astronomical institute by professor August Seydler in 1888–1891. After 1900, the institute moved to Prague-Smíchov and a similar pavilion was erected on the new site, where it was in operation until 1949.

(5) The private observatory of Vojtěch Safarík, professor of chemistry and astronomy at Prague university had address Copernicus Street No. 1 in Prague-Weinberge.

(6) The private observatory in Ondřejov was founded on January 21, 1898 by Josef Frič, owner and director of a factory producing optical and fine mechanical instruments.

On this day, exactly one year after the untimely death of brother Jan, Josef Frič purchased a considerable area of land on and around the hill called Manda (528 m above the sea level), on border of the village Ondrejov, about 40 km south-east of Prague. Fric anticipated growing air and light pollution near the large town and so he looked for a distant site south of Prague, but within one day of drive by a horse team. The observations started in a provisional wooden shed in 1900–1901. The villa with laboratory and study rooms was inaugurated in 1905, two domes were built in 1908–1912. The architectonic style is an excellent Art Nouveau, designed by Josef Fanta (1856–1954), professor of Prague polytechnics, whose other famous works are Prague main railway station and Peace Memorial of Battle by Austerlitz. Two outstanding personalities inspired brothers Frič to devote the life to astronomy and to build an observatory – Jan Neruda, journalist, writer and poet, and professor Vojtěch Safarík (1829–1902), tireless observer of variable stars.

The west dome housed a double astrograph, developed in 1895–1915 by Josef Frič and František Nušl, professor of astronomy at Prague university. Both astronomers invented and constructed also an astrometric instrument called circumzenital and gained international reputation with it. The prototypes were installed in the small houses with tilt roofs. The central dome was equipped by a telescope with 8-inch objective lens made by Alvan Clark – from bequest of Safarík. Nušl administrated the observatory as director since the begining until the World War II.

In 1928, Frič donated the observatory to Charles University by occasion of the 10 years anniversary of Czechoslovak Republic. After the constitution of Czechoslovak Academy of Sciences in 1953, the Ondřejov observatory became the main part of the Astronomical Institute.

Wolfschmidt, Gudrun and Martin Šolc (ed.): "Astronomy in and around Prague." Proceedings of the Colloquium of the Working Group for the History of Astronomy in the framework of the scientific meeting of the Astronomische Gesellschaft (AG) in Prag, Monday, September 20, 2004, organized by Gudrun Wolfschmidt and Martin Šolc. Prague (Acta Universitatis Carolinae – Mathematica et Physica, Vol. 46, Supplementum) 2005.

Figure 27.1: *In the Stockholm old observatory, the main room for observations was the ground floor round central room oriented towards the south. Exhibited are from the left a John Dollond achromatic refractor, which belonged to Samuel Klingenstierna, and was bought in 1760, a quadrant by John Bird from 1757 and a gregorian reflector by William Cary c 1800. (Photo Helen Pohl)*

27. The Old Stockholm Observatory in a Swedish Context and an Argument for the Necessity of an Inventory of the Swedish Astronomical Heritage

Inga Elmqvist Söderlund (Stockholm, Sweden)

27.1 Swedish Astronomical Heritage

Sweden is endowed with a rich treasure of astronomical heritage. Since the end of the 16th century separate astronomical observatories were erected and were places of theoretical and empirical research related to astronomy. Particular architecture and specialized instrumentation has made these places distinctly different from other types of buildings. It is not unusual that an observatory would be included as a prominent feature on cityscapes or be represented as one of the most important buildings in the city. As such the observatory became a symbol of a learned society and its representative function had as a consequence that large sums were invested and prominent architects commissioned.

This article is concerned with astronomical observatories of the modern period, from the end of the 16th century to the 20th. The main focus is on the old observatory in Stockholm, due to its historical importance, and being the oldest separately build observatory which is fairly intact. There is no comprehensive study of Swedish observatories, their instrumentation, and present status of the heritage as whole in relation to the scientific activities that went on there. However, I would like to mention three studies of prime importance in this respect: Nordenmark's *Astronomiens historia i Sverige intill år 1800*, which treats the period up until 1800, Holmberg's *Reaching for the stars: Studies in the History of Swedish Stellar and Nebular Astronomy 1860–1940*, for a later period, and the most comprehensive account on the buildings found in Kristenson's *Vetenskapens byggnader under 1800-talet: Lund och Europa*, for the period up until 1900.

27.2 The Stockholm Old Observatory

The Stockholm old observatory was founded in 1748 and inaugurated in 1753. It is the oldest observatory in Sweden which still in use, today however only for museum purposes and by amateurs.

The idea of a new observatory in Stockholm originated from Pehr Elvius the younger, who had been a student of Anders Celsius at Uppsala. He was astronomer and secretary general to the Royal Swedish academy of sciences. The architect Carl Hårleman, who had already been acquainted to the task of making an observatory at Uppsala a few years earlier got the commission to design the first own building of the academy. At the time of the decision Hårleman was also conveniently president of the academy. As an architect he is the main representative of Swedish rococo.

The building was placed on top of a hill, outside of the city, but well visible from it. This was the first time that a secular building for scientific purposes was granted such a prominent place. The location, the visibility and the architecture was a statement of the importance of the academy and of astronomy.

The ground plan shows a rectangle with a central round room with three windows protruding towards the south, and entrance from a courtyard in the north. Added to the rectangle are two small rooms to the east and west. The central square consists of three floors, and a basement. On top of a the building was placed a small turret. The main location for observation was the central room on the ground floor, besides the meridian room in the room farthest to the east. The observatory housed not only working space for the astronomer, but also on ground level the cabinet of naturalia, library, archive and in the basement a work-shop for instrumentmaking. The living quarters were on the second and third floors.

In Swedish architectural history, the observatory has mainly been regarded as an example of the rococo, and an outstanding work of Hårleman. Comparisons have been made with secular countryside residences, especially the Villa Rotunda and the French tradition of the *Maison de plaisance* as well as churches.[1] However relevant such comparisons might be, the form as an observatory in relation to other such contemporary buildings have not been properly investigated.[2] Conform to the temporary ideal image of an observatory it is a squarish building placed on top of a hill, in front of which it was possible to make outdoor observations. The building also contained other functions which corresponded to

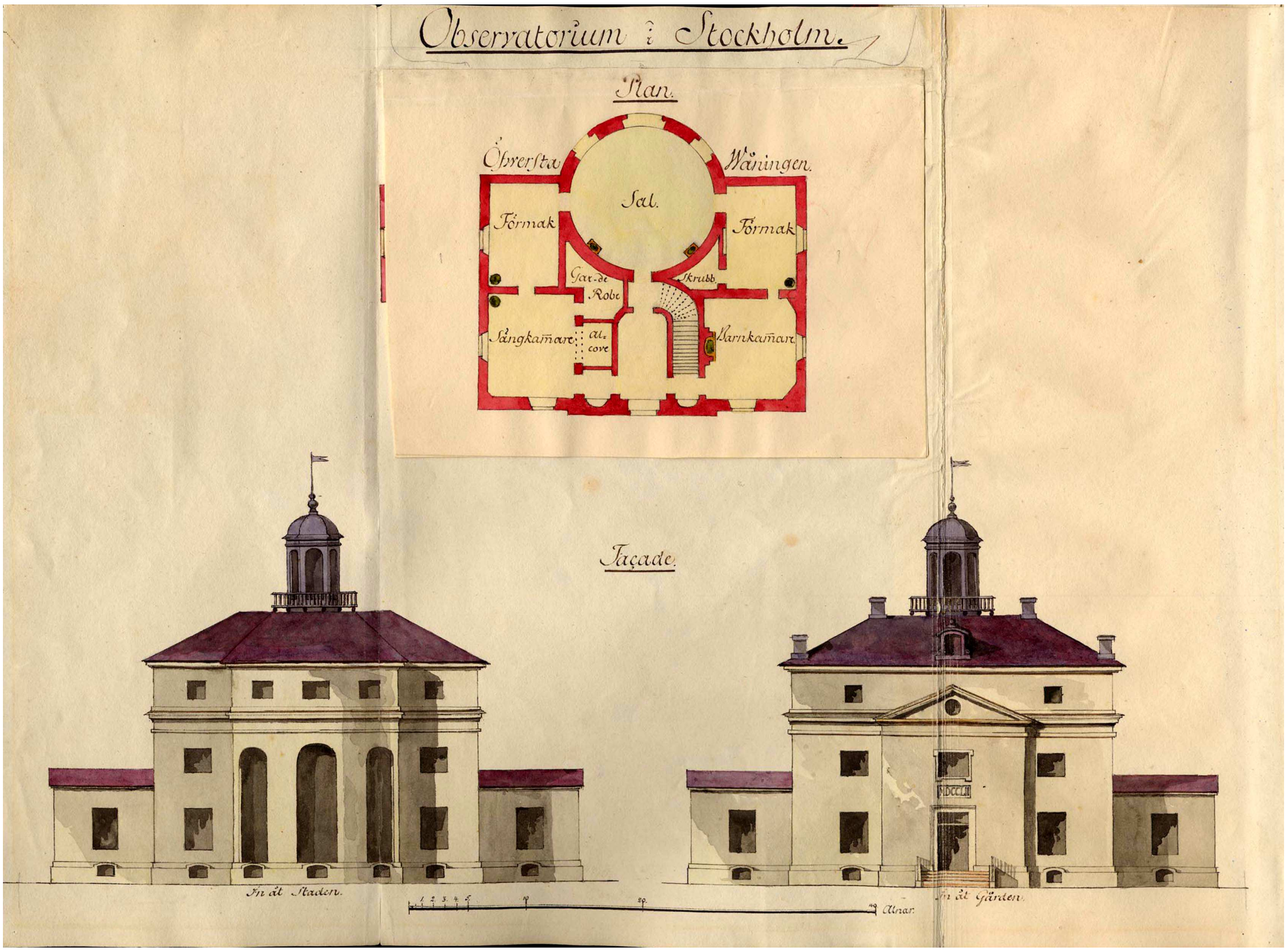

Figure 27.2: *Drawing of the old observatory Stockholm, made by Olof Tempelman in 1797. The architect was Carl Hårleman, and the building was inaugurated in 1753. (Center for History of Science at the Royal Swedish Academy of Sciences)*

the ideal understanding of what an observatory should be: rooms for meetings, library and other collections, living quarters and initially rooms for physical experiments were also planned.[3] In one aspect however, the Stockholm observatory differs: it is not a tower. Here Hårleman set a new trend, which later becomes the usual observatory design.

The otherwise excellent inventory of observatories by Peter Müller enigmatically excludes the Stockholm old observatory. This is odd in that he also treats the architect Simon Louis Du Ry, who designed the Kassel tower observatory connected to the Fridericanum. Müller mentions that Du Ry was educated mainly in Paris and Italy, and it seems the observatory at Bologna was a source of inspiration.[4]

The architecture shows obvious relationships to the Bolognese observatory, but yet, it is not irrelevant that Du Ry had had been involved as an apprentice of Hårleman in Stockholm between 1746 to 1748, where he specifically sought to learn the skills of architectural drawing.[5] One of his tasks had been to draw a fair copy of Hårleman's designs for the Stockholm observatory.[6] Such connections need be further elucidated.

It is however also possible that the Stockholm observatory is omitted because it does not fit in Müller's understanding of the historical development of observatory design. As the Stockholm old observatory was constructed before it became fashionable to make ground floor observatories it does not fit Müller's time line. He writes that the first such observatory was the one at Richmond designed by the architect William Chambers.[7] It had been erected to accomodate for the transit of Venus in 1769. It is probable, that Chambers, born in Sweden and a member of the Royal Swedish Academy of sciences, knew about the design of the Stockholm observatory. Certainly he corresponded with the director of the observatory, but there seems to be no conclusive evidence that the design of the observatory in Stockholm was discussed in the preserved correspondence.[8]

As many observatories at this time, part of the motives behind the construction and funding was the navigational applications. The first responsible astronomer was Pehr Wargentin also secretary general of the academy of sciences. He was already internationally renowned when he came to Stockholm due to his published tables of the movements of the Jovian satellites. He continued his work with these and among his exten-

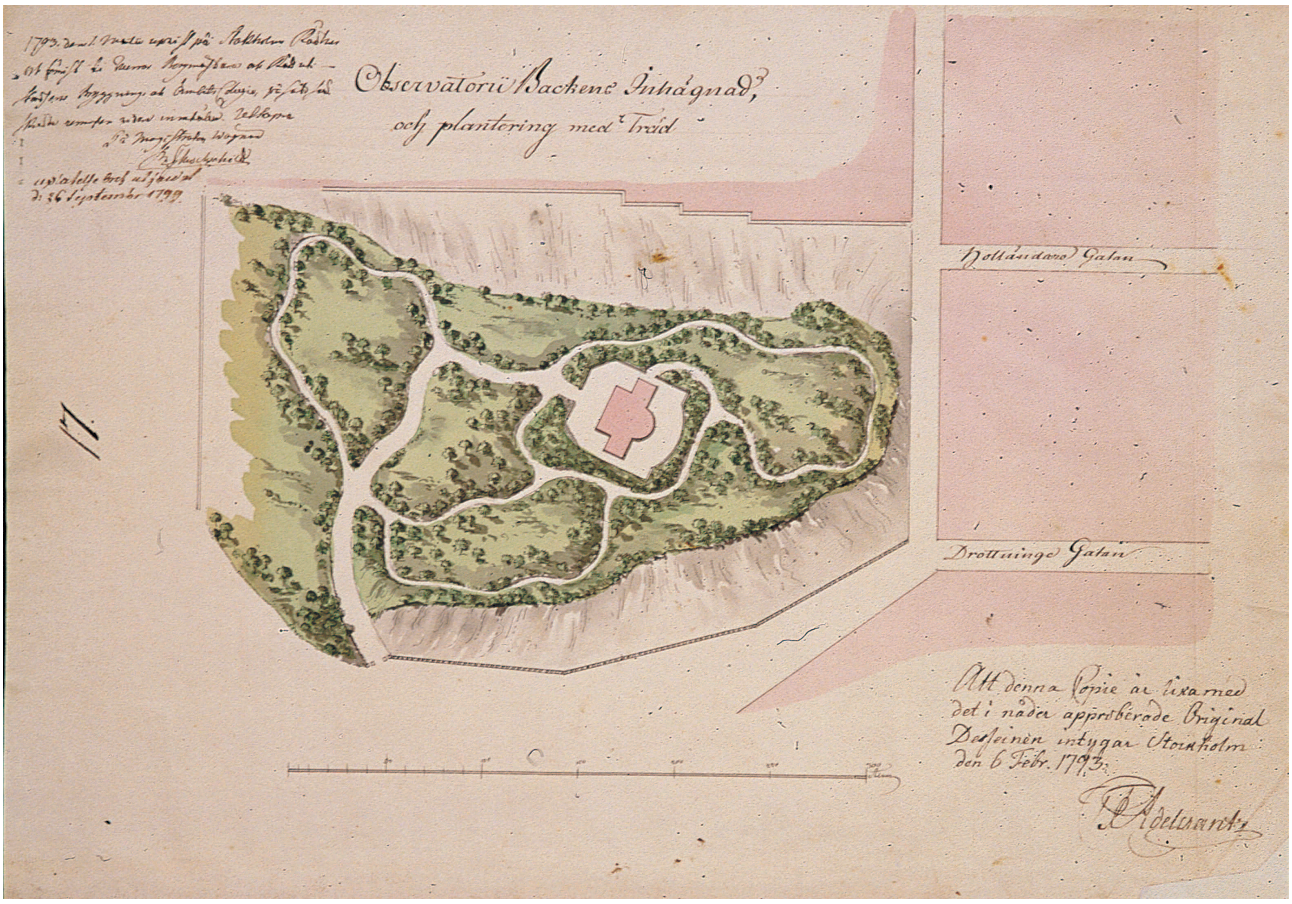

Figure 27.3: *Designs for an English landscape park around the old observatory Stockholm, made by J. F. Adelcrantz in 1793. (Center for History of Science at the Royal Swedish Academy of Sciences)*

sive preserved corresondents were Lalande, who published his tablesin his revised edition og Halley's tables. They were also published in German accounts and in the *Nautical almanach.*[9] The large amount of preserved correpsondence in the archives proves international exchange of observational results and experiences, besides other matters concerning an academy of sciences. The organisation of the national undertakings for the observations during the transits of Venus in 1761 and 1769 were such moments when international cooperation was essential. Swedish astronomers were gaining self confidence, being able to play on the international arena and contribute with valuable research and gaining esteem from abroad.[10]

In the beginning the observatory seems to have been rather void of instruments. A note from Wargentin's dairy even states just after the inauguration that there was no instrument to observe with, but that he instead had to use his plain eyes. This must be an exaggeration. He must have brought some instruments with him. Already before the observatory was built, a few instruments were acquired as gifts, e. g. a two foot reflector and a telescope from Hevelius workshop, now lost. They were probably too old and useless. The first preserved inventory dates from 1775. For the time preceding this year numerous receipts, observational journals, protocols from meetings and the published transactions still makes it possible to get a fair view of the instrumentation.

Besides the astronomer Wargentin, the skilled instrument-maker Daniel Ekström also resided at the observatory. He had had his training in Sweden and England, where he came in contact with among others George Graham and Jonathan Sisson. He also went to Paris, but sources are scant about his whereabouts. Abroad he learned the difficult task of dividing the circle. Ekström was involved with producing instruments for export abroad and for other users within Sweden. Unfortunately he suddenly died. At the death of Ekström, the workshop was divided between his apprentices. Carl Lehnberg took care of the optical workshop and made the first achromatic lens in Sweden in 1760. The other part of the workshop was divided between Johan Ahl and Johan Zacharias Steinholtz. The quality was not satisfactory and they could not cooperate. The workshop was moved away from the observatory. Ahl left for Denmark, where he made a successful career as producing instruments for the observatory in Copenhagen.[11]

Since the followers of Ekström were not considered accomplished enough, Wargentin turned to England to find replacements: A quadrant from John Bird was ordered in 1756 through the agent John Ellicot. In the first inventory it was listed as the far most expensive

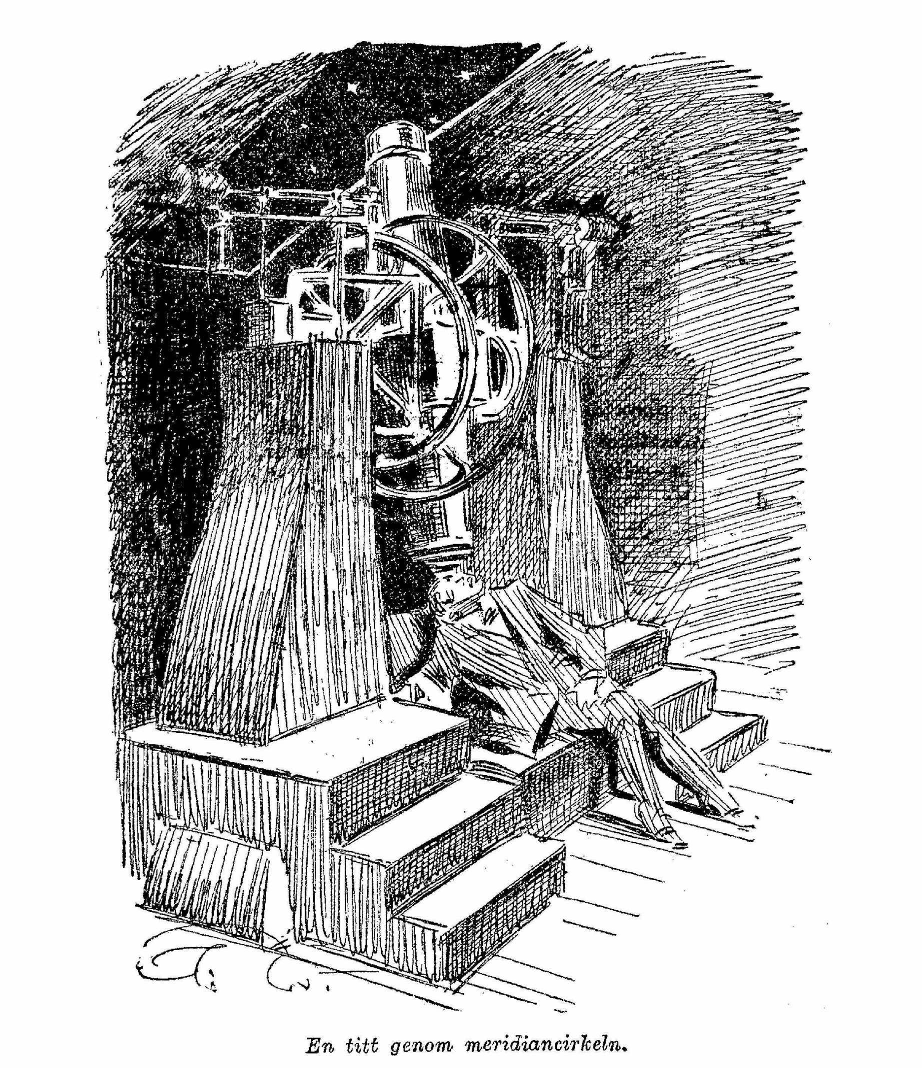

Figure 27.4: *A man observing from the western meridian room with the meridian circle by T. L. Ertel from 1830. The instrument is preserved and exhibited in its original setting at the Observatory museum Stockholm. (Center for History of Science at the Royal Swedish Academy of Sciences)*

instrument. The extensive archives of the academy also contains a letter from Bird which specifies the use, and upkeep of the instrument. The member of the academy Bengt Ferrner visited the studio of Bird in London in 1759 to see whether also a transit instrument could be ordered, and it was decided on a three foot transit telescope. From the mathematician Samuel Klingenstierna a ten foot achromatic tube made by John Dollond could also be obtained. Klingenstierna and Dollond had at first been on friendly terms in correspondence concerning the possibility of an achromatic lens, but later became involved in a priority dispute.[12] The still preserved Dollond's achromatic refractor was an excellent aid in Wargentins study of the Jovian Satellites. A smaller achromatic refractor was also bought from Dollond.[13]

Wargentins diary states that the daily observations were made to correct the clocks. The corrections are very carefully noted with considerations of temperature, whether the clock had been cleaned, if the pendulum has to be prolonged or shortened. A meridian was carefully marked out. Several clocks were ordered from the Stockholm clockmaker Nylander. One of them is still in the collections and on display in the old meridian room. New and more precise clocks were ordered from the Swedish clockmaker Peter Ernst. He seems to have taken care to copy a George Graham clock.

After the transits of Venus in the 1760s no great new orders were made until a seven foot Newtonian reflector was ordered from William Herschel in 1788. By this time the observatory had a new director, Henrik Nicander. During the 19$^{\text{th}}$ century the directors Jöns Svanberg, Simon Anders Cronstrand and Nils Haqvin Selander were all interested in geography and topography. Work was done with fundamental astronomy and to chart accurate star positions. One of the expeditions prepared from the observatory was the one to Lapland in 1802 to 1803, led by Svanberg, questioning the results of Maupertuis measurements from 1736. Later, Selander participated in the measurements for the Struve geodetic arch. He was responsible for the measurements between Torneå and

Stuor-Oivi. Several still preserved portable instruments were bought for these expeditions.[14]

In the 1820s the quadrant of John Bird was taken out of use and new instruments were ordered from a five foot transit from Reichenbach & Ertel in Munich with a lens from Utzscheider and Fraunhofer and a transit circle from Ertel with a Merz objective. The meridian was moved and a foundation was made to stabilize the position of the instruments. In the 1830s a new building adjacent to the courtyard was erected on the initiative by Fredric Rudberg. It was built to house magnetic experiments and was constructed without any magnetic material. In the 1850s the transit circle from Ertel was fitted with A. & G. Repsold microscopes reading seconds. The instruments are placed in the original room in the western meridian room. Stockholm local time was determined at the observatory. In 1879 standard time was introduced. The Swedish standard time was defined as one meridian, three degrees west of the meridian of the Stockholm observatory, in between Stockholm and Gothenburg. Telegraphical signals were sent from the Stockholm observatory, where time was established. Regulator clocks were needed. A Cope & Molyneux clock with a compensated pendulum with mercury made in London about 1825 was used. It was placed in the "clock-room" nearby the meridian room. A regulator clock made by Kessels in Altona in 1839 was commissioned and used as sidereal standard until 1932. These instruments are at present all exhibited in their original location in the museum.

Under the professor Hugo Gyldén, appointed in 1871, the observatory was reshaped. Gyldén had studied in Helsinki, studied and worked in Gotha, and at the Pulkovo observatory. It was probably one of the observatories he had seen during these years, uncertain which of them, that inspired him to have the observatory changed with working spaces in a northern extension and a tower with space for a refractor at the top. The commissioned architect was Johan Erik Söderlund, but due to his untimely death, H. G. Sandels and Frans Gustaf Abraham Dahl continued the work.

A refractor was ordered in 1875 from Repsold & Söhne in Hamburg, with a Merz lens of a diametre of 18,9 cm, mounted equatorially with a clockwork. A portable transit instrument from Repsold was also bought to determine geographical longitude with the help of the electrical telegraph.

Gyldén attended the astrophotographical conference in Paris in 1887. At this time the dry gelatine plate had diminished the needed time for exposure, which made photography more interesting for astronomers. Soon an astrophotographical objective was bought from Steinheil & Söhne in Munich. It was tested with success, and parallax measurements on the photographical material could begin.[15] A number of photographical equipment was bought from the bove mentioned makers but also Carl Zeiss in Jena, Voigtländer, Krüss and the Swedish maker P. M. Sörensen. A photographic laboratory was also established. Besides a number of precision clocks and calculating machines were acquired.[16] Thanks to the preserved published accounts and archival material all acquisitions can be followed.

Gyldén contributed to the photographic use of astronomy, but also to theoretical work in the fields of the motion of the comets, and specifically the perturbation theory of the planetary motions. He worked within stellar statistics measuring the luminosity of the stars, and their distances and motions. He was also engaged as the chairman of the *Astronomische Gesellschaft* from 1896 to his death.

During the professorship of Karl Bohlin, appointed in 1897, the growth of Stockholm presented increasing difficulties. Light pollution and traffic near the observatory hill was problematic. The observational activities continued, and a few new instruments were acquired. The kind of observations that Bohlin published were eg drawings of the planet Mars in 1909–1912 in the heat of the debate of the canals of Mars. He also continued theoretical work on the perturbation theory.

For the eclipse of the sun in 1914, visible in northern Sweden, preparations were untertaken in Stockholm. The main interest was to investigate the corona, which it was possible to photograph. Parliament granted a fund to buy instruments for meteorological, magnetic and electric measurements. A 10-inch Carl Zeiss reflector with a Spectrograph was bought. After the eclipse the instrument was mounted in a newly constructed pavilion north of the observatory. This was the last larger acquisition to be made for the astronomers at the observatory hill. The expedition was planned by Vilhelm Carlheim Gyllensköld, assistant at the observatory. He later organised the historical collections and was the driving force behind the Museum of the exact sciences, a museum which never opened its doors to the general audience. It is this collection that is the foundation of the Royal Swedish academy of sciences. As concerns scientific instruments, it could be considered the foremost as concerns the period from the 18th to the 20th century in Scandinavia. It contains about 6000 inventorie numbers of scientific instruments.

In 1927 Bertil Lindblad was appointed as the new director but now work was concentrated on equipping the new observatory in Saltjöbaden outside Stockholm.

The area around the observatory had become associated to learning. Therefore a number of institutions were placed around the observatory hill around the year 1900. The Stockholm university was only one of the institutions that had buildings erected below the hill (Royal institute of technology, Stockholms school of Economics, the city library). In the 1930ies the astronomers moved out and the Geographical institution moved in. The institution remained there until the 1980ies, when moving to a new university campus at Frescati. When moving out to Saltsjöbaden, the Royal Swedish academy of sciences sold the observatory to Stockholm city in order to finance the building of the new observatory. Different possible usage was discussed. Stockholm city was about to sell the observatory to

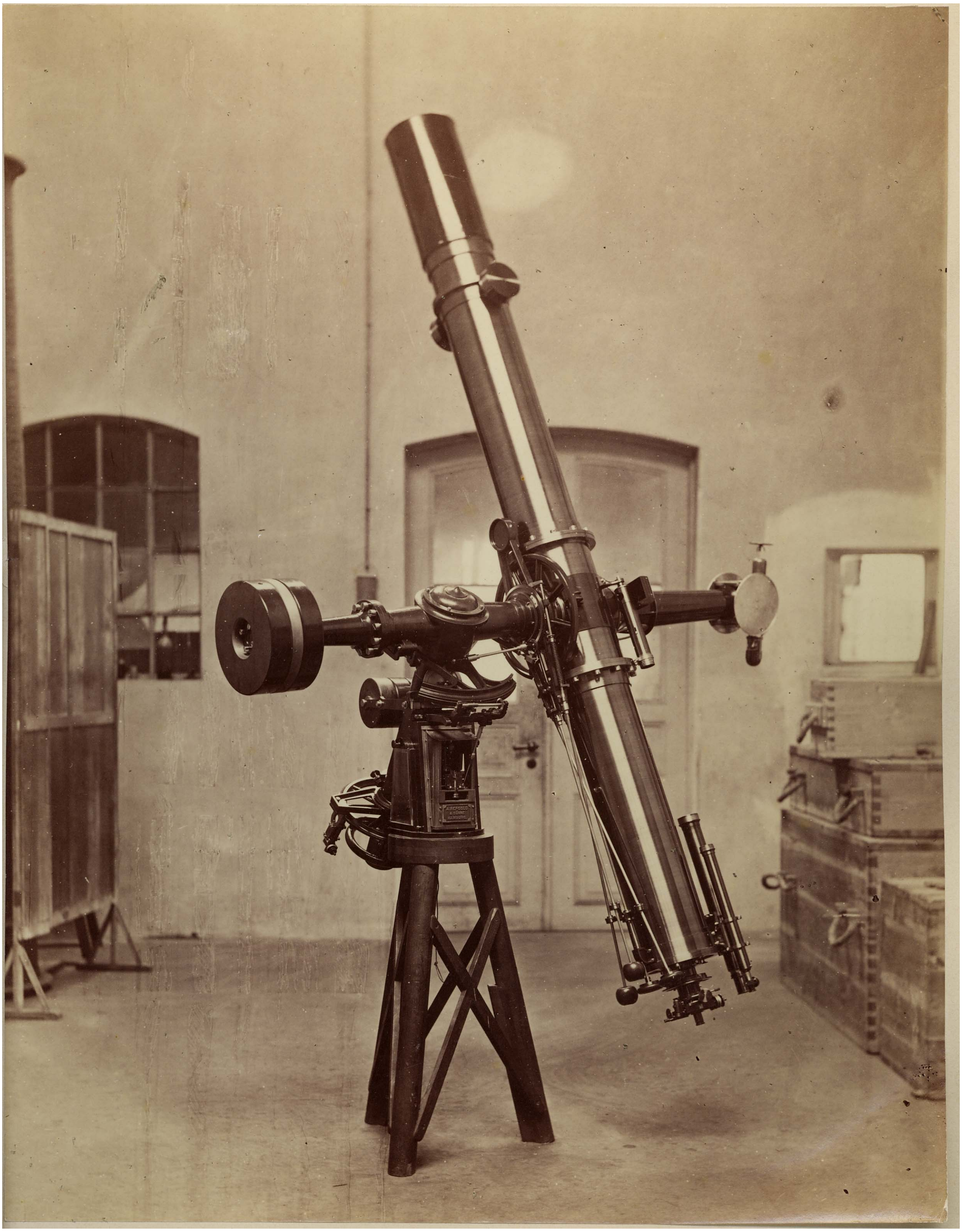

Figure 27.5: *In 1877 a refractor ordered from A. Repsold & Söhne with an objective from Merz was mounted in the new tower at the old observatory in Stockholm. The instrument is preserved, but not on display. In its original place is a user-friendly Zeiss refractor from 1910 which is used for public observations and by amateur astronomers. (Center for History of Science at the Royal Swedish Academy of Sciences)*

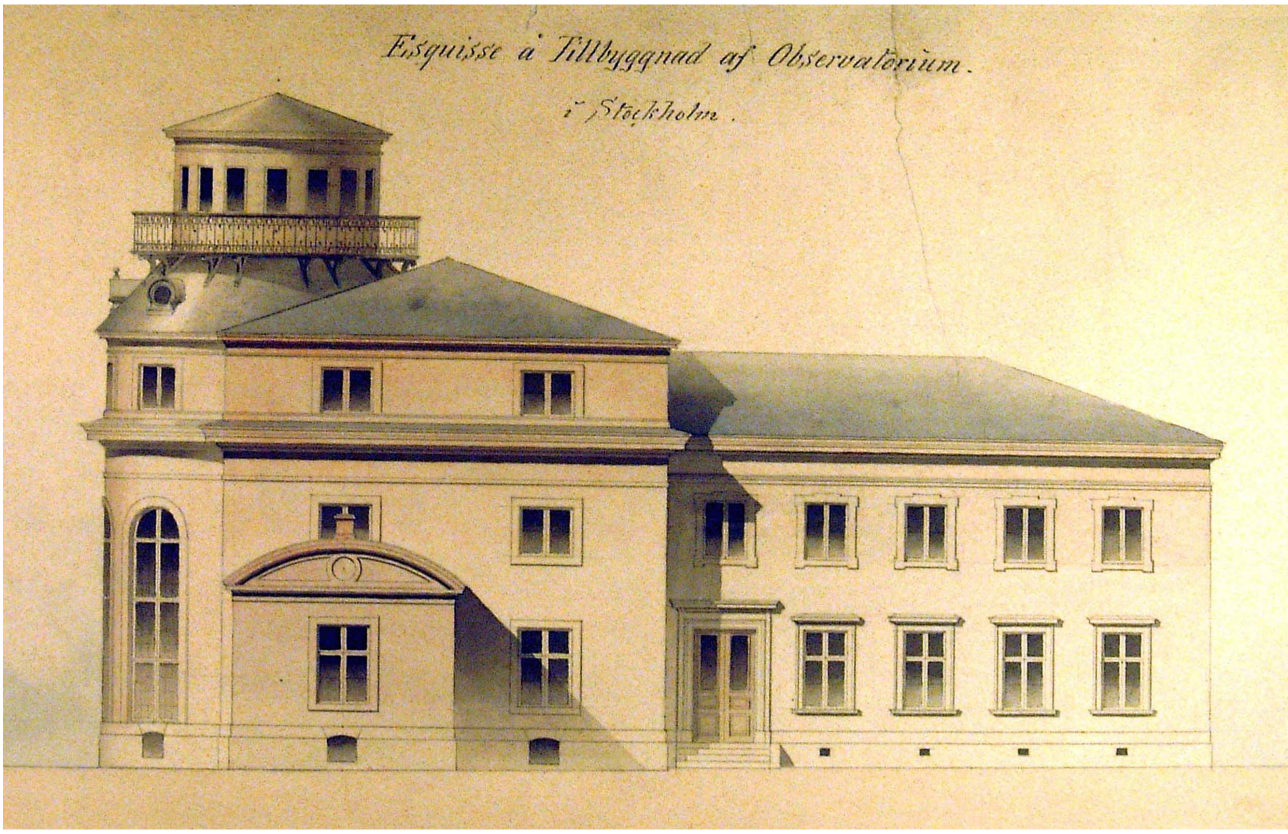

Figure 27.6: *In the late 1870s, the old observatory in Stockholm was extended towards the north and with a tower for a refractor on top of the 18th century building. The architects were Johan Erik Söderlund, H.G. Sandels and F.G.A. Dahl. (Center for History of Science at the Royal Swedish Academy of Sciences)*

the Moslem society so that it should be transformed into a mosque. If there were any ideological or strictly economical motives behind this move is uncertain. The vaulted dome of the round observation room has a sacral atmosphere, and was presumably alluring as a place of religious cult. However this change in the usage of the building was not desirable by the scientific community. And an initiative from several museums and universities found a museum as a private foundation. A museum of Swedish history of science was opened in 1991, and it is now run by the Royal Swedish academy of sciences.[17]

27.3 Other Observatories in Sweden

The Observatory of Stockholm did not emerge from a vacuum, but had several important precedents and followers, of which the main observatories will be mentioned here.

27.3.1 Uraniborg/Stjerneborg – Vhen

The combined castle and observatory erected for Tycho Brahe at Vhen can as by John Robert Christianson (or Victor E. Thoren or Owen Gingerich) be regarded as the place where European "big science", founded on empirical research, was born. From all over Europe came scientifically interested and Tycho could establish a household of the sciences and the arts. The site contained a castle with living quarters, a "museum", and towers for astronomical observation, an alchemical laboratory, a renaissance garden with a subterranean observatory, a printing-shop and a paper-mill with a system of dams to serve the mill. Observations essential to the development of European astronomy were made here. In the work-shops important instruments, works of art and books were produced. The castle, erected 1576–80, was dedicated to Urania and soon became legendary. Tycho abandoned the island in 1597 and it was soon ruined. Despite (or perhaps because of) its ruined state published accounts such as Joan Blaeus *Atlas Maior* (1665) praised and spread the exceptional beauties and treasures of this Utopian place of the arts and sciences. Already during the 17th century it became a place of scientific minded pilgrimage.

The area is listed as a monument (fast fornlämning) and the owner is the National property board, whereas the exhibited objects related to the excavation are the property of Lund university museum. The remnants at Vhen became a matter of regional, national, astronomical and historical identity. Among others the astronomer Carl Vilhelm Ludwig Charlier had been involved in excavations in connection to the 300 year remembrance of Tycho's death in 1901, but the remnants had been covered with sand. In 1929–31 a small building for museum purposes was erected on the grounds. For the 350 years remembrance, the National committee of

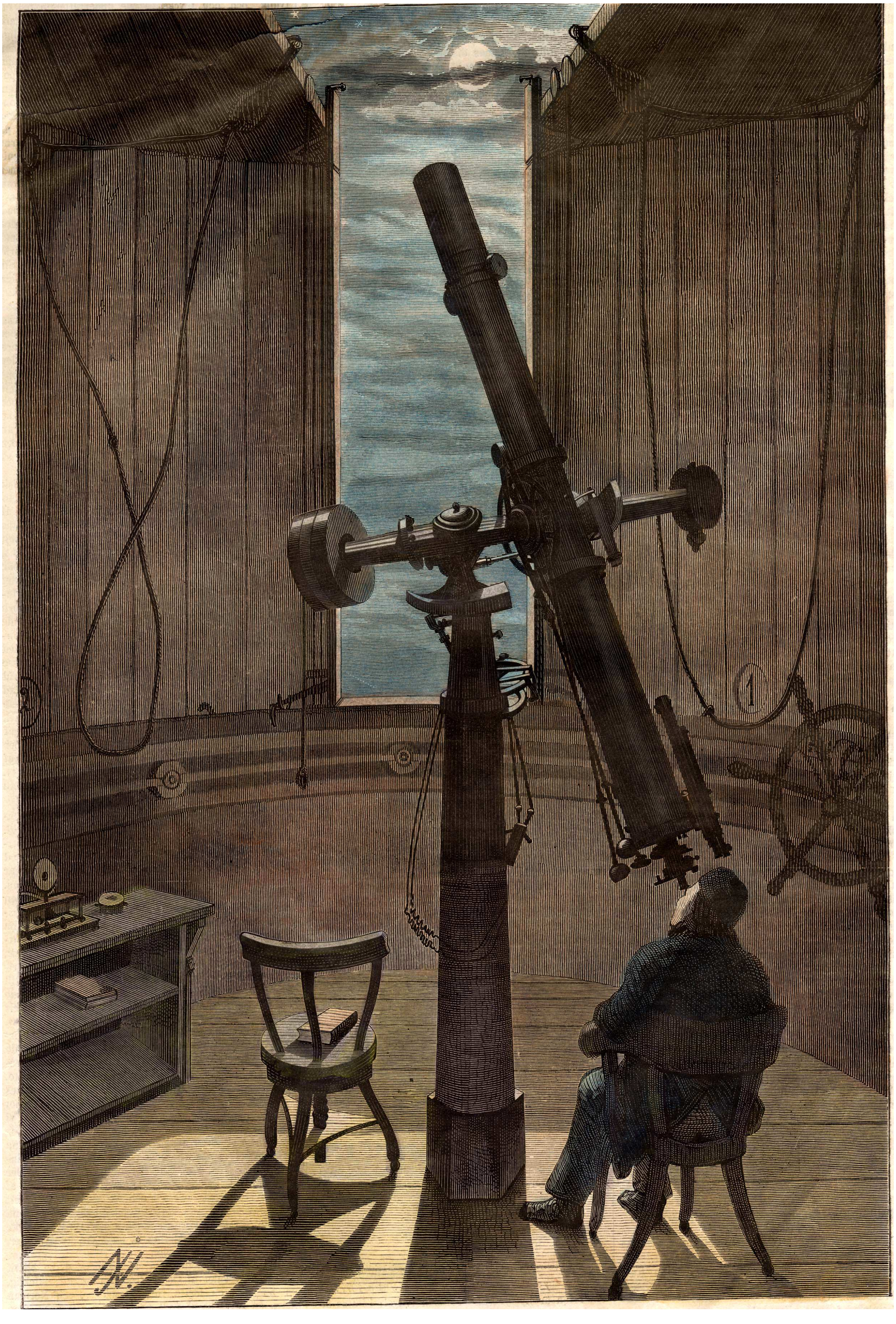

Figure 27.7: *Observation of the moon with the Repsold refractor from the tower, Stockholm old observatory. Nils G. Janzon in Ny illustrerad tidning, 1877. (The observatory museum)*

Figure 27.8: *The old observatory of Stockholm. O. A. Mankell in Ny illustrerad tidning, after 1877. (The observatory museum)*

astronomy with support of the Royal Swedish academy of sciences urged the National board of antiquities to excavate the area and cover it with concrete in order to protect it. They also recommended that it should be made accessible to visitors.[18] In 2005 a new museum in the nearby neogothic church, converted for museum purposes was opened. The museum is important for the tourist industry in the area and has about 40,000 visitors a year.[19]

27.3.2 Uppsala

Uppsala university was founded in 1477. There had been some temporary observing places during the 17$^{\text{th}}$ century. Bengt Hedraeus, who also wrote on the ideal structure of an observatory, had constructed a platform for observation, but as far as we know, the observatory there was never finished and it is not preserved. It seems he was the first to establish a work-shop for mathematical instruments.[20]

On top of an already existing medieval structure, Anders Celsius had the first larger separate observatory built, "Celeiushuset". The architect Carl Hårleman was commissioned. The building consisted of three floors. On top was a tower for observations crowned with a celestial globe. Unfortunately this tower was torn down, but the lower part of the building is preserved. The university now owns the building, but the lower floor houses a shop.

A new observatory was erected in 1844–1853. It was designed in collaboration between the professor of astronomy Gustaf Svanberg and John Way, "ritmästare", but these drawing were changed by the state authorities. The first instrument was a refractor from Steinheil in Munich from 1860. In 1890 the tower was rebuilt and the refractor was in 1893 replaced with a double refractor, with the visual and photographic parts from Steinheil and the mechanics from Repsold.[21] This instrument is still in use by amateur astronomers and for the general public. Work was mainly performed by Herman Schultz for the "New General Catalogue of Nebulae and Clusters of Stars", and Nils Dunér specifically moved forward with spectrographical observations. Other astronomers who contributed were Hugo von Zeipel, Gunnar Malmquist, Östen Bergstrand, and Erik Holmberg.

The astronomical institution moved in the year 2000 to Ångströmlaboratoriet. Into the observatory moved the Department of Education. In the move, the university museum, Gustavianum, was consulted, and a few instruments were transferred to their collections. The astronomical institution is however still the proprietor and responsible for a great number of instruments related to the history of astronomy in Uppsala.

To Uppsala university also belongs the observatory of Kvistaberg, originally a private observatory from 1818, with later additions. These premises are still used for astronomical research.

27.3.3 Lund

Lund university was inaugurated in the 1668. The first observatory was in a tower in the house of the professor of astronomy Anders Spole. The roof was constructed in such a fashion that all sides could be opened, but the observatory is not preserved. In 1753 an already existing building, Lundagårdshuset, was foreseen with a roof-top observatory.

In 1865 to 1867 the first free standing purpose-built observatory was erected. The building was planned by the astronomer Axel Möller, the building entrepreneurs P. C. Sörensen and F. G. Escher, and the facade designed by Helgo Zettervall as a medieval brick fortress. On the grounds were also erected a building for the astrograph, movable on rails, a subterranean building for the seismograph, and living quarters for the janitor on the grounds. Another building, the calculating house (räknehuset) was erected in 1911–12 designed by the architect Henrik Sjöström.[22]

Old instruments were brought from Lundagårdshuset, but a new refractor constructed by Jünger in Copenhagen with optical parts from Merz, with a clock drive by C. V. Holten, was mounted in 1867. A meridian circle by Repsold was mounted in the 1870s. A seismograph was ordered from Georg Bartels of Göttingen. Important contributions were made by Carl Charlier in his work on stellar statistics, galactic structure and cosmological theory, followed by Knut Lundmark, who studied the galaxies and their distances.

In the 1960s a new place for observations outside Lund was erected, at Jävan. The institution within Lund moved to new premises in 2001. All the instruments were cleared from the old building, as it changed ownership to the community of Lund. As far as I could gather, it is the astronomical institution which is responsible for their documentation and care, and a few of the old instruments are on exhibit at present in the new building. Nearby the new brick building is a water tower, with a small cupola mounted on the top.

27.3.4 Saltsjöbaden

In 1931 the Stockholm the new observatory in Saltsjöbaden south of Stockholm was inaugurated. The architect was Axel Anderberg. The main building was put on an elevation with surrounding smaller buildings for different instruments as well as a work-shop and living quarters for the staff. The donors (Knut och Alice Wallenbergs stiftelse) behind the new observatory added the condition that it should be called Stockholm observatory, hence there are now three places with the same name, which is a matter of confusion (the old Stockholm observatory, the observatory at Saltsjöbaden, and the present university institution at Alba nova).

The largest instrument was a double refractor, placed on top of the main building in a dome of eleven meters diameter. It was ordered from Grubb, Parsons & Company, from where a reflector with a mirror of one metre diameter was also ordered. The latter was put in a dome of the same size, but in a separate building. An astrograph from Carl Zeiss was also installed. In 1960 the "Schmidt telescope" was added. There had also been a now removed radio telescope. This equipment made the observatory at Saltsjöbaden one of the better equipped at the time being. The work and instrumentation was thoroughly specialised for astrophysics. The research undertaken under the leadership of Bertil Lindblad was mainly concerned with the properties of stars which would elucidate the structure of the Milky Way, and the rotation of the stellar system. The theoretically informed observational astronomy became fashionable. The international outlook had changed. During the 19th century, Swedish astronomers had collaborated rather with Russian or German colleagues, but now moved westwards to America.[23]

The institution moved to new premises at "Alba nova" in 2001. The larger fixed instruments remain in their original cupolas, but as to their future usage it is uncertain. The buildings are the property of the National property board, but are let to a school which had the buildings converted for accommodated usage.

27.3.5 Other buildings

The usage of churches and other types of buildings in Sweden are as far as I know largely unknown. For example, the tower of Strängnäs Domkyrka was rebuilt after a fire in the 18th century, there is a note, that a balcony should be erected. A gallery or platform at the top was proposed in order to decorate and serve as a place for astronomical observations.[24] I have already mentioned a few private and school observatories. Other examples are Nya Elementar (Stockholm), and Lundsberg (Lungfors). Smaller observatories and their collections still needs to be investigated.

The Radio observatory Onsala was founded in 1949, and is still in active use. Its huge radio telescopes dominate the landscape. A rocket range and research center, *Esrange,* is situated in Kiruna. It was built in 1964.

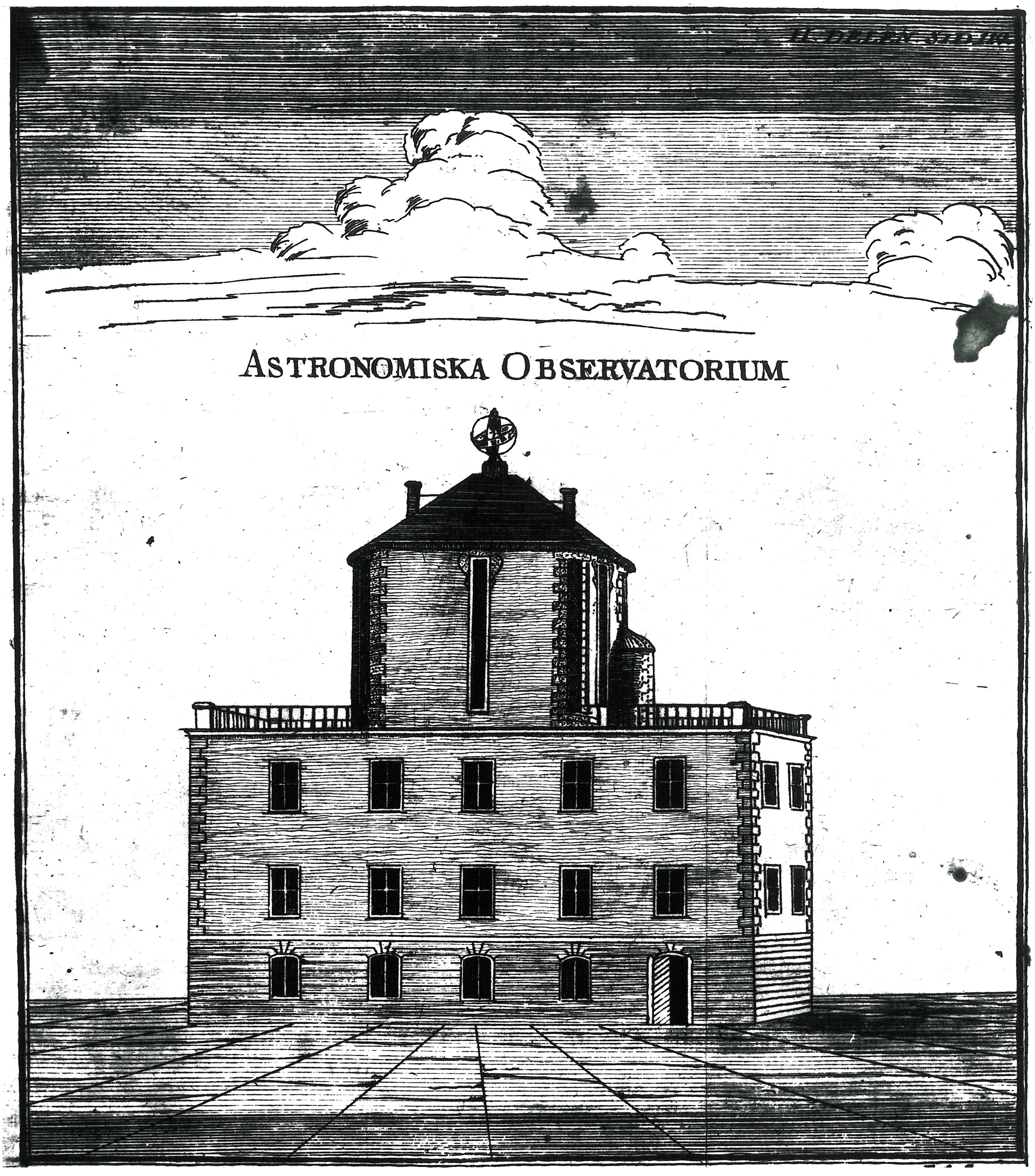

Figure 27.9: *Uppsala university observatory*

Figure 27.10: *Lund observatory (1867)*

27.4 Swedish Heritage Legislation and Protection

The astronomical heritage can be classified within several different types. Depending on whether it concerns an archaelogical site, a building, a park, an instrument or other types of inventories, printed, archival or research material and on the status of the owner of the property different legislation is applicable. For archaeological sites, like remnant from Tycho Brahe's observatory at Vhen, "Fornminneslagen" applies, whereas "Kulturminneslagen" applies for other heritage. Buildings and grounds can be protected in that they are listed by the County Administrative Boards of Sweden. This concerns the observatories in Stockholm (the old observatory and Saltsjöbaden), Lund (Svanelyckan), Uppsala (Observatorieparken) and two schools with adjacent observatories (Skeppsholmen: Gamla sjökrigsskolan, and Karlstad: Gamla gymnasiet). That so many observatory buildings have been protected shows that the astronomical heritage is recognized and is considered important to preserve by the authorities in various parts of Sweden. The legislative protection for buildings can only apply to the building, the grounds, and permanent installations, but not artefacts. As concerns archival material the National archives are responsible for state institutions to which the universities belong. For printed material the National Library of Sweden is responsible.

For the inventories (any furniture or instruments) there seems to be a gap in the legislative protection. It is possible to commission a prohibition of export for specific objects, but there is no legislation which could coerce the documentation and upkeep of artefacts. This means that there is no legislation which could protect an observatory site with buildings, instruments, books, research activities and archival material as a whole entity.

This is unfortunate since there is a risk of loss of heritage value when the inventories together with the traditional activities are moved away from the site. The 19^{th} and 20^{th} century observatories in Lund, Uppsala and Saltsjöbaden (Stockholm) has been abandoned by the universities within the last ten years due to the changing practises of astronomy.

The universities have not been willing or able to keep those buildings for astronomical, museum or public purposes. As a consequence three major observatories have been cleared of their content recently. Fortunately some of the larger fixed instruments remain in their original site in that they are fixed (applies to Uppsala and Stockholm, whereas the Lund observatory seems to have been completely cleared). The usage and access to these instruments are as far as I know restricted to amateurs and private initiatives. The other artefacts – instruments, furniture, documents and books have however been moved and the usage changed. The universities and astronomical institutions in Stockholm, Lund and Uppsala, the latter with the support of the university museum Gustavianum, are the proprietors of the inventories, and are responsible for their preservation, documentation or display. As such this is problematic since the universities have no explicit charge to provide for such tasks. When needs for such purposes have to compete with funds for research it is likely that charges outside the main objectives will come off a loser.

At present there are two organisations in Sweden, the Tycho Brahe museum at Vhen and the Observatory museum in Stockholm (as part of the Center for the history of science at the Royal Swedish academy of sciences), whose main objectives include preservation of an astronomical heritage site with related inventories and public outreach. Besides there are a few museums which either treat modern astronomy, hold astronomical instruments, and make temporary exhibitions on astronomy.

27.5 An Argument for an Inventory of Swedish Astronomical Heritage

Considering the long and complex histories of the above mentioned observatories a comprehensive inventory would be very valuable. The danger of loss of knowledge as well as heritage is urgent in that three major observatories have been abandoned within the last ten years. The French model as undertaken by Françoise Le Guet Tully and Jean Davoigneau under the ministry of culture is an exemplary model. Here the buildings, grounds, artefacts together with the scientific activities and archival material are taken as the point of departure for the way history of French astronomy is told.

A specific field is that of Swedish scientific instruments. Their history has been outlined by Gunnar Pipping and Olov Amelin (1999), but as concerns even this article, the contributions by foreign makers are enhanced. A comprehensive history of Swedish scientific instruments still needs to be written.

As an alternative a proper inventory of astronomical heritage could even take a wider outlook and include different types of cultural activities related to astronomy. That astronomical observatories and related artefacts should be included in such an inventory is obvious. To only include such material as could be identified with the present understanding of the astronomy performed in a modern university context would make a very narrow definition of astronomical heritage. It would leave out the important cultural aspects which makes astronomy relevant to mankind. A proper astronomical heritage inventory should include the area of archeo-astronomy archaeological material such as petroglyphs, burial mounds or ship settings. If also ethno-astronomy with its objects of cult such as eg the shamanic drums depicting the northern cosmology of the Sami people could be considered. The importance and relevance of astronomical phenomena to our cultural heritage is also included in objects of art. This can be exemplified by the first known depiction of Stockholm, "Vädersolstavlan".[25] It was commissioned in 1535 by the onset of unusual astronomical/meteorological phenomena which were considered to be important enough to be recorded. Early spectacular objects can be found in varied collections such as the Visby lenses, archaeological finds, dated to the 10th or 11th century (Länsmuseet på Gotland) or an astrolabe from 1329 (Sjöhistoriska museet), or the armillary sphere and astronomical clock, ca 1580, by Jost Bürgi and Anton Eisenhoit (Nordiska museet).[26] Different kinds of collections also contain objects of international renown which were part of war booty such as the Copernicana collection at Uppsala University library.

A gem is the small 17th century cabinet with scientific instruments at Skokloster Castle.[27] Astronomical instruments together with important printed and archival material is found in the collections of a variety of different types of institutions, and different types of buildings and sites bear witness of activities related to astronomy. In order to get a fuller understanding of the relevance of astronomy to human culture, I advocate that these other aspects should also be included. To sum up, I would propose the necessity and usefulness of a project to make a national inventory of Swedish astronomical heritage. This could result in a new Swedish history of astronomy.

1. H. Alm 1982, Stavenow 1927, G. Alm 1993, Millhagen 2000.
2. Surprisingly the layout of the rooms is similar to the observatory of Kremsmünster, built just after the Stockholm observatory. Those two buildings however differ in the important aspect that the one in Kremsmünster is built as a very high tower. So far I have not been able to establish any relationships between the involved architects or other persons, or if they had a mutual source of inspiration, but it remains to be investigated. Other international correspondence which needs be investigated is the note by Linderoth, that there are drawings of the Observatory of Stockholm in a neoclassical guise in the collections the Heremitage in St. Petersburg.
3. Compare the texts quoted in Donnelly, p. 29.
4. Müller 1975, p. 97. See also Klamt, p. 382 ff.
5. De Robelin, p. 19 ff. Stavenow 1927, p. 91 ff.
6. Alm, H. 1982, p. 120, Folcker 1997, p. 10. He was given this task on 7. July 1746, and the drawings were presumably presented to the academy on July 28 the same year. The whereabouts of these drawings is unknown.
7. Müller 1992, p. 234.
8. In the archives at the Center for history of science at the Royal Swedish Academy of Sciences there are five letters between 1760 to 1768 from Chambers to Wargentin. See also Kristenson, p. 150 f.
9. Sinnerstad, Nordenmark 1939, 1959, Collinder 1970.
10. Frängsmyr 1989.
11. Amelin 1999, Pipping.
12. Amelin 1999, p. 165.
13. Amelin 1999, Pipping.
14. Widmalm, Pipping.
15. Holmberg 1999.
16. Unpublished report on the observatory of Stockholm between 1871 and 1931, Petander, Einar, The observatory museum, Stockholm.
17. The most comprehensive description of the museum and history of the building and instruments is found in Bergström et al. 2003.
18. Berthelson 1953. Holmberg 2001.
19. I would like to thank Göran Nyström for this information.
20. Pipping, p. 43.
21. Kristenson, Holmberg 1999.
22. Kristenson, Holmberg 1999, Schalén et al.
23. Holmberg 1999, Lindblad 2003.
24. H. Alm 1933, p. 66.
25. The original was painted by Urban Målare. The present painting in Storkyrkan in Stockholm is a copy from 1636 by Jacob Elbfas.
26. Inv.-nr. 301.573.
27. Losman.

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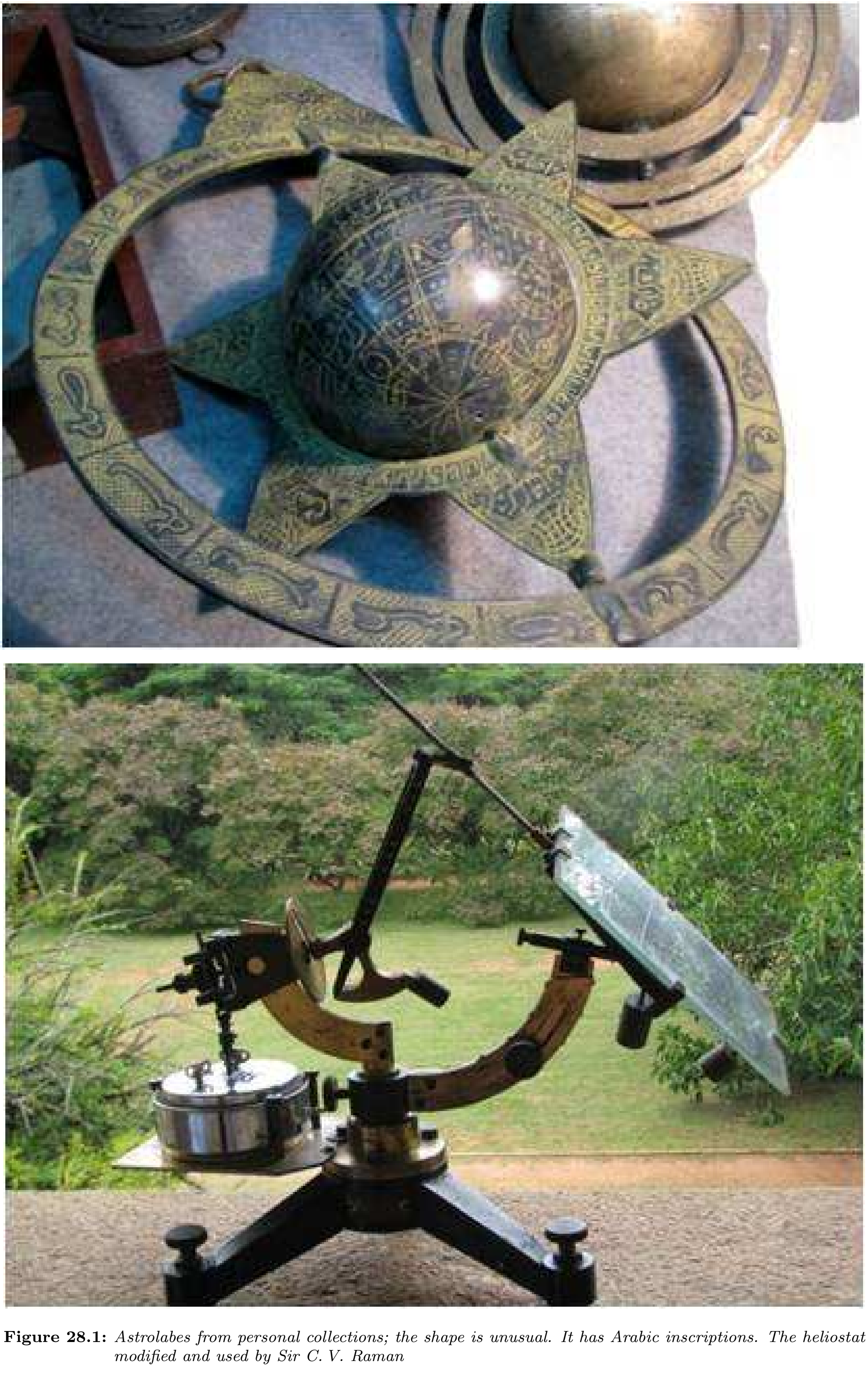

Figure 28.1: *Astrolabes from personal collections; the shape is unusual. It has Arabic inscriptions. The heliostat modified and used by Sir C. V. Raman*

28. Advent of Astronomical Instruments and their Impact – the Indian Context

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Abstract

After the pioneering venture of Portuguese on to the Indian soil, several European navigators landed in India. Keeping the political and cultural impacts aside, the valuable contribution towards development of astronomical instruments is discussed here. By 1900 there were several telescopic observations reported from India and several instruments developed for the solar and stellar observations. That made Kodaikanal as one of the best solar observatories of the twentieth century. Kodaikanal observatory not only had solar imaging facilities but stellar spectrographs. Comet Halley's apparition in 1910 has been successfully documented. Coronographs, spectrographs, polarimetric techniques and photometers were also available in India. The Great Trigonometric Survey of India was another successful project. The impact of these on the overall development of modern science in India is discussed here with special emphasis on instrumentation.

28.1 Introduction

It is fairly well known that astronomy flourished in India since many centuries prior to recorded history of the continent, typical date quoted is 1300 BC. Historians also note that after about 300 AD the development was partly influenced by the impact of planetary sciences from the west. This fact is well demonstrated by the texts of the 6^{th} century AD and later. Further modifications incorporated newer ideas from Europeans and Arabians retaining the original concepts.

Here the discussion is limited to the developments around 19^{th} and 20^{th} century since much of the instrumentation was developed during this period.

The first major step in the advancement of observations was the introduction of telescopes both in Europe and elsewhere. Although Galileo pioneered this venture in the beginning of the 17^{th} century, the commissioning of them for regular observations became a reality much later for reasons very well known. The contemporary Indian scenario may be briefly summarized as

1. Mathematical astronomy was very well advanced with many important texts being prepared all over India, although it was restricted to a small group of people. The model proposed by Nilakantha Somayaji was a unification of the heliocentric and geocentric models. It should be noted that although he was a contemporary of Copernicus, the two models were arrived at independently.
2. Observations were carried out with very simple instruments prior to 17^{th} century. The angular diameters of sun and moon were very precisely known and hence the exact timings of the eclipse could be calculated.
3. The precession of equinoxes was known although the method used for calculating ΔT is not explicitly discussed in any text.
4. Observatories were functional with the name Vedhshala; the only surviving one is at Ujjain. This was known to Greeks as Uzene.
5. Jaisingh established gigantic instruments in the 18^{th} century for improving the accuracy of measurements.

The measuring instruments like sextants, astrolabes were adopted by local artisans and manufactured locally. Fig. 28.1, S. 250, shows astrolabes of different shapes (uncommon in Europe) with Arabic inscriptions.

28.2 Advent of Telescopes

Telescopes were introduced in India by European travelers even before the East India Company was formed. The first record of a gift of telescope is of the early 17^{th} century to the Mughal Emperor Jahangir by Thomas Roe. Colonisation of Goa by the Portuguese was in 1510, followed by the academic activities of Jesuits. Father Anthony Monserate (1536–1600) accompanied Akbar to determine the latitude of longitudes of places Jesuits gifted them to Jaisingh and much later other travelers also. Sawai Jaisingh used the telescope for planetary observations; historians have criticized his attitude of having resorted to masonry instruments in spite of the advent of telescopes elsewhere in the globe. However, this has been justified considering his contact with Jesuits, who were Catholics opposed to the doctrines of

Galileo. His telescopic observations have been documented. They are
1. The ellipticity of the orbits of moon and sun
2. Phases of Mercury and Venus
3. Sunspots and rotation
4. Four satellites of Jupiter
5. Ellipsoidal shape of Saturn
6. Motion of stars, differences in their velocities.

Father Jean-Venant Bouchet (1655–1732) used a telescope in Pondicherry in 1689 for longitude and latitude measurements. He was joined by Father Jean Richaud; together they recorded observations from a 12 ft telescope. There is also a record of a 17 ft telescope which was used by Claude Stanislaus Boudier for simultaneous observations of planetary phenomenon along with Father Guabil in Beijing.

Transit of Venus in 1874 was a very important event and attracted the first ever international collaboration. Le Gentil proceeded to India exclusively for this observation but was unfortunate enough to miss both the transits. The details of his observations and the instruments that he used (and probably left behind) are not known.

Apart from the telescopes other instruments started landing in India after the EIC took over. That effectively saw the end of the Jesuit era, which produced very fruitful results like the discovery of binary nature of Alpha Centauri and so on. Again, here the details of instruments are not documented anywhere.

The highlights of research work carried out during the later part of the 19th century may be identified as the discovery of helium in the solar eclipse of 1868 and the fabrication of a coronograph. However, the instruments themselves were used for further modifications and are not traceable now.

By the end of 20th century there were several well established Observatories – the Madras Observatory was the best among them. The origin of this observatory is well documented at Kodaikanal. Initially it had very simple instruments – quadrants, achromatic telescopes and clocks with compound pendulum, time keepers and a transit instrument. Several lunar occultations were observed from here apart from eclipses and variable stars. Comet Halley in 1836 and 1910, Comet Wilmot in 1845 and several others were observed.

The instruments that were added later are the 6.5″ equatorial telescope in 1845 and a meridian circle in 1856. The orbit of Alpha Centauri was calculated here by Taylor. The "new planet" Neptune and satellites of Saturn and Jupiter were best observed. The Observatory is also credited with the first photographs of the total solar eclipse in 1868 and 1871. The questions raised by the procedures led to the development of another observatory at Dehradun for daily photographs of the sun.

Apart from the Madras Observatory, there were several other short-lived observatories that sprang up during this period (19th – 20th century). There are the following important observatories (and many more):

Calcutta Observatory (1825)

Royal Observatory, Lucknow (1832)

Travancore Observatory (1837)

Poona Observatory (1842).

All of these eventually became the network of the India Meteorological department, carrying out routine weather observations. However, some have been identified in personal collections and are traceable in museums. Most of the instruments were brought by the surveyors. Some of those instruments are zenith sector, transit telescopes, drum chronographs, astronomical clocks.

Later additions were "electrically" driven. Thus in 1872 the first electro-telegraphic determination of longitude was possible at Madras and Bangalore. The expensive equipments which were procured for the survey were left behind for various reasons and eventually made available for astronomy.

There were many attempts to revive the interest in positional astronomy since it played only a secondary role for all practical purposes. This is best indicated by a comment by Sir George Everest as a remark on the loan application for setting up an observatory in Poona: *"the discovery which astronomers ... are likely to make in science would hardly repay the inconvenience occasioned by retarding the operation of the Great Trigonometric Survey of India...."*
This is one of the main reasons for the closure of the observatories after the survey was over.

28.3 Dawn of Astrophysics

Initial observations were oriented towards positional astronomy. Norman Pogson as the first non surveyor director of the Madras Observatory initiated observations of what was termed "physical astronomy". Thus the observatory at Kodaikanal was equipped with photoheliograph, spectrograph and similar instruments.

Around the same time a first Indian astrophysicist was in the making. Kavasji Dadabhai Naegamvala was awarded Rs 5000 (today equivalent of US$ 500) from the Maharaja Takthasinghji of Bhavanagar in Gujarat to establish an observatory at Poona. He procured a 16.5″ Newtonian reflector with a 4″ finder and a spectrograph. His spectroscopic observations of novae, variable stars and nebulae were published in MNRAS. After his retirements the instruments were transferred to the Kodaikanal Observatory and are still functional.

The period around 1900 may be considered to be very important in the development of astrophysics in India. The Kodaikanal Observatory (Fig. 29.1, S. 254) was very well equipped with several instruments like a 3-prism spectrograph and a new telescope of 12″ with 20′ focal length.

John Evershed took charge of the Observatory in 1907 and added several instruments; one of them was a prismatic camera. His study of the radial motion of sunspots evolved in to the famous "Evershed effect".

Around the same time (1908) another Observatory at Hyderabad also was blossoming. This was the effort of a rich noble man Nawab Zafar Jung. He procured a 15″ reflector and an astrograph. After his death this was taken over by the Government and even now it is functional.

It is very interesting to note how these small beginnings have helped India achieve success with many observatories today including the world's tallest at Hanle on the Himalayas.

Keeping in mind the theme of this meeting we may summarise the important events as

1. Exposure to new instruments and techniques for the natives who were well versed with the necessary mathematical background. This produced an expert observer like Chintamani Ragoonathacary, the first Indian to become a member of the *Royal Astronomical Society.*
2. Some observatories which started at the initiatives of individuals were closed after his death or retirement. The instruments reached Government funded institutes and were forgotten. However, some have survived till date. A small 6″ was donated to a school teacher in Bengal as a loan for observing the opposition of Mars; the teacher was not in a position to bear the expenses for its shipment back to the US. Neither was the agency interested in getting it back. The telescope reached *Indian Institute of Astrophysics* and is being used even today for planetary observations. The 20″ telescope and the spectrograph used by Kavasji Dadabhai Naegamvala (1857–1938) also are being used even today.
3. Instrumentation talent nurtured as an inevitable solution for servicing the equipments resulted in excellent technicians. The mention should be made of Mir Mohsin whose skills were greatly appreciated; he built a 18″ telescope on his own. He was called from Madras to Calcutta to work for the Great Trigonometric Survey; the recommendation for his higher salary reads – *"though he could not read English, he would have taken a leading place among European instrument makers"*.
4. The impacts of these instruments naturally lead to well equipped university laboratories, which were beginning to attract natives. Many institutes heavily depended on imported equipments and local technicians were trained to service the same. This generated a new breed of instrument makers for special skills of glass blowing, lathe operation and so on. The best example is that of a heliostat which was used by Sir Chandrasekhara Venkata Raman (1888–1970). This devise would let a mirror track the sun and throw the light onto a spectrograph. It was a simple modification of a small alarm (spring loaded) clock (see Fig. 28.1, p. 250). The sunlight itself was the source of light for the famous molecular spectroscopy experiments whose results are known to us today as "Raman effect", which fetched him a Nobel Prize.

28.4 Conclusion

The impact of the European instruments on the development of modern science in India is invaluable. It nurtured local talent and elevated them to reach international standards in spite of the political and sociological hurdles. Thus India at the dawn of independence in 1947 had a very respectable opening balance.

28.5 Acknowledgements

The author gratefully acknowledges the support provided by Dr. Gudrun Wolfschmidt, the Chairman, SOC, for this work. Acknowledgements are also due to the Directors of Indian Institute of Astrophysics for using the archival material, Raman Research Institute for the photograph of the heliostat used by Sir C. V. Raman and Jawaharlal Nehru Planetarium for encouragement. I am thankful to Drs Vagiswari and Christina Birdie of the library of Indian Institute of Astrophysics and to Prof S M R Ansari for reprints.

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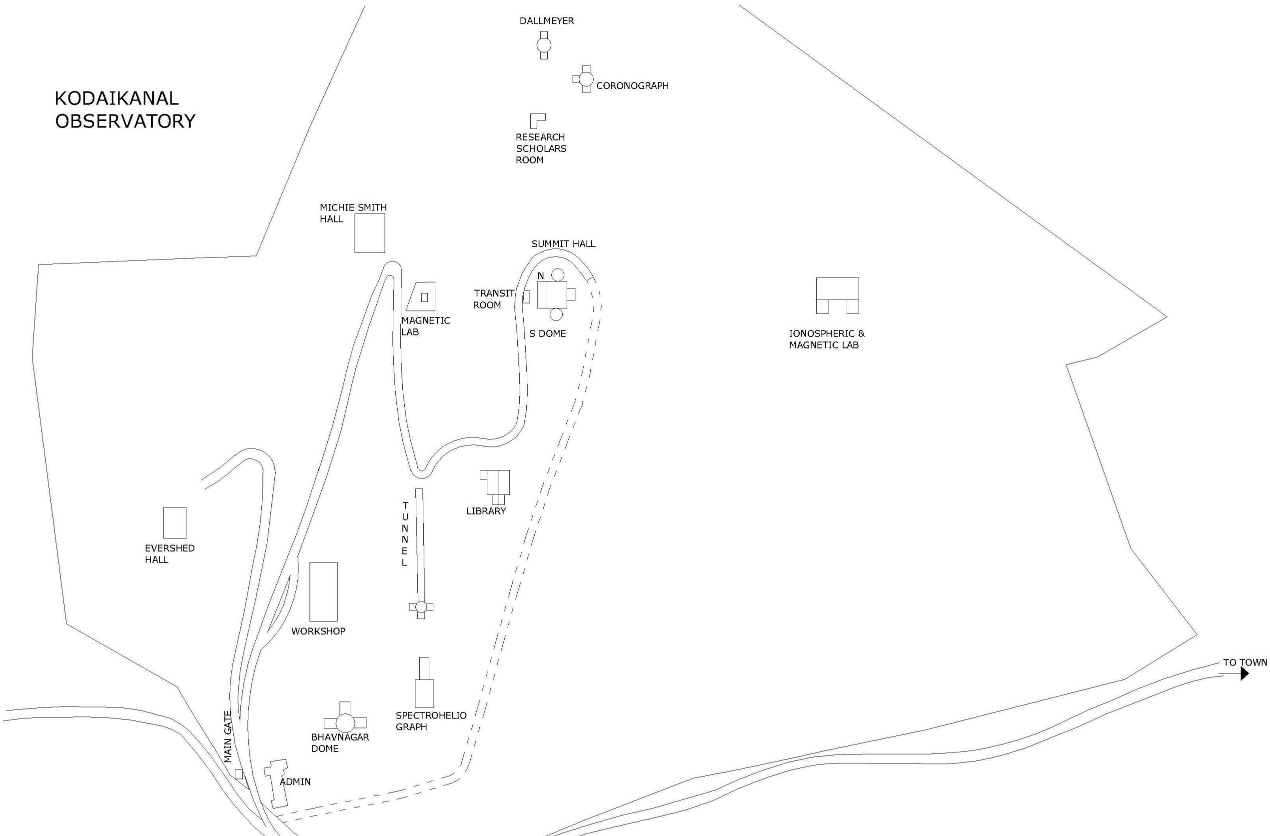

Figure 29.1: *Kodaikanal Observatory, founded in 1899, general plan*

29. Kodaikanal Observatory (1899)

Rajesh Kochhar (Chandigarh, India)

29.1 Introduction

Solar Physics Observatory, Kodaikanal, in Palani Hills (now Tamil Nadu state, India) was formally established on 1 April 1899 as a successor to Madras Observatory which began as a private set-up in 1786. If the twin transits of Venus of 1761 and 1769 led to the institutionalization of modern positional astronomy in British India, the 1874 transit did the same for astrophysics.

Spectroscopic and photographic techniques were used in the Indian observations of the solar eclipses of 1868, 1871 and 1872 which attracted many observers from Europe also. But the scientists' agenda for the 1874 transit ran deeper. What was advertised was the momentary passage of Venus in front of the solar disc; what was planned was a long-term study of the disc itself. The *British Association for the Advancement of Science* even passed a resolution asking the government of India to make arrangement for observing the event and to provide instruments which were afterwards to be transferred to a solar observatory. Such was the prestige enjoyed by science and scientists in Europe at the time that the British empire as the owner of most of the world's sunshine could not but respond favourably if partially.

The transit was "officially" observed from Roorkee. Post-1874 India did serve as a sunny field station for Europe. From 1878 till 1925, ... In 1878 an Observatory was set up in Dehra Dun, with instruments sent out for the transit, for daily photography of the sun, which were sent to England on weekly basis. The arrangement came about as a result of the personal equation of the influential British scientist Joseph Norman Lockyer (1836–1920) with the Secretary of State for India, third Marquis of Salisbury (1830–1903) and lingered on till 1825 when the Observatory was dismantled and its instruments sent to Kodaikanal.

Following the Italian transit expedition led by Pietro Tacchini (1838–1905), a well-equipped astrospectroscopic observatory was set up in 1879 in the Jesuit-run St Xavier' College Calcutta. Regrettably it failed to produce any results.

Better luck awaited Takhtasinghji Observatory set up by Bombay government at Poona in 1888 for use by Kavasji Dadabhai Naegamvala (1857–1938) who regularly sent data to Lockyer. The observatory was closed down in 1912 on Naegamvala's retirement and its instruments were handed over to Kodaikanal.

A hundred years previously, colonial government had desperately sought the help of positional astronomy as a navigational and geographical aid. Its stake in new astronomy was however peripheral. Madras Presidency was hit by a severe famine in 1876–1877 due to failure of monsoon. The famine commission in its report submitted in 1881 pointed out that there was "sufficient evidence" of a correlation between monsoon and sunspot activity and recommended that "India should assist in the work of solar observations".

29.2 Kodaikanal Observatory

It was decided in 1893 to establish Kodaikanal Observatory with Charles Michie Smith (1854–1922), Madras Astronomer and a protégé of Astronomer Royal William Henry Mahoney Christie (1845–1922) as its director. In 1895 the plans for buildings and instruments were approved by the London-based Indian Observatories Committee, chaired by Lord Kelvin. The formal government sanction followed as a matter of course. The same year, the 100-acre site, locally known as Nadingipuram, was acquired and a road opened to the top. In October foundation stone was laid by the Madras Governor, third Baron Wenlock (1849–1912), in October. In July 1897, the north-south line was laid out atop the hill for the main building, then known simply as the observatory.

The Astronomer Royal, in India for the 22 January 1898 eclipse, visited Kodaikanal on instructions from the Secretary of State. At the time the foundations of the director's residence and of the main building were being dug. Plans were modified on Christie's suggestion. Instead of the three dome originally envisaged, only two were to be built with a diameter of 18 feet instead of 15.

While the local artisans were capable of conventional construction, domes were beyond their competence. The first building to be completed was the director's residence. Michie Smith moved in February 1899, in time to personally receive and handle more than thousand coolie loads of books and instruments. (The director's residence was named Michie Smith Hall in 1985 and now serves as a guest house.)

Once on site, Michie Smith "personally undertook the erection of the domes", doing with his own hands "all the

Figure 29.2: *Kodaikanal Observatory, Summit hall, housing the north and south domes*

work that could not be done by a common native village carpenter or blacksmith. This included the driving of some 2,300 rivets". At long last the two domes were "practically ready" by December 1899.

Early instrumentation for Kodaikanal came from four sources; original Madras equipment; instruments sent out to country-regionIndia for the 1874 transit; the ones expressly designed and constructed for Kodaikanal and assembled at Madras; and those sent from other government observatories.

29.3 North and South Domes

A six-inch telescope by Lerebours & Secretan of Paris, on English mounting, was installed in the north dome. Of 1850 Madras vintage, it was remodelled by Sir Howard Grubb in 1898. In 1912 it was adapted for white light photography of the sun and has been continuously used for daily taking a 20 cm solar picture the purpose since 1 August 1912.

The south dome has seen a succession of three telescopes. The first one to be installed was the transit-of-Venus six-inch Cooke equatorial. (After its first use in Roorkee, it was loaned to Lockyer for use in South Kensington. It was sent to Poona in 1885 and transferred to Madras in 1893 for Kodaikanal.) In 1912 this was replaced by another six-inch Cooke telescope received from Poona at the closure of the Takhtasinghji's Observatory. This telescope remained in tact till 1960 when the mounting was retained but the telescope tube was replaced by the eight-inch aperture telescope by (Troughton & Simms), which was renovated for photoelectric work.[1] It is now used for observing comets and for visitors.

The transit room was begun in 1900–01 and completed in 1903. It houses a five-inch aperture Cooke transit telescope. As part of Indian magnetic survey a magnetic laboratory was completed in 1902.[2]

It was under the charge of Survey of India from 1904 till 1918 when it was returned to the Observatory. It was closed in 1923 nd restarted in 1948. The laboratory is no longer in use.

29.4 Spectroheliograph, Photoheliograph and Tunnel Telescope

A spectroheliograph for photographing the sun in calcium K line received from Cambridge Scientific Instru-

Figure 29.3: *Kodaikanal Observatory, Spectroheliograph building and a plaque commemorating the discovery of Evershed effect*

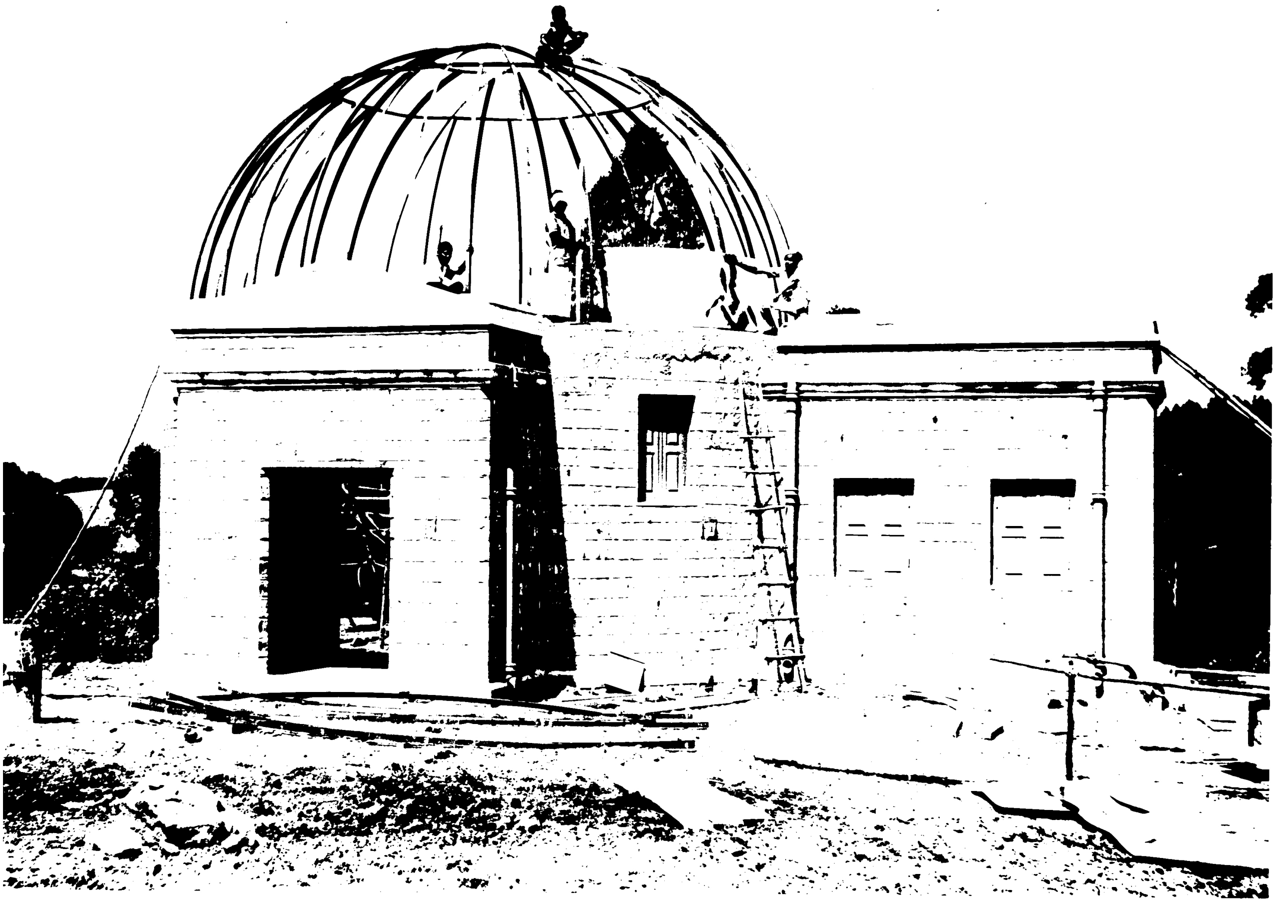

Figure 29.4: *Kodaikanal Observatory, Bhavnagar dome under construction*

ments Company was set up in 1904). John Evershed joined the Observatory on 21 January 1907. From a study of the photographs of the solar spectra taken with a spectrograph, Evershed himself had devised, he discovered, on 9 January 1909, the phenomenon of radial outflow of gases in a sunspot (Evershed effect). He went on to build in 1911 a new spectroheliograph for photographing the sun in hydrogen-alpha light. A third one was built in the 1960s to take solar pictures in any chosen colour.

Kodaikanal now has an uninterrupted record of solar activity with the same equipment for about a century now. Interestingly the spectroheliograph building houses a pendulum clock by John Shelton. Made for the 1769 transit of Venus it is similar to the one used by Captain James Cook in his voyages.

A photoheliograph, known as Dallmeyer No. 4, was received at Madras in 1895, on loan from Greenwich Observatory. It was first set up in an iron shed and then, in 1907, housed in a domed building. It was used for daily photography till August 1912 when as already noted the Lerebours & Secretan telescope was employed for the purpose. The Dallmeyer was dislodged from its dome in 1912 itself to make way for the transit-of-Venus Cooke from the south dome.

A residence, similar to but smaller than the Michie Smith Hall, was completed in 1908 for Evershed. Renamed Evershed Hall in 1985 it now serves as guest house.

A major instrument received in 1912 from Poona was the "Bhavnagar" telescope, with a 20-inch mirror by Dr A. A. Common and mechanical parts by Grubb. It was installed in a dome erected for it in 1951.

The most recent solar facility at Kodaikanal is a tunnel telescope with a 38 cm aperture, 36 m focus lens, made by Grubb & Parsons. Installed in 1958 it was acquired as a part of International Geophysical Year.

29.5 Landscaping

A comment now on landscaping. Most of the 100-acre grounds of the Observatory was either rock or grass-covered slopes. To reduce the disturbing effect of the sunshine on the bare ground and to modify the strength of the winds to which the Observatory was exposed, Michie Smith decided to cover the ground with trees and shrubs. In 1899 itself some 1500 trees were planted.

In 1904 seeds of various types of pines were received from Lick Observatory and Pasadena in southern California from which a large number of saplings were raised and planted. There was always danger of forest fires and at least one case of suspected arson in 1910. Wild grass

Figure 29.5: *Kodaikanal Observatory, Tunnel telescope, Grubb & Parsons, 1958*

was replaced by short grass, and wide fire lines were kept in good order.

To bring the story up-to-date, on 1 April 1972, Kodaikanal Observatory became the field station of the newly created *Indian Institute of Astrophysics*, headquartered at Bangalore.

1. The telescope had been installed in Madras in 1862 and was sent out to Kodaikanal in 1931.
2. Kodaikanal is barely half a degree north of magnetic equator.

29.6 Bibliographical Notes

(1) Most of the information is taken from the official annual Madras and Kodaikanal Observatory reports.

Two additional significant documents are:

(2) Report on Indian Observatories and their Organization, by Sir Norman Lockyer, 1898.

(3) Report on Indian Observatories, with Special Reference to the Proposed Scheme of Re-Organization, by W.H.M. Christie, 1898.

For a broader perspective, see

(4) Kochhar, Rajesh K.: The growth of modern astronomy in India 1651–1960. In: *Vistas in Astronomy* **34** (1991), p. 69–105.

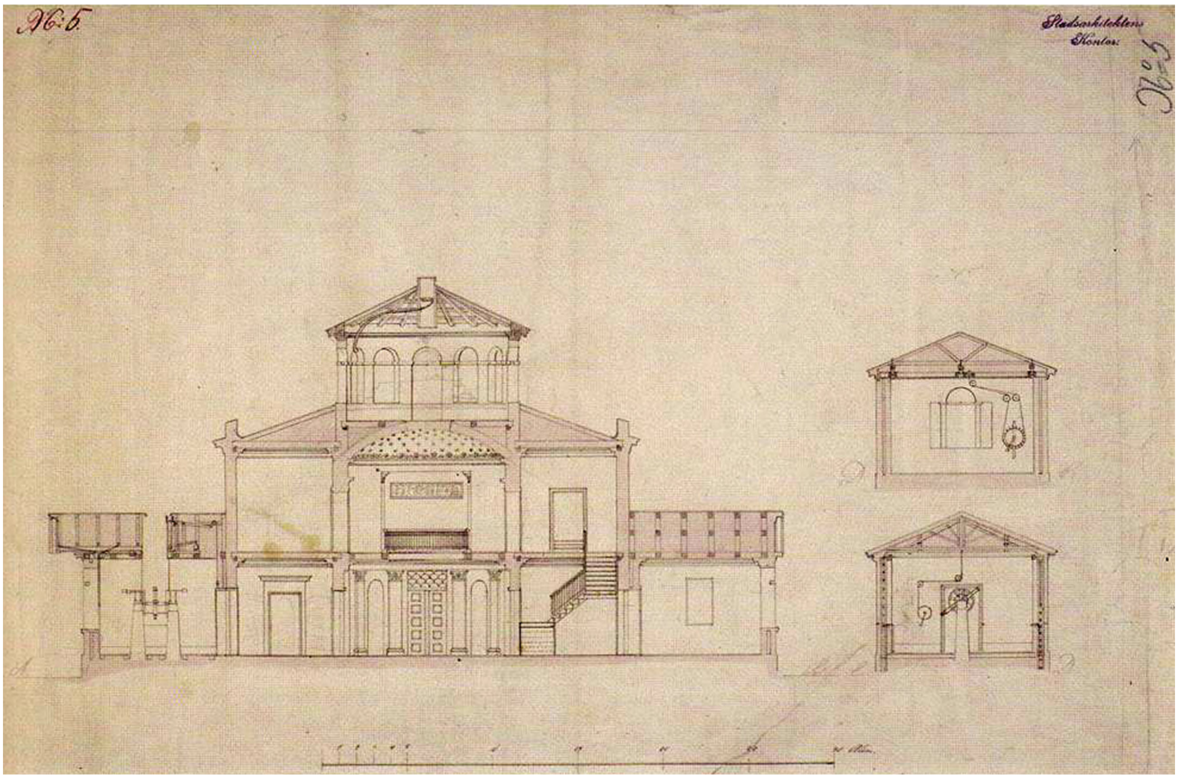

Figure 30.1: *Above: Christopher Hansteen (1784–1873); Below: The Observatory in Christiania (Above: Portrait from his Reise-beretninger. Christiania: Chr. Tønsbergs forlag 1859. Below: Draft by Heinrich Christian Grosch sent to Schumacher in 1828. From Elisabeth Seip (ed.): Chr. H. Grosch. Arkitekten som ga form til det nye Norge. Oslo: Pax forlag as (2001) 2007, p. 135.)*

30. Christopher Hansteen and the Observatory in Christiania

Vidar Enebakk (Oslo, Norway) and Bjørn Ragnvald Pettersen (Ås, Norway)

30.1 Introduction

The early nineteenth century was a turbulent period in Norway due to Napoleonic wars. As a result Denmark had to turn over Norway to Sweden at the peace treaty in Kiel on 14 January 1814, and the Constitution of Norway was introduced on 17 May 1814. In the preceding years, however, an important feature of the growing nationalism was the insistence on a separate university in Norway. Thus, the Royal Frederik's University in Christiania (today: Oslo) was officially created through a royal decree by Frederik VI, the king of Denmark and Norway, on 2 September 1811. In the first decades the most important Norwegian scientist was Christopher Hansteen (1784–1873), professor of applied mathematics and Director of the observatory in Christiania. Not only did Hansteen put Norway "on the map" through his many international networks within geomagnetism, astronomy and geodesy, he also located Norway in relation to astronomical time and geographical space. In this paper we will primarily focus on the construction and instrumentation of the observatory in Christiania during a period of gradual political separation from Copenhagen. At the same time we will emphasize the close collaboration between Christopher Hansteen in Christiania and Heinrich Christian Schumacher (1780–1850) in Altona at the south border of the Danish-Norwegian kingdom, thus highlighting the close relationship between Hansteen and the Hamburg area at the beginning of the nineteenth century.

30.2 Hansteen in Christiania

Christopher Hansteen initially studied jurisprudence at the University of Copenhagen, but his interests were soon drawn towards geomagnetism and astronomy. In 1811 he won a gold medal for a treatise on geomagnetism which was later expanded and published as *Untersuchungen über den Magnetismus der Erde* (1819).[1] Meanwhile, on 1 June 1814, he was formally appointed Lecturer of applied mathematics at the newly established University in Christiania, and on 4 March 1816 he was promoted to professor. Hansteen is perhaps best known for his work on geomagnetism and his elaboration of a model of the earth consisting of two magnetic axes and four magnetic poles. Based on this theory, Hansteen carried out an expedition to Siberia between 1828 and 1830 in search of the second magnetic north pole.[2] Despite a negative result, Hansteen's expedition was of great importance to the new nation. Upon his return in 1830 Hansteen's efforts were rewarded by the government, who approved the construction of a new astronomical observatory. It was completed in 1833.

Hansteen and the observatory served many social, cultural and political purposes within the new national state. Along with his duties at the university, Hansteen also gave lectures at the military academy in mathematics, mechanics, geodesy, and astronomy. He further attracted general attention as the editor of the official *Almanac* of Norway from 1815 to 1862. In 1817 he took up a part time position as Director of *Norges geografiske Opmaaling* (Geographical Survey of Norway) which he held until 1872. In 1823 he began publishing *Magazin for Naturvidenskaberne* (Journal of Natural Sciences) with two other professors, thus creating a forum for science news and extended papers on specialized topics. The following year he was co-founder of a scientific society called *Den physiographiske Forening*, which served as a precursor to the Academy of Science in Christiania established in 1857. Finally, Hansteen was appointed to the national commission for weight and measures in 1818. He designed the new Norwegian system of standards in 1824, and he served on this body until 1872. Most of his functions, however, were related to his work at the university observatory in Christiania where Hansteen served as Director from 1815 to 1861.[3]

30.3 Schumacher in Altona

Christopher Hansteen's most important contact and collaborator on the continent was Heinrich Christian Schumacher. He was Director of the new observatory in Altona outside Hamburg from 1823 and is perhaps best known as the founder of the journal *Astronomische Nachrichten* which he edited from 1821 to 1850. It was the leading international journal in the field of astronomy in this period and it made the observatory in Altona *"the centre of international relations between* *astronomers."*[4] For instance, Hansteen published regularly in *Astronomische Nachrichten* and he had a total of ten contributions to the first full volume which was published in 1823.

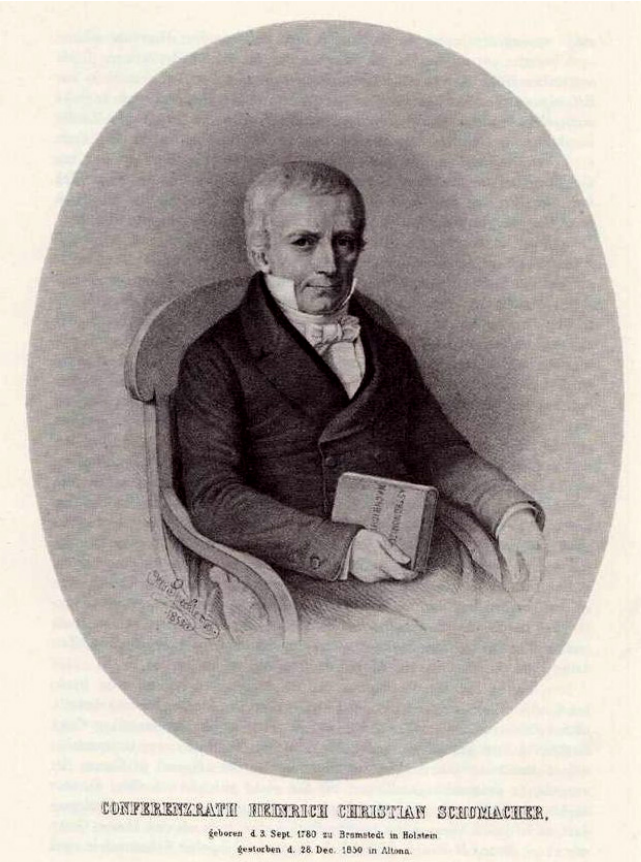

Figure 30.2: *Heinrich Christian Schumacher (1780–1850) (Portrait from Einar Andersen: Heinrich Christian Schumacher. Et mindeskrift. København: Geodætisk Instituts forlag 1975, p. 102.)*

In the early nineteenth century the city of Altona, being a part of Schleswig-Holstein, was subject to the Danish-Norwegian kingdom under king Frederik VI. During the preceding one and a half century the observatory on top of the Round Tower in Copenhagen was the centre of the Danish-Norwegian network of astronomical and geodetic sciences. Both Hansteen in Christiania and Schumacher in Altona developed new and more sophisticated observatories in the periphery of the kingdom during the 1820s and 1830s. In the following we will focus on the circulation of knowledge, skills and instruments between Hansteen in the north and Schumacher in the south of the double-monarchy. We will emphasize Schumacher's role as Hansteen's mentor and his mediator with German scientists and instrument makers like Johann Georg Repsold – the Director of the new state funded observatory at Millerntor in Hamburg from 1825 – in addition to Ertel, Kessels, Merz, Reichenbach, Utzschneider and Fraunhofer.

Schumacher was born in 1780 in the small town of Bramstedt in Holstein between Kiel and Hamburg. His father Andreas Schumacher, a senior civil servant who was close to king Frederik, died early and the mother, Sophia Hedevig Rebecca Schumacher, moved to Altona. Here the young Heinrich Christian attended school from 1794 to 1799 under Rector Jakob Struve, father of the astronomer Friedrich Georg Wilhelm Struve who was born in Altona and later, in 1839, became Director of the new observatory in Pulkovo near St. Petersburg. From April 1799 Schumacher studied jurisprudence in Kiel and two years later in Göttingen. Here he met Carl Friederich Gauß who in 1807 had become Director of the new observatory in Göttingen, and Schumacher studied with him during the winter of 1808–1809.[5] In 1810 Schumacher was appointed extraordinary professor of astronomy in Copenhagen. Still, as he did not get along well with Thomas Bugge, the ordinary professor of astronomy and director of the Round Tower observatory, he resided in Hamburg in this period and began a three-year observing programme of circumpolar stars with Repsold's meridian circle. By 1811–1812 he acquired a flat at Herrengraben 12 near the observatory at Millerntor so he could collaborate closely with Repsold. 1813 Schumacher temporarily accepted the position as director of Mannheim observatory, but two years later, when Bugge died on 15 January 1815, Schumacher was appointed his successor to the ordinary professorship and called to Copenhagen.[6]

In the meantime Schumacher actually tried to obtain a position at the proposed university in Norway. During the winter of 1811–1812 he wrote to the university planning commission in Copenhagen offering his services and at the same time suggesting the construction of a new and well equipped Norwegian observatory (not in Christiania, actually, but at Königsberg, which was a possible location for the university at this point).[7] About the same time the planning committee received an offer for a meridian circle from Johann Georg Repsold in Hamburg. On this occasion, the committee requested the advice of Thomas Bugge, who was negative to the proposal: *"Bugge had no confidence in this new idea"*; Hansteen later explained, *"the zenith distance of the celestial pole would have to be determined with a mural quadrant and a 12 foot zenith sector of the kind available at the Round Tower in Copenhagen."*[8] Thus, following Bugge's advice, the committee turned down Repsold's proposal. Instead, the instrument was acquired by Gauß and after further modifications during 1817 it was mounted by Repsold personally in the eastern meridian room of the Göttingen observatory.[9] Later, Hansteen saw the instrument here on his visit to Gauß in 1839 when he was introduced to his geomagnetic observatory and its instruments. Yet, Repsold's proposal may have been intended to serve an additional purpose, as support for Schumacher's and as foundation for an even closer collaboration and integration between Christiania and Altona/Hamburg. It was an obvious strategic move to combine Schumacher's application to the Norwegian university with an instrument proposal from his close friend and collaborator Repsold, since this new university had to establish everything from scratch. In his application Schumacher offered to build a first-rank observatory with instruments from Hamburg and Munich, provided sufficient funds were granted. He also requested Gauß to send him a letter about the Mannheim position in such wording that he could use it to influence decision makers in Copenhagen towards an appointment in Christiania, stating to Gauß that he would not seriously consider going to Mannheim. Nonetheless, instead of Schumacher, Hansteen was appointed to the position at the new Norwegian university.

Schumacher's main activities in the early nineteenth century were related to surveying, mapping and the determination of correct time and position. His plans were sketched out in a letter to king Frederik dated 14 April 1816. Schumacher suggested a major operation of astrogeodetic observations to measure the length of the meridian from Skagen at the north-tip of Jylland to Lauenburg in the south of the kingdom just east of Hamburg. The king responded positively in a letter dated 18 May 1816, thus laying the foundation for *Den danske Gradmaaling.*[10] As part of the project Schumacher would also produce an improved national network based on new triangulations which in turn could be used for mapmaking: *"Mit seinem Vorschlag einer Gradmessung brachte Schumacher das dänische Königreich nicht nur in die erste Linie aktueller Forschungen, sondern flocht es auch in ein Netz der internationalen wissenschaftlichen Zusammenarbeit ein."*[11] Only later, from 1821, and quite reluctantly, Schumacher also accepted the task of conducting a topographical survey of Holstein, a part of Denmark-Norway which had not been included in the previous survey by his predecessor Thomas Bugge in the 1770s.[12]

Schumacher chose the church tower of St. Michaelis in Hamburg as the starting point of his triangulations. Together with Repsold he located suitable observation stations around the city, and they further located a suitable location for the baseline at Braak near Ahrensburg to the north-east of Hamburg. Here they conducted precision measurements of the 1,8 km long "Braaker Basis". Both end points were astronomically determined with a portable universal-instrument so they might serve as starting points for further triangulations. With a specially designed baseline instrument constructed by Repsold the measurements of the "Basis Braak" was largely complete by September 1819. Based on control measurements the next year it was determined that the divergence of the 1800,876 meter long baseline was only 3,6 mm.[13] Schumacher had recruited two military officers to assist him with the observations and measurements, as he explained in a letter to Gauß on 16 November 1817, *"weil diese den meisten Einfluss auf Bauern haben, und eine etwas militarische Behandlung mitunder nicht ohne Nutzen ist."*[14] In the same letter Schumacher had also suggested his own survey of Holstein to be connected with Gauß' triangulation of Hannover south of the national border, by establishing a common baseline. Thus, Gauß participated with Repsold and Schumacher at the "Braaker Basis" while Friedrich G. W. Struve visited regularly to learn more about this scientific enterprise.[15] The official triangulation of Hannover was not commissioned to Gauß by George IV of England until 1820. By this time he had already learnt much from the collaboration with Schumacher and Repsold in the area of Hamburg: *"In Jahren 1821 bis 1823 hat Gauß die Messungen zur Bestimmung des rund zwei Breitengrade umfassenden Gradbogens Göttingen-Altona durchgeführt."*[16]

Naturally, Hansteen would be involved in the same kind of topographic and astrogeodetic surveys in Christiania in the northern part of the kingdom as director of *Norges geografiske Opmaaling.* In 1824 he measured a baseline on the frozen Christiania-fjord to set the scale of triangulations in the region.[17] Questions regarding surveying instruments would also form the main content of the correspondence between Hansteen and Schumacher, of which 93 letters from Schumacher, dating from October 1815 to January 1849, are being kept at the Institute of Theoretical Astrophysics at the University of Oslo, while Hansteen's letters to Schumacher are deposited at the Staatsbibliothek zu Berlin. The other main topic in the correspondence was their common efforts towards building new observatories in Christiania and Altona, respectively.

30.4 The Observatories in Altona and Christiania

When Hansteen was appointed at the new University, no appropriate place existed for astronomical observations. Initially he conducted his observations from a pavilion in the garden of his private house in the city. By a royal decree of 25 February 1815 the university decided to fund a small octagonal observatory for Hansteen the walls of Akershus fortress in Christiania. The initiative, however, did not come from Hansteen:

As early as 1813 the establishing of an observatory at Akershus had been suggested by Major Benoni Aubert, the Director of the military geographical survey of Norway. Also, it was Aubert who initially suggested that Hansteen, as newly appointed professor in applied mathematics at the university, should be appointed co-Director of the national topographical survey with responsibility for the civilian and scientific aspects of the institution – a position Hansteen officially had from 20 May 1817.[18] The initial proposal for an observatory, however, was submitted by Aubert to Copenhagen with a negative result largely because of the political situation with Norway being separated from Denmark after the peace negotiations in Kiel. The new Norwegian nation, however, immediately recognised the need for such an institution in relation to national surveying and mapmaking. This first university observatory became a site where geodetic techniques suitable for establishing an improved national geodetic net based on triangulation and astrogeodetic observations were developed.[19]

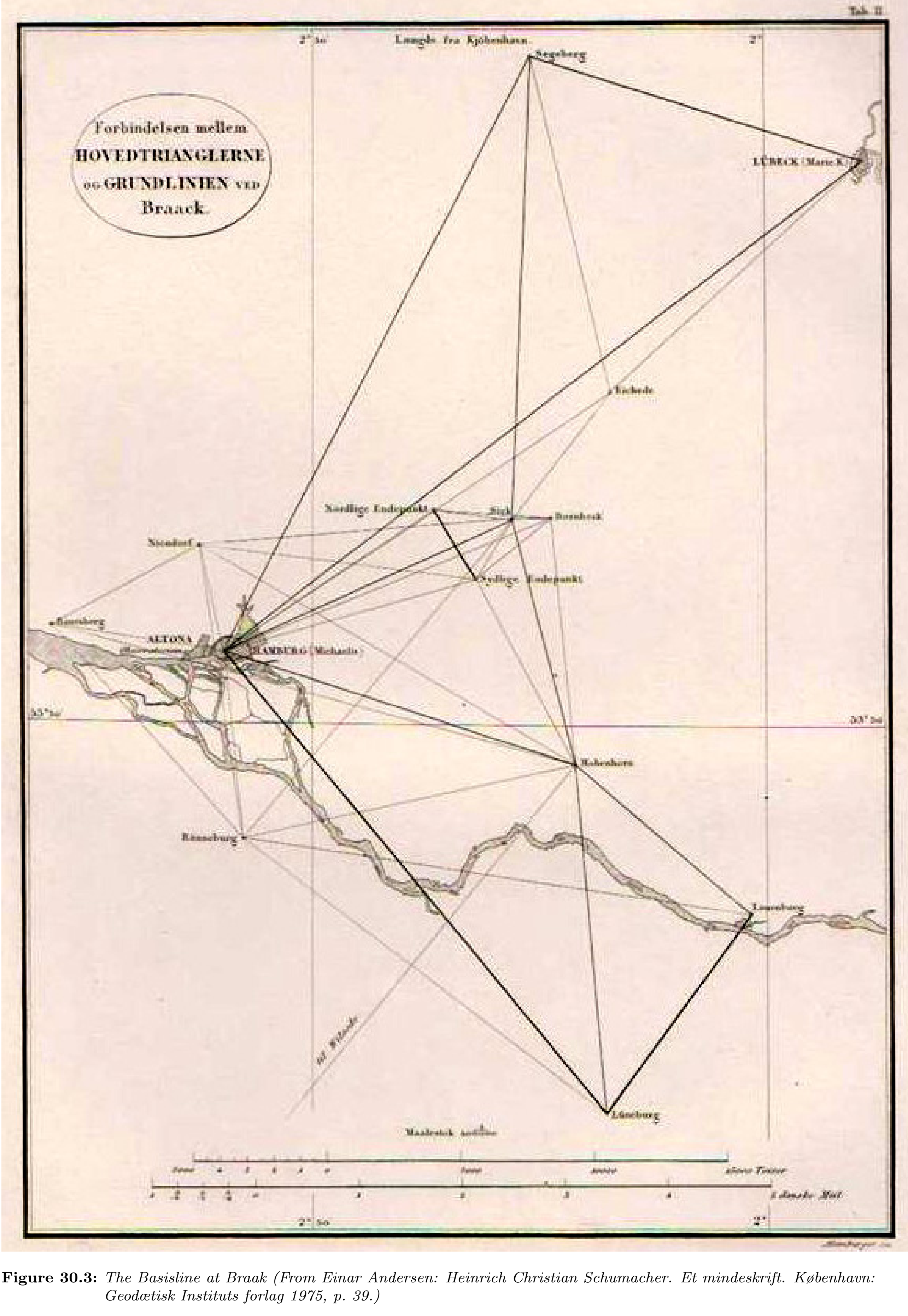

Figure 30.3: *The Basisline at Braak (From Einar Andersen: Heinrich Christian Schumacher. Et mindeskrift. København: Geodætisk Instituts forlag 1975, p. 39.)*

Nevertheless, the quality of the building was poor and Hansteen kept conducting most of the observations from his private house while at the same time working relentlessly to establish a proper observatory. Thus, a royal resolution of 11 December 1826 stated that the university should indeed invest in a new and proper observatory building. A suitable location was bought by the university at Sollie just outside the city in 1827. On 28 August 1830 it was decided by the National Assembly that the necessary funds should be allocated to the construction of the new observatory.[20] The most decisive argument – strategically and successfully used by Hansteen throughout the process – was that the gradually increasing collection of valuable scientific instruments needed a proper place for protection.

The close collaboration between Hansteen and Schumacher was crucial, regarding the building itself as well as the instrumentation. In fact, the most important features of the new observatory in Christiania were directly imported from Altona. Initially Schumacher made most of his observations from his private house on Palmaille, a building he bought when permanently settling down in Altona in 1821. Unfortunately, few details exist concerning his new observatory which was funded directly by the Danish king and was first mentioned in *Astronomische Nachrichten* in March 1823.

The building was constructed to contain the main instrument, a meridian-circle by Repsold, which defined the main meridian for the Danish land survey. In addition to the meridian room, which had a movable roof on wheels opening a small slit necessary for making observations, the building also had a small round tower in the south-west corner containing a Borda-circle acquired from Reichenbach in Hamburg in 1819, only later to be replaced by a Fraunhofer-refractor (1.28 m). *"In summa handelte es sich also um ein kleines, aber feines Observatoriumsgebaüde, oder wie G.* SVANBERG *es später ausdrückte, um ein 'Musterobservatorium'."*[21]

Schumacher's observatory in Altona most literally served as a model for Hansteen's observatory in Christiania. Hansteen visited Schumacher and his new observatory in 1825 and he was very much impressed by the building. In April 1827 Hansteen sent to Schumacher a series of sketches for the new observatory in Christiania made by his architect Christian Henrik Grosch, and in November the same year Schumacher sent drawings of his observatory in Altona to Christiania. Hansteen also sent architect Christian Heinrich Grosch to Altona to make detailed sketches and measures of Schumacher's observation rooms.[22] As a result, the meridian room in Christiania has exactly the same dimensions as in Schumacher's observatory. Even the construction of the movable roof was copied. Despite other obvious architectonical and structural differences, Schumacher's observatory in Altona was the main inspiration and model for Hansteen's observatory in Christiania. In what follows we will further elaborate how Schumacher and the Hamburg-connection was important also for the instrumentation of the Norwegian observatory.

30.5 The Astronomical Instruments

Hansteen developed a wide network of personal contacts within the university as well as in national politics and in ministerial circles, including Norwegian civil servants and military officers. This network was used both as a source of information and to help promote his own scientific goals. Within the university, Hansteen continuously argued that new instruments were required to improve his preliminary results. As a new nation within a double monarchy, Hansteen argued that the country and its natural resources must be surveyed and mapped in order to facilitate further national development and prosperity. He received funds from the university to acquire improved astronomical and magnetic equipment and from the Geographical Survey of Norway to acquire geodetic instruments. He thus made a name for himself as a purchaser of scientific instruments in the international markets and demonstrated ability to specify requirements and select the proper instrument maker for the job. He kept himself informed about the product line, quality and prices of the various companies in Denmark, England, France and Germany through correspondence with Schumacher. He used this unique role at the university to obtain repeated annual grants for new instruments in astronomy and geodesy. The first decade or so he focused on portable instruments (accurate chronometers, sextants, universal theodolites, and magnetic devices), since these were needed both to improve his positioning work in Christiania and could be used for national surveying purposes, plus would serve him on expeditions to remote areas of Norway, and to Denmark, Sweden, England, Germany, and Russian Siberia.

From the interim observatory and the Siberian geomagnetic expedition he possessed a transportable universal instrument by Reichenbach, an astronomical theodolite by Ertel, a pendulum clock by Abraham Pihl, a small transportable refractor by Fraunhofer, and a collection of chronometers and sextants.[23]

When Hansteen moved into the nearly completed observatory building with his family in September 1833 he had also acquired a meridian circle by Ertel in Munich with 11 cm objective lens by Fraunhofer; a pendulum clock by Urban Jürgensen in Copenhagen; and an 11 cm refractor by Utzschneider in Munich on altazimuth mounting by Repsold in Hamburg.

Several expansions took place during the following decades. An equatorial refractor by Repsold was installed in the tower observing room in 1842. A portable comet seeker by Merz was acquired in 1851. A pavilion to the north of the main building was set up to accommodate a 19 cm equatorial refractor by Merz in 1857. A transit instrument by Pistor and Martins was acquired in 1869 and set up in a separate observing hut due south of the meridian circle. A pavilion to the east of the main building was set up in 1884 to house a 13 cm refractor by Merz on equatorial mounting by Olsen.

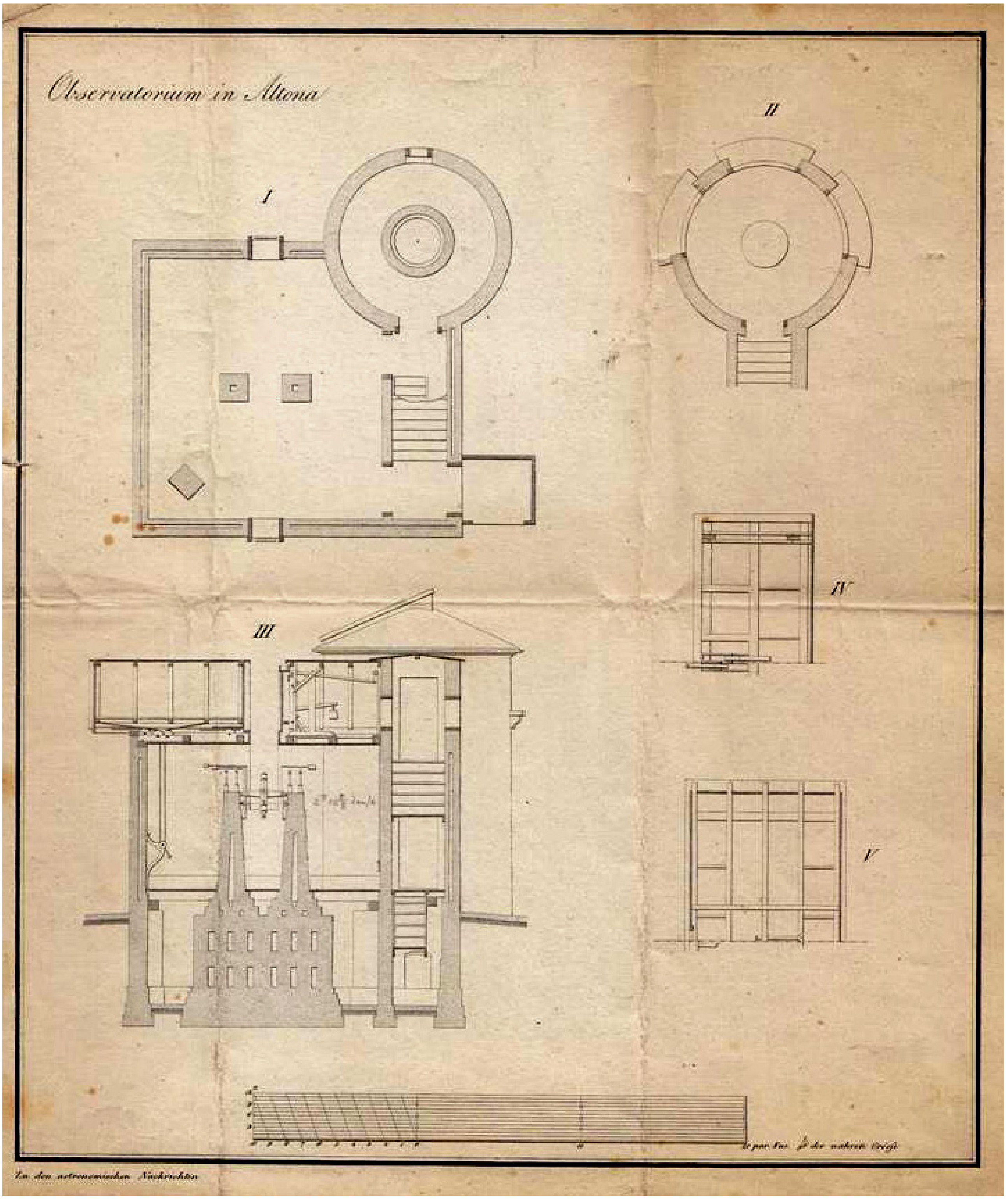

Figure 30.4: *The Observatory in Altona. Draft sent by Schumacher to Hansteen in 1827. From the Archives of the Institute of Theoretical Astrophysics, University of Oslo.()*

During its 100 years of existence, the activity at the observatory evolved along the research lines of classical astronomy. Some observing projects were carried out exclusively with one instrument, while others used the available instrument collection at any given time. There were occasional observing campaigns with additional observers recruited from other sciences, but the major projects lasted for decades and were carried out by the director/professor and his assistant.

30.5.1 The Meridian Circle

The meridian circle remained the main instrument of the observatory throughout its history. It was initially used to determine an accurate geographical position for the observatory, which came to serve as the fundamental point for all geodetic surveying and national mapping in Norway till 1950. This also included the Norwegian part of the *Mittel-Europäische Gradmessung* 1862–1883.[24] Qualifications and experiences for such work had been established during participation in the Struve geodetic arc in Finnmark 1845–1850.[25]

The most significant observational contribution to astronomy was the meridian circle astrometry program (1870–1887) for the *Astronomische Gesellschaft* zone catalogue and its follow-up (1897–1907) to determine stellar proper motions. The meridian circle was also used for targets of opportunity, e. g. astrometry of Neptune for the first decade after its discovery in 1846, and astrometry of numerous asteroids and comets between 1847 and 1919.

The meridian room was in the east wing of the observatory building. Hansteen had ordered the meridian circle from Ertel in Munich in November 1826 through the assistance of Schumacher. The Norwegian National Assembly funded a 3-year instrument grant in the autumn session that year. At the time Ertel was producing a meridian instrument for Stockholm. Schumacher somehow persuaded him to sell it to Christiania and when half the price was paid in advance by Hansteen, the matter was settled.[26] Ertel indicated delivery by the end of 1827, but the silver limbus of the divided circle cracked and had to be remade. The meridian circle left Ertel's workshop in February 1828 and arrived Hamburg about a month later where it had to await shipping opportunity for Christiania. International communications opened up when the Christiania Fjord became ice free in mid April and the instrument arrived in May 1828. Hansteen left for his Siberian geomagnetic expedition a week later, so the instrument was stored for several years with Mr. Clausen, a local instrument maker. It was assembled and mounted in the meridian room in 1834 and was first submitted to considerable testing.

The objective lens by Fraunhofer had a focal length of 163 cm and observations were usually made with a magnification of 180. The 3 feet vertical circle (Ø=94 cm) was divided to $3'$ and could be read directly to $2''$ using 4 verniers and 2 microscopes.

On a separate pillar in the meridian room a pendulum clock by Urban Jürgensen in Copenhagen was mounted and regulated to show sidereal time. It had been ordered already in 1815 and was delivered to Hansteen in the summer of 1826. It served as the main clock of the observatory till mid 1841, when it was replaced by No. 1365 by Johann Heinrich Kessels in Altona. A meridian marker was put up on the island Lindøya in the Christiania Fjord, 2,7 km due south of the observatory.

The initial adjustment and testing of the meridian circle allowed Hansteen to derive a preliminary latitude value in April 1835, but also revealed mechanical deflections and problems related to reversals of the horizontal axis when alternating the divided circle east and west of the telescope. This required the construction of a horizontal levelling device, delivered from A. & G. Repsold at the end of 1838. Mechanical deviations could now be monitored and the instrument began producing consistent results. Hansteen rejected all previous efforts and carried out a new observing program from October 1839 to July 1841, involving 11 reversals of the axis and 113 individual observations. The result was a latitude value of $59°54'43.19''±0.36''$.

Carl Fredrik Fearnley had just graduated at age 25 when he was appointed *Observator* in 1844. He immediately planned a new and larger meridian observing program to control and improve Hansteen's latitude value. A collimator arrived that summer from Repsold to monitor any deviations of the telescope optical axis away from the meridian. Fearnley carried out 894 individual observations from September 1844 to June 1848, involving 30 reversals of the axis. The result matched Hansteen's value at $59°54'43.21''±0.55''$.[27] Fearnley then applied corrections to the stars' declinations and arrived at the official latitude value for Christiania; $59°54'43.7''$.

Hansteen and Fearnley attempted several types of observations to determine the longitude of the observatory. They observed lunar occultations of stars with the Utzschneider and Repsold refractors in the tower and timed solar eclipses with a portable, small Fraunhofer refractor. The accuracy of these results would only allow a preliminary longitude value and was never published.

During the summer of 1847 up to 21 chronometers were repeatedly sent by steamship between Christiania and Copenhagen to determine the longitude difference ($7^m25.0^s$) from astronomical time determinations at the two observatories. This provided the official longitude value of Christiania. These coordinates defined the fundamental reference point in the geodetic datum for Norway for more than a century, and compare well to more modern results. In 1865, telegraphic signals were used to calibrate clocks in Copenhagen, Christiania and Stockholm during meridian circle observations.[28] This yielded a longitude difference between Christiania and Copenhagen of $7^m25.15^s \pm 0.06^s$.

Figure 30.5: *The Utzschneider/Repsold refractor, kept at the Institute of Theoretical Astrophysics, University of Oslo. (Photo: Kine Selbekk Ottersen)*

30.5.2 The Utzschneider/Repsold Alt-azimuth Refractor

The 11 cm Utzschneider refractor appears to have been mostly used to entertain visitors (sometimes royals and other dignitaries), except for timing of the occasional solar eclipse or lunar occultation. Hansteen had ordered it from Utzschneider and Fraunhofer in 1826, but when it was delivered in 1828, two years after Fraunhofer's death, Utzschneider had sold the Fraunhofer lens to someone else and put in a 11 cm objective lens made by one of Fraunhofer's pupils. It did not deliver the image sharpness expected by a Fraunhofer lens. Hansteen sent the telescope to Georg Repsold in Hamburg and asked him to construct the mounting for it while he was on his geomagnetic expedition in Siberia. The instrument arrived Christiania in 1833 with a portable alt-azimuth mounting and was put up in the tower observing room. It was replaced by a Repsold equatorial refractor in 1842. From then on it was put out on the rooftop balcony when an astronomical event called for it.

30.5.3 The Repsold Equatorial Refractor

By saving a fraction of his annual budget since 1828, Hansteen had accumulated a sum large enough to acquire an equatorial refractor ten years later. Upon request, Schumacher advised him strongly to order the instrument from A. & G. Repsold in Hamburg.[29] Hansteen accepted this and discussed technical details by correspondence with Repsold during 1838.[30] The instrument had divided circles on both axes with diameter 50 cm and was intended for position determinations of objects outside of the meridian. An interesting detail is that Repsold proposed to make the divided circles on glass rather than on a silver limbus in a brass wheel, which was customary at the time.[31] Hansteen worried that the glass might break and went for the traditional solution. Further discussions took place at Repsold's workshop during a visit by Hansteen in July 1839, and upon his return to Christiania, Hansteen transferred advance payment. When the instrument left Repsold's workshop in June 1841, Hansteen removed a window and parts of the brick wall of the tower observing room to gain access from the outside to bring in a heavy telescope stone pillar in the centre of the room. The wall was restored, but the masonry remained wet for weeks due to an unusually rainy summer. Hansteen did not risk putting up the instrument in these humid conditions and delayed the operation till the following summer. In August 1842 Repsold's assistant, Mr. Flittner, arrived Christiania to mount and adjust the 12 cm equatorial refractor.

The refined adjustment was left to Hansteen's newly appointed assistant, Emil Bertrand Münster. He observed stars at right ascensions 6, 12, 18, and 24 hours and near the celestial north pole to determine the accurate orientation of the telescope axes, the location of the zero points on the divided circles, and the collimation error. This would allow absolute values of equatorial coordinates to be determined directly with the instrument. When Münster resigned in 1844 to build a career in mineralogy, the work was completed by his successor as *Observator*, Carl Fredrik Fearnley.[32] The Repsold equatorial refractor was the last instrument acquired with Schumacher's assistance and advice.

Fearnley equipped the Repsold equatorial with filar and ring micrometers in 1847 to derive positions of comets and asteroids relative to nearby comparison stars. When needed, he used the meridian circle to determine positions of new comparison stars, which then served to determine positions of comets and asteroids with the equatorial refractor. Determinations of comet positions on the equatorial refractor evolved into a routine program that continued for 67 years. A total of 36 comets were observed. In 1874 Fearnley studied the bright comet Coggia through a direct vision spectroscope. By narrowing the entrance slit to the size of the core itself, he searched for emission lines and molecular bands. He concluded that the observed spectrum was dominated by reflected sunlight from the comet and the sky background. These were the first night-time spectroscopic observations in Norwegian astronomy.

The solar eclipse of 28 July 1851 was total in Christiania. Hansteen timed the events and concluded that the zone of totality was somewhat south of the predicted location. Thus the theory of lunar motion was in need of improvement. He also observed the apparent changes of a prominence during totality. So did Fearnley, who was on leave in Germany at the time. He made detailed drawings of the prominences and concluded as Hansteen that the prominences were solar phenomena and not lunar. The observed changes were only due to the moon acting as a moving curtain that gradually revealed more of the prominence. This view was generally accepted after the solar eclipse in 1860.

A giant sunspot appeared in May 1857 and was visible for more than three solar rotations. Fearnley made accurate drawings to determine positions and morphological changes. He detected sunspot proper motions in solar latitude and different rotation periods due to the differential rotation of the Sun. In 1858 he also monitored sunspots, and when he noted a prominence during the annular solar eclipse of 15 March 1858, he related its limb position to the projected location of a sunspot he had measured on the disk 6 days earlier, and realized that the two phenomena were geometrically and physically related.

In 1873 Fearnley acquired a spectrohelioscope from Merz in Munich which enabled him to view solar prominences in H_α-light outside of eclipses. He studied the morphology and size of numerous prominences and made very detailed drawings with excellent spatial resolution.

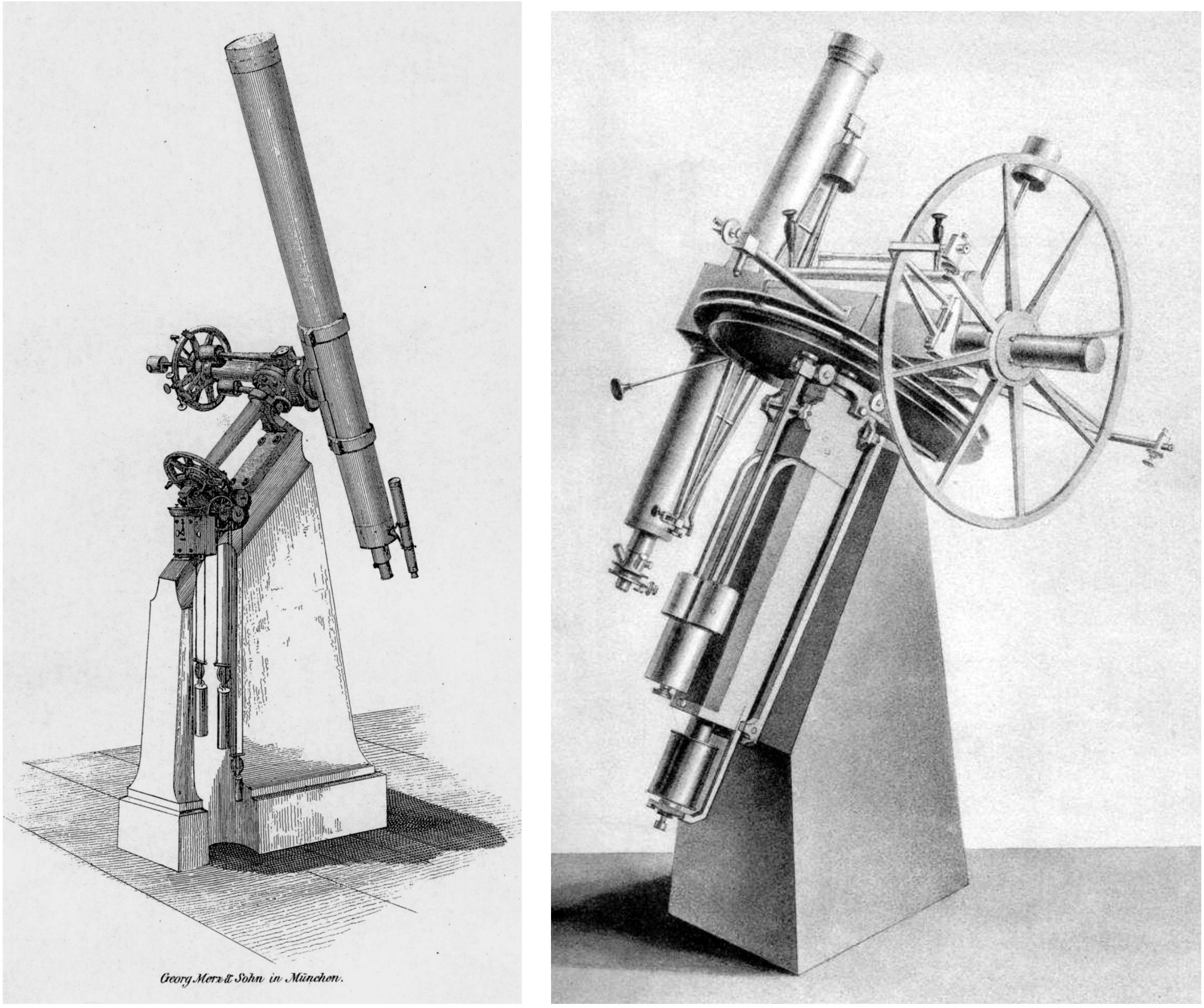

Figure 30.6: *Left: The Merz equatorial refractor; Right: The Repsold equatorial refractor (1842) (Photocopy from a print in the Archives of Deutsches Museum, München, Merz papers. Repsold, Johann Adolf: Zur Geschichte der Astronomischen Messwerkzeuge von 1830 bis um 1900. Zweiter Band. Leipzig: Verlag von Emmanuel Reinicke 1914, Fig. 27.)*

30.5.4 The Merz Equatorial Refractor

The 19 cm f/17 Merz refractor on equatorial mounting was the largest instrument at the observatory. It was ordered in 1853 and arrived two years later. It was mounted in the north pavilion in 1857 and was the last instrument acquisition during Hansteen's Directorship. As the city expanded, observing conditions deteriorated and in 1908 the Merz refractor and the north pavilion was dismantled to give space for a new University Library.

The Merz refractor was used to determine positions of comets and asteroids with a ring micrometer. During the Eros opposition in 1900 a filar micrometer was used to obtain relative positions on 49 nights. They were supplemented by meridian circle observations on 11 nights. This data set was combined with observations from many other observatories to determine a solar parallax value of $8.807''$.

30.5.5 The Merz/Olsen Equatorial Refractor

A 13 cm Merz refractor was furnished with an equatorial mounting by Christian H. G. Olsen, the leading instrument maker in Norway at the time.[33] It was put up in the east pavilion in 1884 where it continued to be available to the public twice a week for the next 50 years. It was used occasionally for timing astronomical events, e. g. lunar occultations, partial solar eclipses, and the transits of Mercury in 1891 and 1907. (A historical detail is that occultation timings generated the first published results from each of the equatorial refractors).

When the University Observatory closed down in 1934 the Merz refractor was lent to a nearby school where it was actively used for a couple of decades. It was recovered from storage in 1990 and was refurbished to serve the public at Oslo Solar Observatory until 2008.

30.6 The Future of Hansteen's Observatory

In 2011 the University of Oslo will celebrate its 200th anniversary. Plans have been made to establish a visitor centre in Hansteen's observatory aimed as school children and promoting both the sciences and the cultural history related to the building. This will include not only the international dimensions of Hansteen's scientific work – for instance his close collaboration with Schumacher in Altona – but also the history of scientific instruments and instruments makers like Repsold, Kessels, Reichenbach, Utzschneider, Fraunhofer and Merz who – in addition to the Norwegian instrument maker Olsen – contributed to Hansteen's observatory.

Hopefully this recognition of the international dimensions of Norwegian science in the early nineteenth century will be relevant also for other international efforts promoting science and the history of science in relation to observatories today.

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1. Hansteen 1819.
2. Hansteen and Due 1849.
3. Schroeter 1911.
4. Hamel 2001, p. 118.
5. Bauermann 2005.
6. Andersen 1975. Lühring 2007, Ch. 5.
7. Grønningsæter (1984) 2001, p. 17–18.
8. Hansteen 1854a, p. 6–7 (our translation).
9. Bauermann 2005, p. 64. Koch 2005.
10. Andersen 1975, p. 26.
11. Lühring 2007, p. 74.
12. Andersen 1968.
13. Lühring 2007, p. 85.
14. Quoted from Andersen 1975, p. 32.
15. Andersen 1975, p. 45.
16. Kertscher 2005, p. 157.
17. Pettersen 2002.
18. de Seue 1878, p. 53, 72.
19. Pettersen 2002.
20. Schroeter 1911.
21. Lühring 2007, p. 90ff., quoted from p. 100.
22. Grønningsæter (1984) 2001, p. 75–76. Rogstad 2003, 70f. Seip (2001) 2007.
23. Pettersen 2002.
24. Pettersen 2007a.
25. Pettersen 2007b.
26. Letter from Schumacher to Hansteen 29 December 1826, archived at University of Oslo, Norway.
27. Hansteen and Fearnley 1849.
28. Fearnley et al. 1890.
29. Letter from Schumacher to Hansteen 26 December 1837, archived at University of Oslo, Norway. In our translation, Schumacher wrote: *"With respect to your equatorial (telescope), my remark is that Ertel is not Reichenbach, as you already know from your meridian circle. Ertel's workshop has become more and more like a factory. He looks only for profit. Under no circumstances would I advise you to have your instrument made in Munich. But the young Repsold is by far the best artist of today. Even Struve, who is one of Ertel's closest friends, could not overlook the evidence and had to order both main instruments for Petersburg Observatory with Repsold, namely a meridian circle and a transit instrument, both 8 feet long. These instruments are almost completed and you may see them if you come here early this year before they are shipped away. My honest advice, given in total conviction, is to order your equatorial with Repsold. If you request so, he will send you a preliminary drawing and when you have reached agreement about the construction, he will estimate the cost. The funds at your disposal are more than enough."*
30. Letter from Hansteen to Schumacher 4 January 1838, archived at Staatsbibliothek zu Berlin, Germany, and from Hansteen to Repsold the same day, archived at Staatsarchiv, Hamburg.
31. Letter (and instrument description) from Repsold to Hansteen 23 November 1838, archived at University of Oslo, Norway.
32. Münster was appointed professor of mineralogy in 1862.
33. Pettersen 2004.

Figure 30.7: *The Merz/Olsen refractor (Photo: Bjørn Ragnvald Pettersen)*

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Figure 31.1: *Equatorial telescope (26 cm aperture and 3 m focal length), G. &S. Merz, Munich, A. & G. Repsold, Hamburg, 1867 (Photo: Matthias Hünsch)*

31. The Telescopes of Hamburg Observatory – History and Present Situation

Matthias Hünsch (Hamburg, Germany)

Abstract

During its 175-year-long history, the Hamburg observatory has operated a large variety of telescopes of nearly all kind of optical design. This collection demonstrates vividly the transition from classical astronomy to astrophysics. Most of the telescopes are preserved, a good fraction of them are still operationable at their authentic site in Bergedorf.

31.1 Introduction

Hamburg observatory dates back to the beginning of the 19th century, when Johann Georg Repsold (1770–1830) established a private observatory at the "Albertus Bastion" on the old fortification wall of the city of Hamburg. However, in the course of the french occupation, this observatory had to be demolished after a few years.

In 1820, Repsold addressed a proposal to the senate of Hamburg, justifying the requirement of a state observatory due to the demands of navigation and time service. The government accepted under the condition that the new observatory would be established as a joint institute together with the navigation school and that Repsold would provide the necessary instruments on his own behalf.

In 1825, the observatory building was finished and equipped with several instruments of Repsold's workshop. Unfortunately, Repsold died in 1830 during a fire, yet a private foundation allowed to aquire the instruments from Repsold's heirs. By 31 October 1833, the Hamburg parliament declared the observatory to be run as a full state observatory, and Charles Rümker (1788–1857) was appointed as its first director.

The scientific work and duties of the observatory were completely devoted to the requirements of navigation and trade: keeping time and measuring star positions for celestial catalogues. The instruments were chosen to serve these tasks as good as possible. George Rümker (1832–1900), who succeeded his father Charles Rümker as director of the observatory, continued the duties until his retirement.

At the end of the 19th century, the growing city of Hamburg with its nearby harbour, industry and street lamps made observations increasingly difficult. Therefore, the third director, Richard Schorr (1867–1951), urged the government to transfer the observatory to a new location at the outskirts of the city, where observing conditions were still good.

Between 1906 and 1912, a completely new observatory was erected in Bergedorf, about 25 km to the southeast from the city centre of Hamburg. The domes were arranged as separate buildings, unlike most of the earlier observatories, yielding more favourite observing conditions. The new telescopes allowed on the one hand the continuation of the traditional purposes for time service and positional astronomy, on the other hand they reflect the transition to more astrophysical observational tasks. At its inauguration in July 1912, Bergedorf observatory ranked among the leading astronomical observatories of the world.

31.2 Telescopes at Millerntor Observatory

The observatory building at Millerntor consisted of two larger box-shaped wings, each carrying a wooden dome, that were connected by the transit hall having a roof with two slits. A number of smaller instruments were provided by Johann Georg Repsold including a 6-foot Fraunhofer refractor and a 5-foot transit instrument.

31.2.1 Transit Instrument

The transit instrument ("Passageinstrument") of 11 cm aperture and 5-foot focal length was built by Repsold himself and was installed in 1829. The instrument was mainly used for time service and stayed in operation until around 1903, just before the closure of the Millerntor observatory. Then it was dismantled, overhauled by the Repsold company and re-installed in Bergedorf in 1910 in a small shelter to the north of the new meridian circle, so that the calibration mark ("Mire") in between could be used for both instruments. Again, the transit instrument served for time keeping, yet mainly as a back-up instrument for the meridian circle. It was last

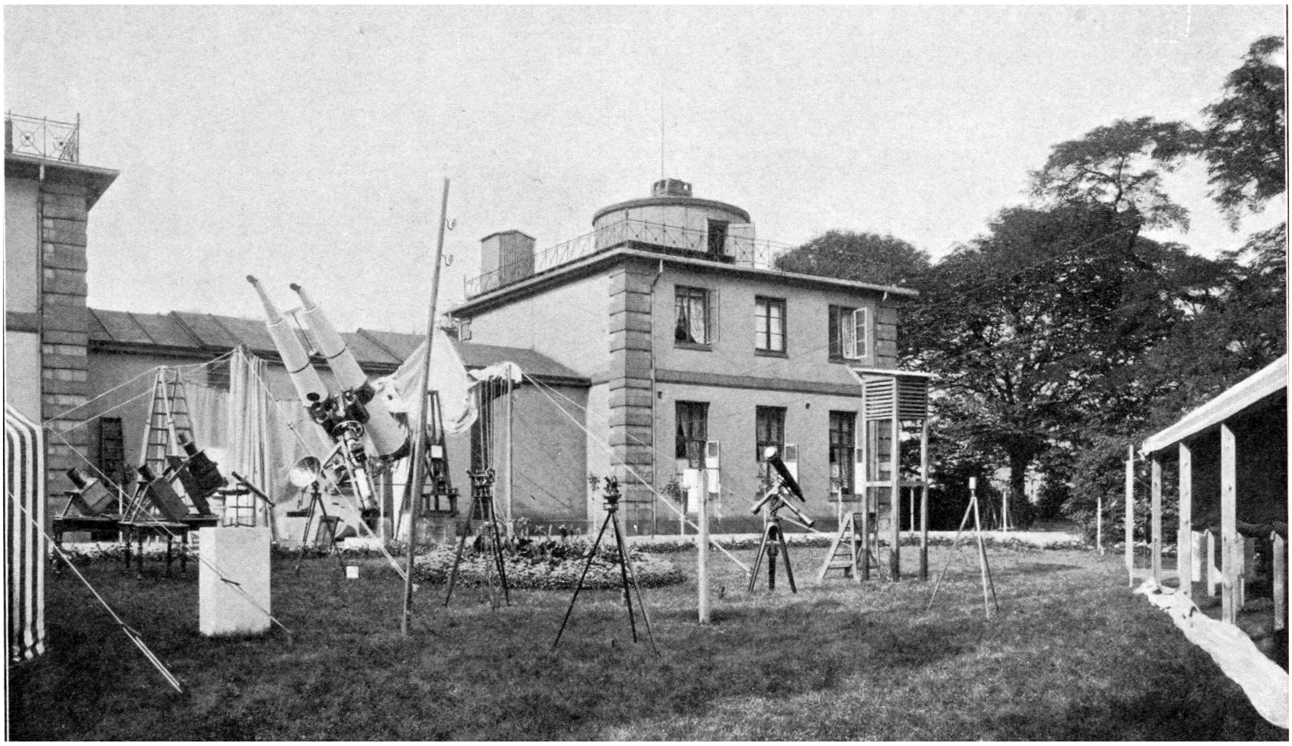


Figure 31.2: *Telescopes, prepared for the solar eclipse expedition in 1905, in front of the old observatory near Millerntor (Hamburg Observatory)*

mentioned in the annual report of 1939. Its fate seems to be unknown.

31.2.2 Meridian Circle

The second instrument at the transit hall was the meridian circle of 4-inch aperture and 1.62 m focal length. This telescope was build by A. & G. Repsold (the sons of Johann Georg Repsold, who succeeded their father in instrument making) in 1835.[1] In addition to time service this instrument was extensively used for measuring accurate positions used for a number of star catalogue.[2] It was last used in 1909 and then stored at the observatory. However, it seems to have not been used again and it is not known where it remained.

31.2.3 Equatorial

The only significant extension to the instruments at Millerntor was the Equatorial, a refractor of 26 cm aperture and 3 m focal length, that was installed in 1867 in a new dome at the north side of the observatory building. A. & G. Repsold made the tube, the mounting and the movable observation chair while the objective lens was figured by G. &S. Merz in Munich. Later a second object glass was purchased from Hugo Schröder.

The telescope was equipped with unusually large setting circles in order to measure right ascension and declination differences directly and at any position in the sky (not restricted to the meridian). However, the positional accuracy did not come up to the expectations and remained far inferior to transit measurements. The telescope was mainly used for observations of comets, minor planets and variable stars. In addition, a large programme for measuring celestial positions of "nebulae" was carried out and published in the annals of the observatory.[3]

In May 1908, the telescope was dismounted and refurbished at the Repsold company, and in June 1909 it was rebuild at its new location in Bergedorf. Also, the old dome and the observing chair could be used further on. Again, planets, comets and variable stars were the main targets of the instrument, yet as the new and larger telescopes at Bergedorf came into operation, the Equatorial was less and less used for scientific purposes. It was only after the second world war that the telescope experienced a new fruitful period of scientific use when it was handed over to Max Beyer (1894–1982), a skilled amateur astronomer who made decade-long observation records of comets and variable stars.

From the end of the 1970s on the telescope fell into disuse, and the dome and the mechanical parts deteriorated gradually. In 2004–2005, the "Förderverein" restored the whole building. The telescope can now be used again for observations.

31.3 Telescopes at Bergedorf – The Original Instruments

31.3.1 Meridian Circle

The new meridian circle was again built by A. & G. Repsold, at that time probably the leading manufacturer of transit instruments. It has an aperture of 19 cm and a focal length of 230 cm. Several instruments of similar size were made by the Repsolds in the beginning of the 20th century, among them meridian circles for Kiel, Santiago, La Plata and other observatories. The lens was provided by Steinheil in Munich.

The meridian circle was installed in a separate dome of cylindrical shape with a movable slit in north-south direction. The first test observations were made in 1911, regular observations for time service started in 1913. Besides the regular time service and numerous smaller observation programmes, the main duty of the meridian circle were the observations for the grid stars of the *"Zonenunternehmen der Astronomischen Gesellschaft"* (AG catalogues). Between 1928 and 1933 the observations for the second AG catalogue (AGK 2) were performed, while from 1956 until 1962 the observations for the second repetition, the third AG catalogue (AGK 3) were made. In both cases, the meridian observations yielded accurate positions for several thousand grid stars, which allowed to determine the positions of numerous fainter stars on photographic plates taken with the AG astrograph.

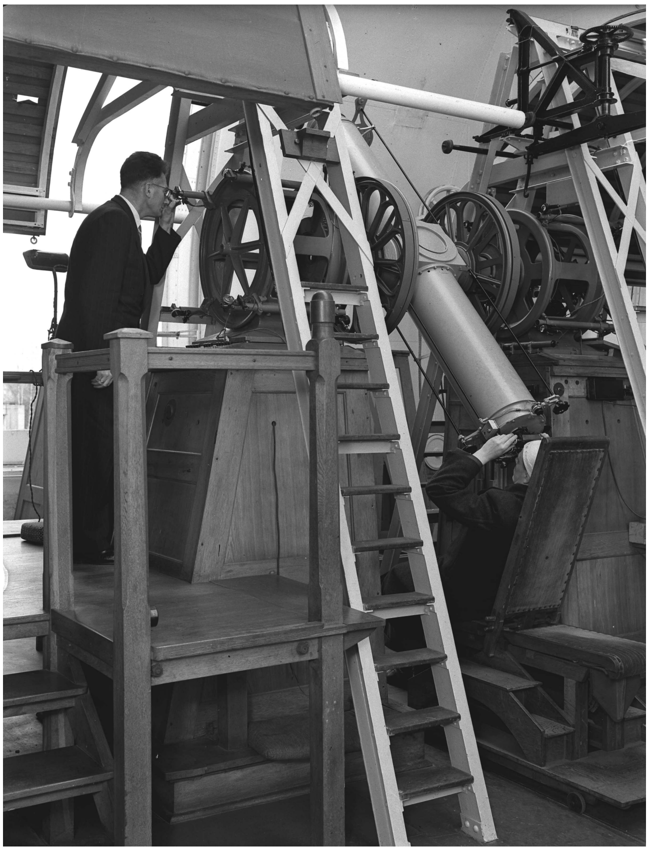


Figure 31.3: *19 cm Meridian circle, Steinheil, Munich, A. & G. Repsold, Hamburg, 1912 (Hamburg Observatory)*

After completion of the third AG catalogue project and being not used for time service any more, it was decided to remove the meridian circle in order to refurbish and modernize it and to relocate the instrument in the southern hemisphere. In 1967, the instrument was transfered to Perth in Australia, where it started a comprehensive observation project on a southern fundamental catalogue project – Perth 70 (1969–1975). Later, additional catalogues (Perth 80 and Perth 83) were published, and the observations with the Hamburg meridian circle came to an end in 1987. Finally, the instrument was purchased by the Deutsches Museum in München, where it is still kept in store.

31.3.2 Large Refractor

At the turn of the centuries, when the first plans were made to relocate Hamburg observatory to a new site, the competition between refractors and reflectors was just culminating. The largest refractors had already been put into service (Pulkovo, Nice, Lick, Meudon, Yerkes, Potsdam) and the first big reflectors with silver-on-glass mirrors had just demonstrated their capabilities. Yet, a large refractor was still considered as an essential part for a powerful astronomical observatory, in particular for "classical" duties like measuring stellar parallaxes, double stars and visual observations of planets.

Hence, a large refractor (fig. 31.4, p. 278) was ordered at the Repsold company, while the lens was manufactured by Steinheil in Munich. The aperture is 60 cm and the focal length 9 m, thus yielding a focal ratio of f/15. The two-element object lens glass of the Fraunhofer design is corrected for the visual range. Later on (in 1925), a second object glass corrected for photographic plates was ordered, which can be exchanged with the visual object glass. It was refigured by Bernhard Schmidt in 1931. The Hamburg refractor is the only large refractor in the world that allows such an exchange of the front lens.

While the dome and the moving floor (made by Zeiss) were completed in 1909 and the telescope was delivered by Repsold in 1911, the lens could only be installed in 1914 as Steinheil had difficulties to obtain glass disks of sufficient quality. During the first years the refractor was used by Kasimir Graff for visual observations of planets and for visual photometry of variable stars. Later, photographic photometry of variables and stellar clusters became the main observation tasks, performed by Johannes Hellerich. For an intermediate period, a prism spectrograph made by Zeiss was also used at the refractor, but later this instrument was transfered to the 1 m reflector.

After the war, the telescope was used by Georg Thiessen for spectrophotometric observations of the Sun. He discovered the existence of a weak large-scale solar magnetic field.[4]

From 1952 on, photoelectric photometers were attached to the refractor. In particular, a very fast photometer originally intended to measure stellar diameters by means of lunar occulations allowed some of the first optical period determinations of the recently detected Crab pulsar. After a modernization of the instrument during the early 1980s the refractor was used for high-

Figure 31.4: *Large refractor (60 cm, 9 m), Mechanics: A. Repsold & Söhne, Hamburg, 1911, Optics: Steinheil, Munich (visual objective, 1914, photographic objective, 1925) (Photo: Matthias Hünsch)*

precision astrometric observations. The scientific use of the instrument came to an end around 1990.

Today, the large refractor is still in operation for public observing nights. Its moving floor allows an easy access to the eyepiece, and with its sharp imaging capability the refractor is especially suited for observations of the moon, the planets and double stars. It is in a generally good condition and probably the most impressive instrument of the observatory.

31.3.3 1 m Reflector

The 1 m reflector (see fig. 5.12, p. 50) ranks among the most interesting and historically most valueable telescopes in Germany if not in Europe. At the time of its installment it was the fourth largest reflector in the world, it is the first large reflector built by Zeiss, it is one of the largest telescopes resting on a Zeiss-mounting after Franz Meyer, it was used by one of the most prolific astronomers of the 20th century, and finally the instrument is nearly in its original condition.

At the begining of the 20th century it became more and more evident that large reflectors are far superior to refractors when taking astronomical photographs due to their light gathering power and freeness from chromatic aberration. Therefore, a reflector of 1 m aperture was ordered at Zeiss for the new Hamburg observatory. The telescope was delivered by the end of 1911. However, its imaging quality did not satisfy and Zeiss had to make a new mirror cell. Regular observations thus started in early 1913. In its original configuration, the telescope is a Newtonian reflector of 3 m focal length, yielding a very fast focal ratio of f/3.

During the first years, the 1 m reflector was mainly used by the then director Richard Schorr for the search for comets and minor planets.

From 1920 until 1931 the young Walter Baade took over the telescope and started observations more devoted to modern astrophysics. In particular, he systematically took photographs of stellar clusters, variable stars, and galaxies. He discovered that stars do not only exist in the galactic disk but also in the galactic halo, and his observations in Bergedorf laid the foundations for his famous concept of the different stellar populations. Baade even just failed to discover the true nature of the galaxies, as he could resolve individual stars in M 33 with the 1 m reflector. However, these stars were not cepheids, and Baade was not able to demonstrate their extragalactic nature by means of the period-luminosity relation. Shortly afterwards this was achieved by Edwin Hubble using the 100-inch telescope on Mt. Wilson. Besides this astrophysical work Baade also searched for comets and minor planets, and among his discoveries is the unusual object Hidalgo, the first known minor planet that has an orbit extending far beyond Jupiter.

Shortly after WW II the 1 m reflector was converted to a bent-Cassegrain system (sometimes also called Nasmyth system) of 15 m focal length by inserting two auxilliary mirrors into the tube.

From 1947 on, the telescope was used exclusively for stellar spectroscopy, feeding a Zeiss prism spectrograph originally built for the large refractor. The spectrograph has a very compact design and allows by different combinations of prisms and camera objectives various dispersions between 8 and 72 Å/mm. It was used for radial velocity measurements and spectroscopy of Zeta-Aurigae systems, novae, spectroscopic binaries and standard stars until 1972.

After two short periods of testing a new grating spectrograph and photometric work, the telescope was only used for teaching purposes during the 1980s and 1990s. Although still fully operationable the telescope is now in poor condition and needs a comprehensive restauration. Conservation work on the dome and building started in 2008 (see contribution of Beatrix Alscher, p. 293, and the article about the restauration of the building, p. 333).

31.3.4 Lippert Astrograph

The Lippert astrograph was a combination of three different photographic refractors and two visual guiding refractors on the same polar-axis-type mounting. This instrument was a donation of the wealthy businessman and amateur astronomer Eduard Lippert (1844–1925) and thus bears his name.

Of the five telescopes, two long-focus refractors (a photographic triplet of 34 cm aperture and 3.40 m focal length – following the Carte-du-Ciel dimensions – and a 23 cm guiding telescope) were mounted on the one side of the declination axis, while the other side carried two short-focus refractors (a triplet and a Petzval four-lens objective) of 30 cm aperture each and 1.50 m focal length, and a 20 cm guiding telescope. For the photographic refractors, plates of 24 cm×24 cm or even 30 cm×30 cm format could be used, allowing to image fields of several degrees extension. Additional objective prisms could be inserted in front of the lenses. The whole instrument as well as the dome was made by Zeiss, and the long-focus instrument became operationable in 1911. Among the first exposures were photographs taken of the solar eclipse of 17 April 1912. The central zone of this annular eclipse was situated just 40 km south of the observatory. The short-focus objective lenses could not be delivered before 1914.

Research at the Lippert astrograph can be divided into three different topics. The first is a long-term project, the so-called *"Bergedorfer Spektraldurchmusterung"*, which consists of the determination of stellar spectral types in 115 northern selected areas down to 13$^{\text{th}}$ magnitude. This decade-long project is part of a compehensive international programme originally suggested by Jacobus Kapteyn. The aim was to unveil the structure of the Milky Way by determining various stellar parameters as complete as possible for 206 selected areas distributed uniformly across the celestial sphere. The plates were taken between 1923 and 1933, the catalogue was published in five volumes between 1935 and 1953.

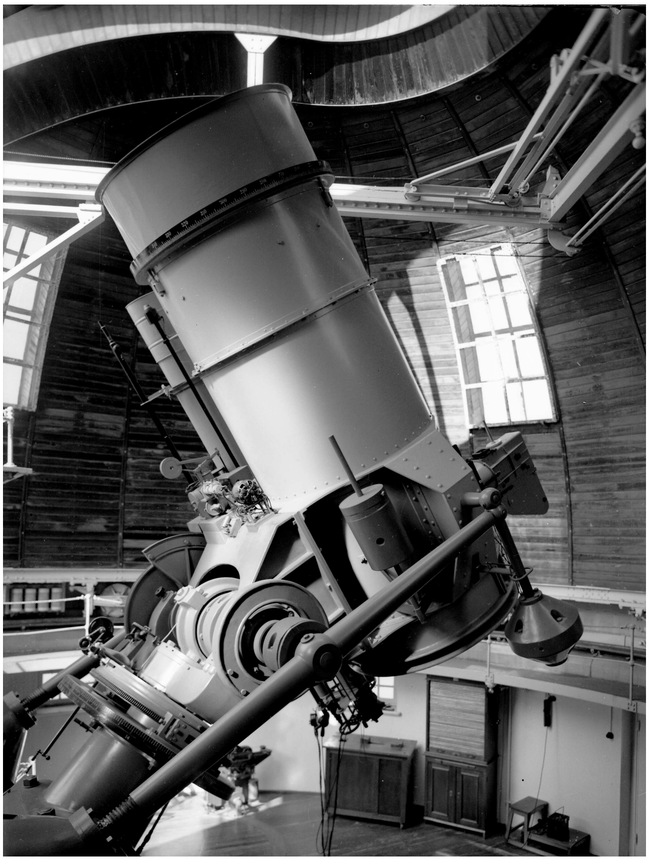
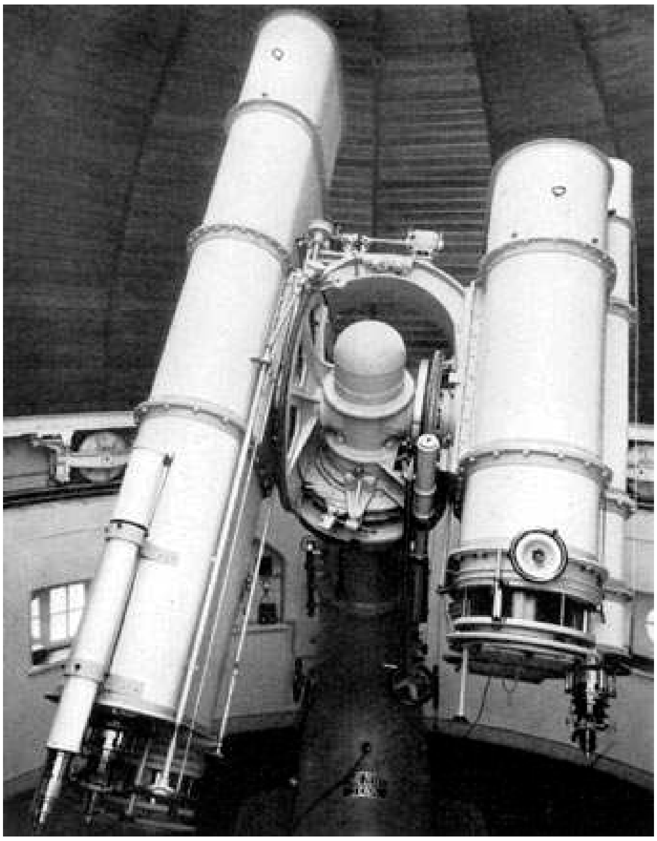


Figure 31.6: *1 m reflector, Carl Zeiss, Jena 1911 (Hamburg Observatory)*

The second field of research were photographic observations of variable stars, and the third was the discovery of comets and minor planets. The latter was more a by-product of the numerous photographs, yet a significant number of objects were discovered by Arnold Schwassmann and Arno Arthur Wachmann, who were in charge to perform the observations for several decades.

In 1957 the long-focus refractors were replaced by a 60 cm Newtonian reflector that was later converted into a Cassegrain system of 9 m focal length. The short-focus refractors remained in place until 1974, but they were rarely used after the big Schmidt telescope became operationable. The variable-star observations were transfered from photographic to the photoelectric method and continued until the early 1980s.

The Lippert telescope underwent strong changes during the decades, and from its original optical configura-



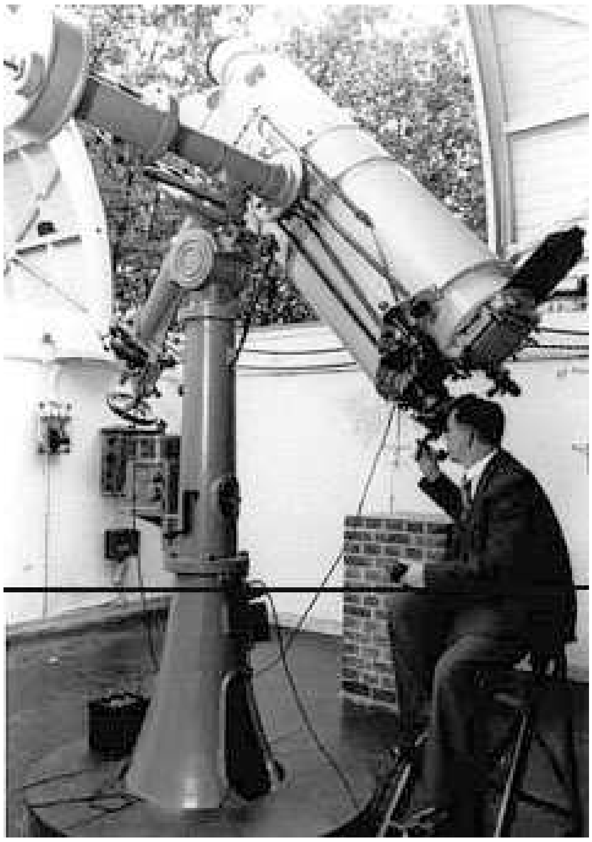


Figure 31.5: *34 cm Lippert astrograph in its original configuration, Carl Zeiss, Jena, 1911; AG Astrograph, Carl Zeiss Jena, 1924 (Hamburg Observatory)*

tion only the 20 cm guiding refractor and a finderscope are still on the mounting. The telescope is now mainly used for teaching purposes, either by students or by school classes.

31.4 Additional Telescopes in Bergedorf before 1945

31.4.1 AG Astrograph

In 1925, the Zeiss works delivered a small astrograph consisting of a 15/206 cm four-lens refractor and a visual guiding telescope of about the same size. In spite of being one of the smallest telescopes in Bergedorf, it became of significant importance since the major part of the photographic plates for the first and second repetitions of the AG catalogues were taken with this instrument (1929–1930 and 1956–1964, respectively). The instrument was installed in a small building with a cylindrical roof that could be opened by rolling the two halfes away on rails. The telescope was dismantled many years ago but it is still stored at the observatory.

31.4.2 Original Schmidt Telescope

The first Schmidt telescope (cf. fig. 38.2, p. 328) was constructed and built by Bernhard Schmidt (1879–1935) and erected at Bergedorf observatory in 1930. It has an aperture (diameter of correction plate) of 36 cm, a mirror diameter of 42 cm, and a focal length of 62.5 cm. The telescope was mounted on a Zeiss German-type mounting in a small shelter with a moveable roof. According to its very fast focal ratio and its absolutely coma-free field-of-view, this telescope revolutionized celestial photography and became the prototype of many Schmidt telescopes following worldwide.

The telescope was transfered to different locations two times. During the second world war it was taken by the German army in order to observe the coast of the British channel in the infrared. Unfortunately, the mirror was damaged and later replaced by a new one made by Zeiss. After the war, the telescope was transfered for a second time to Asiago observatory in Italy from 1955 to 1960. Afterwards, it returned to Bergedorf and remained at its original location until 1979, when it was dismounted and since then kept in a small museum in honour of Bernhard Schmidt.

31.4.3 Double Reflector

Schmidt also constructed and built a larger telescope of the coma-free design invented by him. A 60 cm Schmidt telescope was mounted together with a 60 cm Newtonian-type reflector on an English-type mounting in the northern part of the observatory grounds, close to the original Schmidt telescope. The instrument was completed in 1934, shortly before Schmidt's death. Both telescopes had a focal length of 3 m for comparison purposes. This seems to be quite astonishing since the advantage of the Schmidt design is not so obvious for telescopes of such a long-focus type. Only very few plates have been taken with the Schmidt telescope, which was mechanically not satisfying due to its very long tube. The Newton reflector, however, was used until 1957, when it was transfered to the Lippert astrograph. The mirror and correction plate of the Schmidt telescope are preserved and now on display at the Schmidt museum.

31.5 New Telescopes at Bergedorf after 1945

31.5.1 Large Schmidt Telescope

By the end of the 1930s, when Richard Schorr came close to his retirement, an offer was made to Walter Baade to become the director of Hamburg observatory. Baade demanded the erection of a large Schmidt telescope as a key requirement for his agreement. The state of Hamburg accepted his claim, and funds for building such an instrument were foreseen in the budget of the forthcoming years.

Figure 31.8: *60 cm double reflector, Bernhard Schmidt, Hamburg, 1934: 60 cm Schmidt telescope and 60 cm Newtonian-type (Hamburg Observatory)*

However, working conditions in Germany became worse under the Nazi regime, and the second world war was not far. Baade refused as he was given prospects for an even larger Schmidt telescope in the clear Californian skys. Nevertheless, the agreement to aquire a large Schmidt telescope even survived the war, and plans to build the instrument were resumed. The telescope was ordered from Zeiss in Jena, and the contract for the fork mounting was given to the mechanical works of Heidenreich & Harbeck in Hamburg. The whole instrument was completed in 1954 and observations started in the same year.

At that time, the Hamburg Schmidt telescope was one of the largest of its kind. The mirror has a diameter of 120 cm, the correction plate measures 80 cm (which is also the aperture of the instrument). The focal length of 2.40 m yields a focal ratio of f/3. Plates of 24 cm×24 cm could be inserted into the tube, and an objective prism was also purchased.

Among the various scientific projects performed with the instrument is a spectral survey of the northern milky way, which lead to a comprehensive catalogue of O- and B-type stars. Additional topics were the study of open clusters and the discovery of comets and minor planets. However, observing conditions became worse during the 1960s due to the growing light pollution 25 km away from the city centre of Hamburg.

Therefore, in 1974 the telescope was disassembled in 1975 and later transfered and remounted at Calar Alto observatory in southern Spain. The fork mounting did not stay empty for a long time as even within the same year the new Oskar-Lühning telescope was installed in the dome of the former Schmidt telescope.

31.5.2 Salvador Reflector

After the original Schmidt telescope was transfered to the Schmidt museum, the Zeiss mounting was equipped with a 40 cm Cassegrain reflector of 8 m focal length. The origin of that telescope is somehow unclear. Yet, it is known that the instrument operated from 1967 until 1970 at a southern station in Stefanion, Greece. The purpose was to perform an extensive observation programme on magnitudes and colours of M-type stars. The telescope is now used for public viewing events.

31.5.3 Zonenastrograph

The Zonenastrograph is a five-lens refractor having an effective aperture of 23 cm and a focal length of 205 cm. The objective produces extremely sharp images of stars that can be measured to about a 1/1000 mm on plates up to 24 cm×24 cm, yielding a field-of-view of 6° × 6°. The instrument was delivered by Zeiss in Oberkochen in 1973 and was used for regular observations in Bergedorf until around 2000. More than 2000 plates have been taken and used for various astrometric projects including the *Hipparcos* input catalogue. In 2002, the Zonenastrograph was disassembled and transfered to Haute-Provence observatory in France.

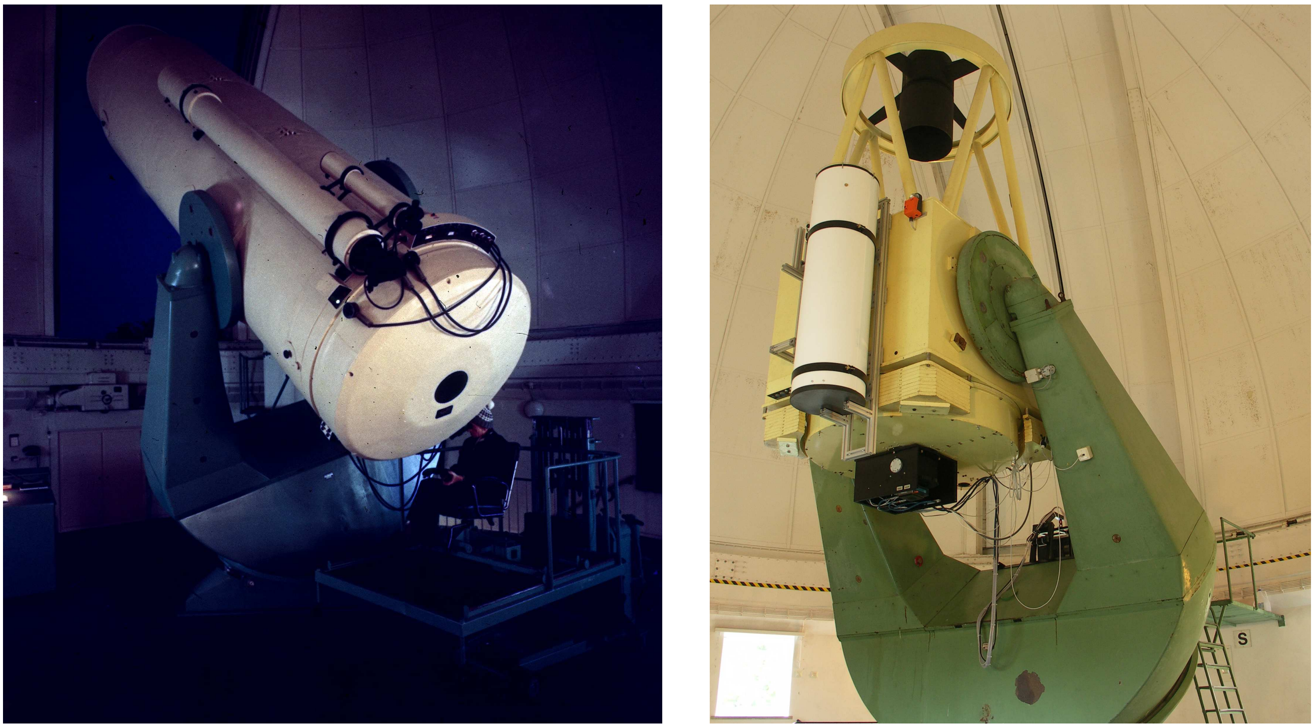


Figure 31.7: *Large 80 cm Hamburg Schmidt telescope, Zeiss, Jena, Heidenreich & Harbeck, Hamburg, 1954; 1.20 m Oskar-Lühning telescope, Grubb, Parsons & Company, 1975 (Left: Hamburg Observatory, Right: Photo: Matthias Hünsch)*

31.5.4 Oskar-Lühning Telescope

Shortly after the tube of the large Schmidt telescope had been removed from its dome in Bergedorf, a new telescope was installed at the fork mounting. The Oskar-Lühning telescope is a Ritchey-Chrétien system of 1.20 m aperture and 15.6 m focal length. The instrument was build by Grubb, Parsons & Company, who delivered it by the end of 1975. It is still the second largest telescope in Germany. The aquirement of the instrument was only possible because of a private foundation. It was named after Oskar-Lühning, wo intended to study meteorology and astronomy, yet was missed in World War II.

The main observational purpose the telescope was intended for was photometry and spectroscopy. However, rather little use of the instrument was made until the turn of the centuries. From 1998 until 2001, the telescope underwent a comprehensive modernization of the mechanical parts. A completely new control system was installed as well as a modern CCD camera. It is now possible to observe via remote control. Today, the telescope is used for scientific and teaching purposes. In spite of the unfavourable observing conditions close to the city of Hamburg and the northern german climate, the instrument bears the advantage of easy access and possibility to perform long-term observation programmes.

31.5.5 Hamburg Robotic Telescope

The HRT (fig. 37.5, p. 322) is an alt-azimuth mounted telescope of 1.20 m aperture and 9.60 m focal length. The telescope was delivered by Halfmann Teleskoptechnik in July 2002 and it was erected in the building of the former Zonenastrograph. The main purpose is a long-term project of robotic spectroscopic observations of magnetic activity in late-type stars. The telescope will be equipped with HEROS, a powerful Echelle spectrograph provided by the Landessternwarte Heidelberg.

After a comprehensive observational testing phase in Hamburg the whole instrument is going to be relocated at a site of much more favourable observing conditions.

31.6 Conclusion

During its 175 year-long existence, the Hamburg observatory owned a large variety of astronomical optical telescopes of nearly all types, among them refractors, reflectors, astrographs, Schmidt telescopes and different transit instruments.

These telescopes illustrate very well the transition from classical astronomy of the 19^{th} century to modern astrophysics of the 20^{th} century until present. Few observatories in the world can provide such a complete collection of different instruments. Moreover, a significant contribution to astronomical research has been achieved with these instruments.

Most of the telescopes are still existent, the larger and more important instruments are still in their authentic environment, and they are preserved to a large extent close to their original condition.

Therefore, the Hamburg observatory is an outstanding example for an astronomical observatory at the transition from classical astronomy to modern astrophysics.

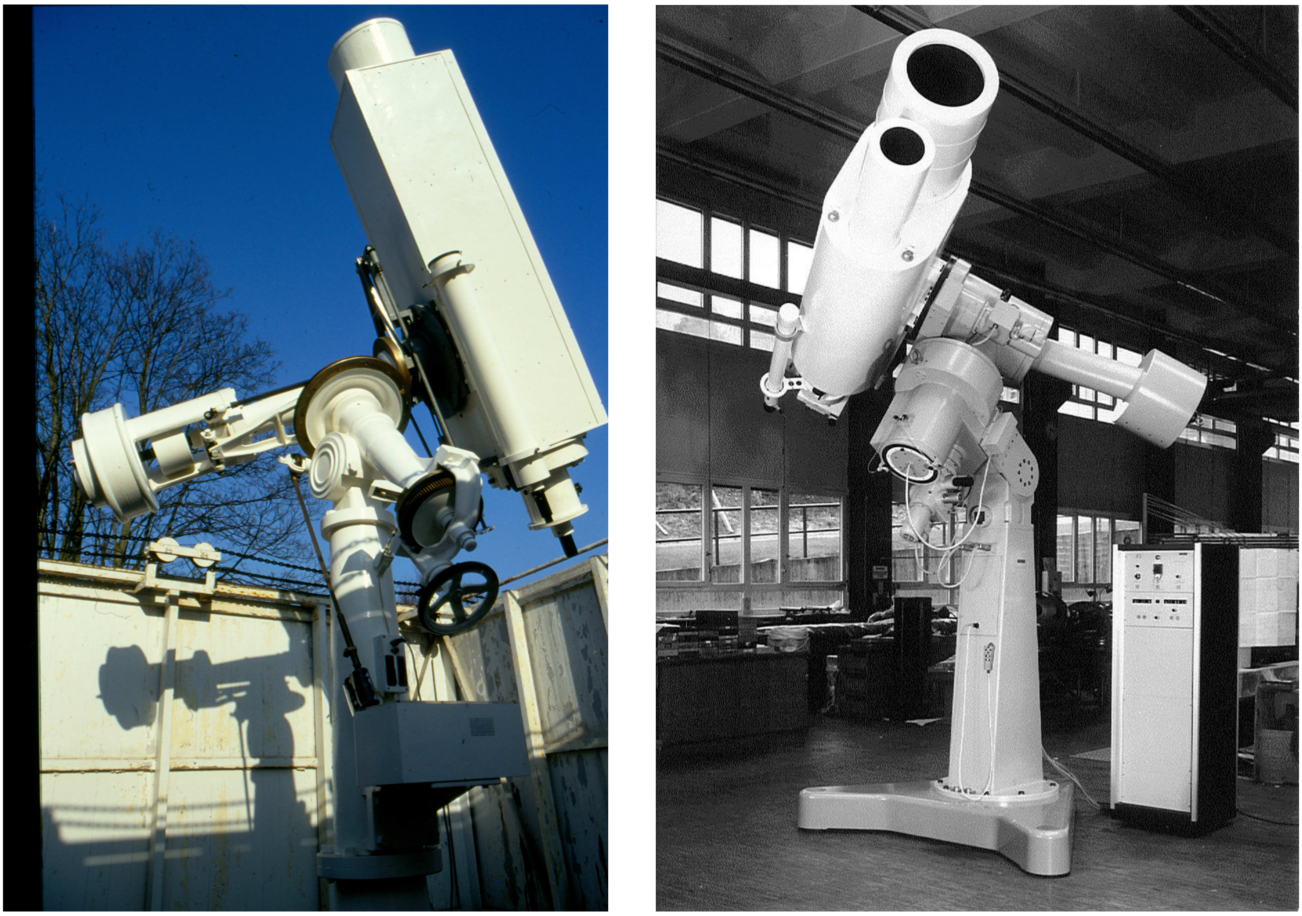


Figure 31.9: *40 cm Salvador reflector (1967) and 23 cm zone astrograph, Zeiss, Oberkochen (1973) (Hamburg Observatory)*

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1. The meridian circle is described in AN 349, 225 (1837).
2. *"Mittlere Oerter von 12,000 Fixsternen für den Anfang von 1836, abgeleitet aus Beobachtungen auf der Hamburger Sternwarte"*, and *"Neue Folge der mittleren Oerter von Fixsternen für den Anfang von 1850, abgeleitet aus den Beobachtungen auf der Hamburger Sternwarte"*, Hamburg 1843–1859.
3. Mitt. Hamburger Sternwarte No. 1, Hamburg 1895.
4. The discovery of strong *local* magnetic fields in sun spots was already made by George Ellery Hale in 1908.

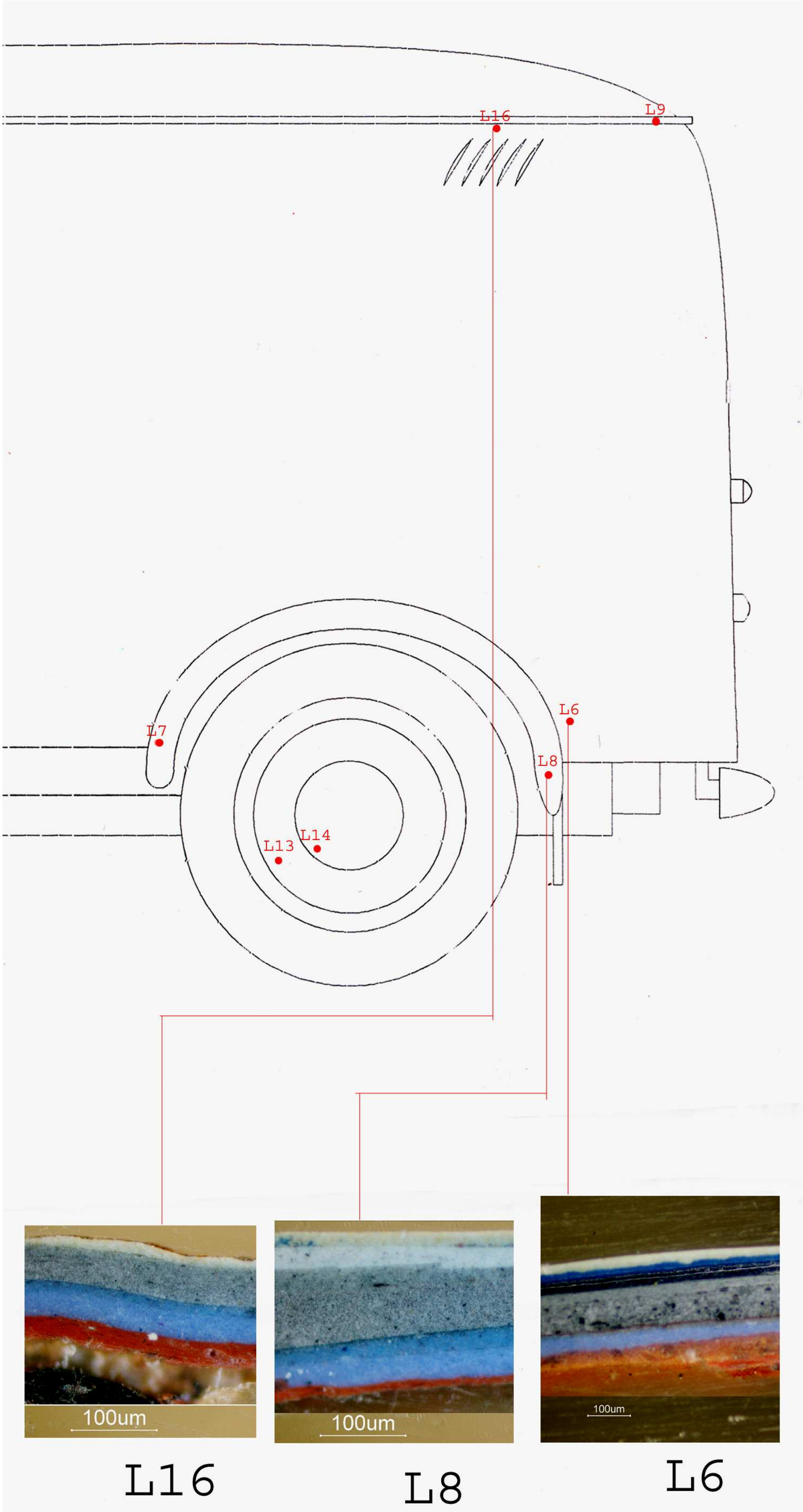


Figure 32.1: *Mapping of layers of lacquer; van from 1950 (HTW, Hilsky)*

32. Large Devices of Industrial Culture: the Preservation of their Historical Evidence

Ruth Keller-Kempas (Berlin, Germany)

Figure 32.2: *Lac flaking off and corrosion are the main problems of instruments in observatory (HTW, Keller-Kempas)*

Abstract

Development of material science and engineering technology is present in devices of the last 150 years. How can the historical evidence of their construction and use, the transfer of technological stages of development be preserved as a special quality in cultural tradition?

The conservation of technical artefacts as a cultural heritage of western civilisation has developed scientific methods of conservation so as to respect their authenticity as materialised references of the past. During the last fifteen years these methods have been evaluated in the unique training program for this specialisation of conservation discipline at the HTW Berlin, University for Applied Sciences. They are enough standardised now to be applied without hesitation on objects being kept indoor in a museum or private collection. It is much more difficult to keep devices outside or – as is the case in Observatory – at climates changing between inside and outside situations.

The paper will show a few examples of how to develop concepts for conservation and how it is technically possible to preserve the very important original surfaces of the objects, their authentic materiality. As soon as the objects are kept as part of cultural history or history of science they change their function and can not be kept in the same manner as before. They give evidence of their materiality. The archaeometry of modern times is a new and expanding branch of historic research. Moreover the surface of a historic device is the point of contact between passed times and the presence – for the general public as much as for the scientists. It will be demonstrated how large the loss of historic information and thus of cultural value of objects can be by renovation instead of considerate conservation. Some examples of careful conservation work carried out on big objects other than an observatory are presented.

The paper will then summarise the possibilities and difficulties of doing such work on large devices still in use. The scientific research in this specialist field of conservation has only just begun und will be continued in large scientific projects in the future:

"The relation to the past is always an integral dimension of the form of being of the present, and restoration, dealing materially with the object, always exteriorizes this relationship in a manifest an indisputable manner, even in its least conscious aspects."[1]

32.1 Observatories

They are large and fascinate by their literally "extraterrestrial" orientation towards space. Built as instruments for the exploration of the sky, they are often of national importance. When they were succeeded by newer installations, the historical observatories discussed here gradually lost their scientific importance and at the same time gained in cultural value. Visible from a large distance, they now point towards a period of sky exploration that determined our understanding of the world. The ancient striving of mankind to find out the secrets of the night sky was given new possibilities in the 19th century.

Rapid developments in physics, engineering and material technology, especially in the technology of the production of glass, opened up the possibility of manufacturing very large and bright mirrors, that could be adjusted precisely to the needed requirements, despite their enormous weight. This makes the remaining telescopes from the late 19th and early 20th century that can still be found in observatories unique and irreplaceable worldwide material testimonies to this period of feverish research in astronomy and the manufacture of

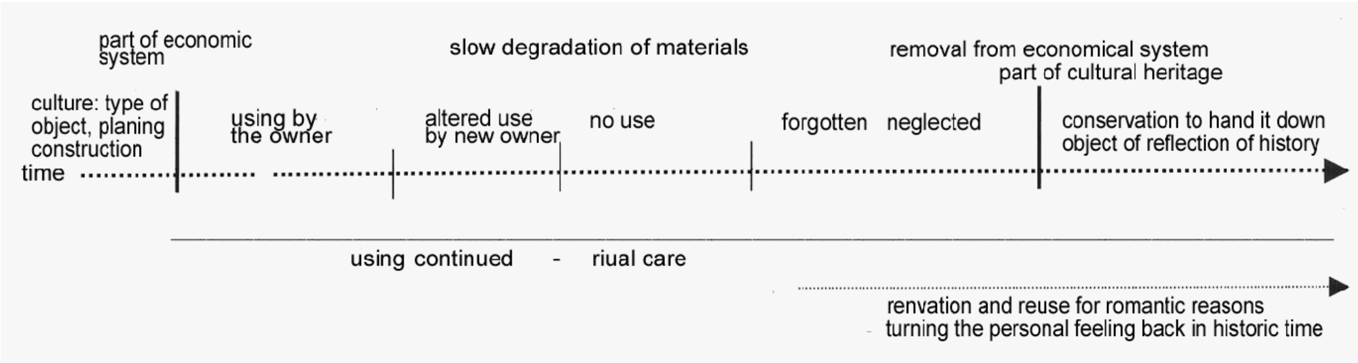


Figure 32.3: *Time scale: from construction to use and status of an object as cultural heritage (HTW, Keller-Kempas)*

instruments closely related to it. The question that needs to be answered here is how they can be preserved according to international requirements without losing their attractive use.

32.2 Preservation of Material Heritage of Industrial Culture

The museum-standard conservation of a large astronomical apparatus that meets international requirements for the preservation of cultural heritage is not known.

Nonetheless it is methodically possible to fall back on conservation techniques for other objects of material heritage. A training and research department of the *University of Applied Sciences* (HTW) in Berlin, specialized in this class of objects, has developed this field of speciality during the past 15 years. Their work is based on the high source value that objects of the industrial age have for the history of science and industrial archaeology, as well as the economic, scientific and technological context of society. Large or small, it is always individual objects that become representative for many others and need to be passed on to future generations in the most authentic state possible.

The methods employed by this field of speciality are based on international ethical guidelines for the preservation of cultural heritage, as for example laid down in the ICOM *Code of Ethics for Museums* of 2006.

The **§2.23 Preventive Conservation**, the paragraph concerning measures related to the environment and not the object itself, is of importance for observatories in so far as the change between exterior and interior climate is an important problem in the conservation of scientific instruments as cultural heritage, that can only be resolved by continuous care. The Code puts the highest priority on prevention and calls it an *"important element of museum policy"*. Furthermore: *"It is* **an essential responsibility** *of members of the museum profession to* **create and maintain a protective environment** *. . . "*.[2] Even if the historical observatories are not necessarily preserved in the form of museums, these requirements can be applied to them as they can be to many other technical objects.

The **§2.24 Collection Conservation and Restoration** summarizes the work to be carried out on the object: *"The museum should carefully* **monitor the condition** *of collections to determine when an object or specimen may require conservation-restoration work and the services of a* **qualified conservator-restorer. The principal goal should be the stabilisation of the object or specimen.** *All conservation procedures should be* **documented** *and* **as reversible as possible**, *and all alterations should be clearly* **distinguishable from the original** *object or specimen."*[3]

Table 32.1: *Documentation*

Bezeichnung Bild	deutsch	englisch	Photo / Author
fig. 32.3	Zeitleiste: von Herstellung über Nutzung bis zum Status eines Objekts als Kulturgut	Time-scale: from production to use and status as an object of cultural heritage	Keller-Kempas

Figure 32.4: *Missing areas of chrome on the back of a car mirror; Metal leaf in a galvanic bath: chrome is being plated; As above, after filling missing area with the plated metal and gilding oil; N. B. for New Built on the head of a reconstructed screw to replace a missing one (HTW, Grundmann, Matin Pour, Grundmann, Gehrmann)*

Figure 32.5: *Last layer of van's lacquer, before cleaning; Last layer of van's lacquer after cleaning, filling in and retouching (HTW Berlin)*

32.3 Documentation and Concept

As for any conservation project the conservator's work begins with a detailed documentation and examination of form, function, material and manner of production of the object. The materials of each production group, their construction and the marks on the surface that production, use and ageing have left, are recorded purely as phenomena, in an almost criminological sense. This apearance is generally known as "Patina". Written and oral history and scientific analysis supplement the documentation.

The findings are recorded in a time-line (fig. 32.3, p. 286). The attempt is then made to find a workable preservation concept, taking into account the guidelines of the international codices and the requirements of the object's socio-cultural environment (owner, users, public interest).

It is important that the time layers seen in fig. 32.3 all contribute to the present state of the object and to its quality as a material witness of history. The focus on a single historical period would mean an inacceptable loss of historical truth and source quality. Only the entirety, or the condensation of the different non-verbal statements of the object can justify us to speak of the preservation of its "authenticity" or "aura".

32.4 Practical Conservation and Restoration

The prime task is conservation, meaning the preservation of existing material. Conservation science is occupied with research on how to slow down in the best possible manner, if not stop, degradation processes of the most diverse materials in their beginnings and in more advanced states. Accretions that may speed up decay, such as dusts that can bind humidity and aerial pollutants, usually have to be removed.

Corrosion products may need to be treated with neutralizing substances and binders, in order to preserve the historic material. Sometimes an additonal reversible coating can aid preservation. Parts at risk are stabilized mechanically, additions that have a stabilizing function remain visible. All treatments of the object are documented, additions are marked, as is explained later on.

The restoration intervenes in the object with cleaning, in-filling, additions and also retouching, following the requirements of the restoration concept. Exact documen-

Figure 32.6: *Dirt and corrosion underneath a van, 1950; Underneath the historic van after cleaning and conservation; Chrome plated steel covered by corrosion products; before (left) and after (right) the local cleaning by scalpel (HTW Berlin; HTW, Grundmann)*

tation is important as well as the marking of additions to the object according to the following system developed by Dietmar Linke at the HTW Berlin in the 1990's:

The year the addition was made and one of the following combinations of letters denote the type and date of the addition.

N. B. **N**ew **B**uilt for an addition that exactly reproduces the historical model (fig. 32.7 left, p. 290).

F. R. **F**ree **R**econstruction for an addition that is indispensible from a conservator's point of view but has no exact model.

C. S. **C**onservation **S**tability for further stabilizing measures that are attached to the object (fig. 32.7 right, p. 290 und fig. 32.6, p. 289).

A few examples of documentation, conservation and restoration of missing areas in metal, metallic coating and lacquer surfaces will supplement the short theoretical descriptions, in the hope that the methods for the conservation and restoration of technical objects can also benefit the historic scientific instruments in observatories.

1. Paul Philippot in: Jukka Jokilehto: A History of Architectural Conservation. Oxford 1999, VII.
2. aus: `http://www.icom-deutschland.de/, schwerpunkte-ethische-richtlinien-fuer-museen.php` (30.6.09).
3. aus: `http://www.icom-deutschland.de/, schwerpunkte-ethische-richtlinien-fuer-museen.php` (30.6.09).

Figure 32.7: *Detail of large device with corroded metal, dirt and degraded rubber, material before conservation; Detail as in the left figure, after cleaning, consolidation and conservation of the materials (HTW, Halm)*

Figure 32.8: *Corroded sound absorber; C. S. Conservation Stability by a matal wove as duplicating material (HTW, Voigtländer, Brandt)*

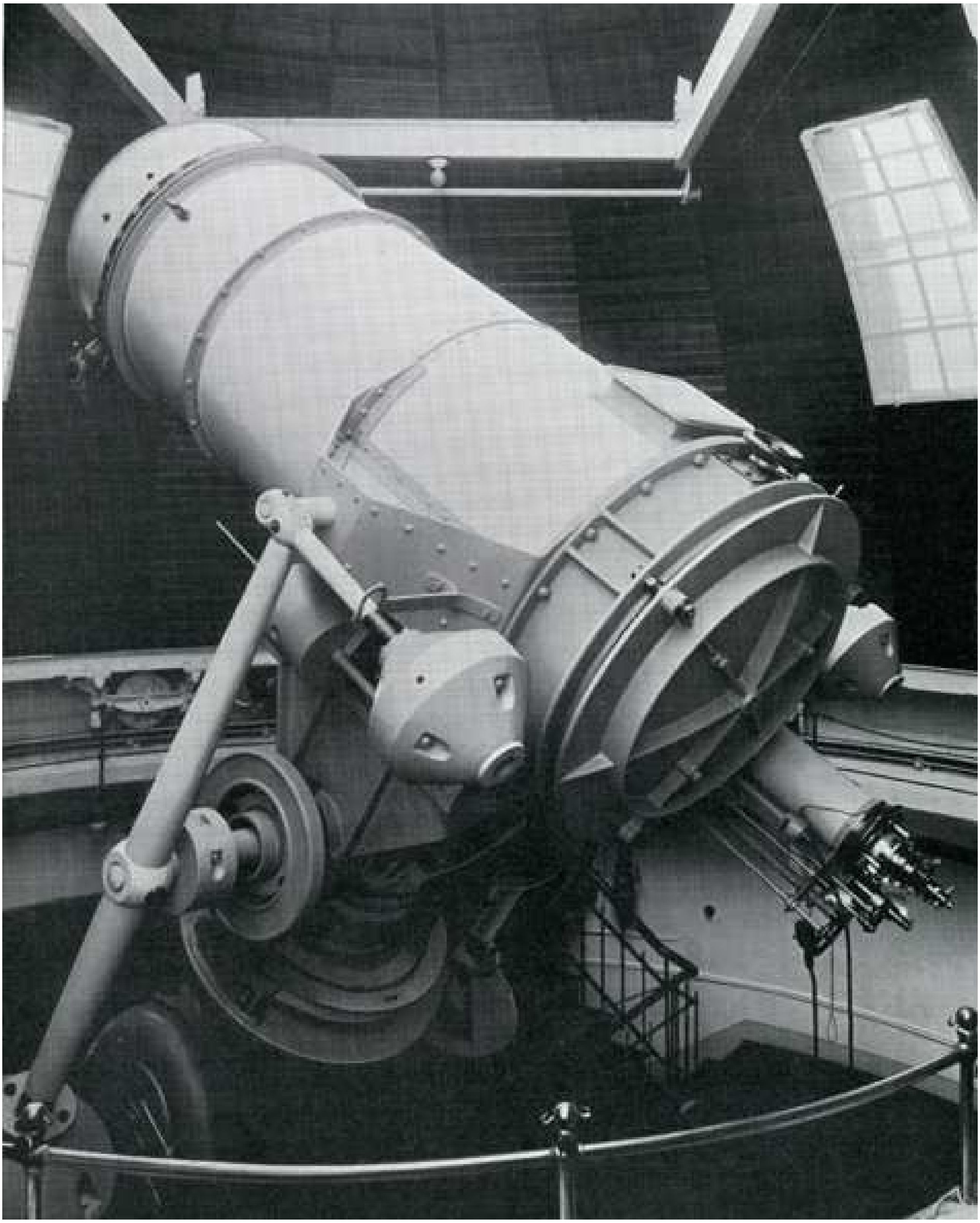


Figure 33.1: *The 1m-Reflector of Hamburg Observatory*

33. The 1 m-Reflector of the Hamburg Observatory: an Object of Technical Heritage – a Preservation Concept

Beatrix Alscher (Berlin, Germany)

33.1 Introduction

Within the scope of my diploma thesis, supervised by Prof. Dr. Keller-Kempas on behalf of the FHTW/University of Applied Sciences Berlin and Prof. Dr. Gudrun Wolfschmidt on behalf of the University of Hamburg, I have developed a concept of preservation for the 1 m-reflector (see Fig. 33.2A) of the Hamburg Observatory that mainly focuses on the issue of preserving the functionality of this device and its further utilization, as well as requesting the maintenance of the traces of its use.

By conserving and restorating technical heritage it is possibile to ensure the transfer of the technology's development phases through their legacy. The awareness for the traces of its production and utilization as well as the perception of a technical object that is fully functional allows for the creation of concepts to maintain the irrecoverable values of the historical and material authenticity of an object. The realization of such concepts is particularly difficult in the field of technical heritage.

Maintaining the functionality, for instance, may conflict with preserving a coating that already bears traces of use.

Since the early last century Georg Dehio's motto, "conserve, don't restore", has been one of the principles of the preservation of historic monuments that should also apply to handling of technical cultural assets.[1]

Renovation work has not only been applied in the past to preserve technical cultural assets for the purpose of restoring it to almost brand new condition. The renovation of the Potsdam double reflector dating from 1899, for instance, involved repainting and also fitting state-of-the-art controls in 2005, which is in contrast to different approaches such as the conservation measures performed on the large reflector of the 1887 Kuffner Observatory in Vienna which was completed in 2002, whereas old coatings were exposed and preserved. It was also necessary to modify the mechanics here, but the original components were preserved and are now presentable.[2]

The main focus of the presentation was the following question: Why is it so important to preserve the traces of use in particular and how can we meet this requirement? I therefore would like to present the instrument in more detail and sketch out the current status of its condition in order to then proceed to the problems of its preservation that result from the atmospheric environment inside the building and the current condition of the instrument's paint coat. Moreover I will present approaches for handling this situation, which are thought to be open for further discussion.

The device weighs 26 tonnes and extends approx. 5 m into the dome, whereas the main tube bearing the 1 m mirror is approx. 3.6 m long – just to give an idea of the dimensions (see Fig. 33.8A and 33.8B).

Currently we see a historic instrument with traces of use as well as conversions and auxiliary fittings that have been undertaken over the course of time. It is witness to a long period of astronomical research and demonstrates the requirements placed on relevant technology of the time.

The instrument is the first large Zeiss telescope fitted with a counterbalancing device by Franz Meyer. With its optics, mechanics and the 10 m dome construction (see Fig. 33.8B) it forms an ensemble that represents a historic period in the construction of telescopes by the astronomy department of Zeiss, which was founded in 1897.

It is one of the very few large astronomical instruments from the first decade of the last century, whereby its condition still demonstrates a high degree of authenticity. Fortunately the instrument has been neglected over the last three decades. This has changed its overall condition for the worse, of course, but it also means that today we can observe the instrument with all its documents of time as they have not been destroyed by new paint coatings and modernization efforts at the expense of the ancient substance, as it has happened with many other similar devices.

It is the combination of the Hamburg Observatory astronomy park with the complete photo plate archives including the hand-written observation books that partially include the writings of Walter Baade that further add to the great value of the reflector telescope as a monument.

The instrument is fitted into a dome structure, which was completed in 1909. The extension was built in 1926 (see Fig. 33.6A and 33.6B).

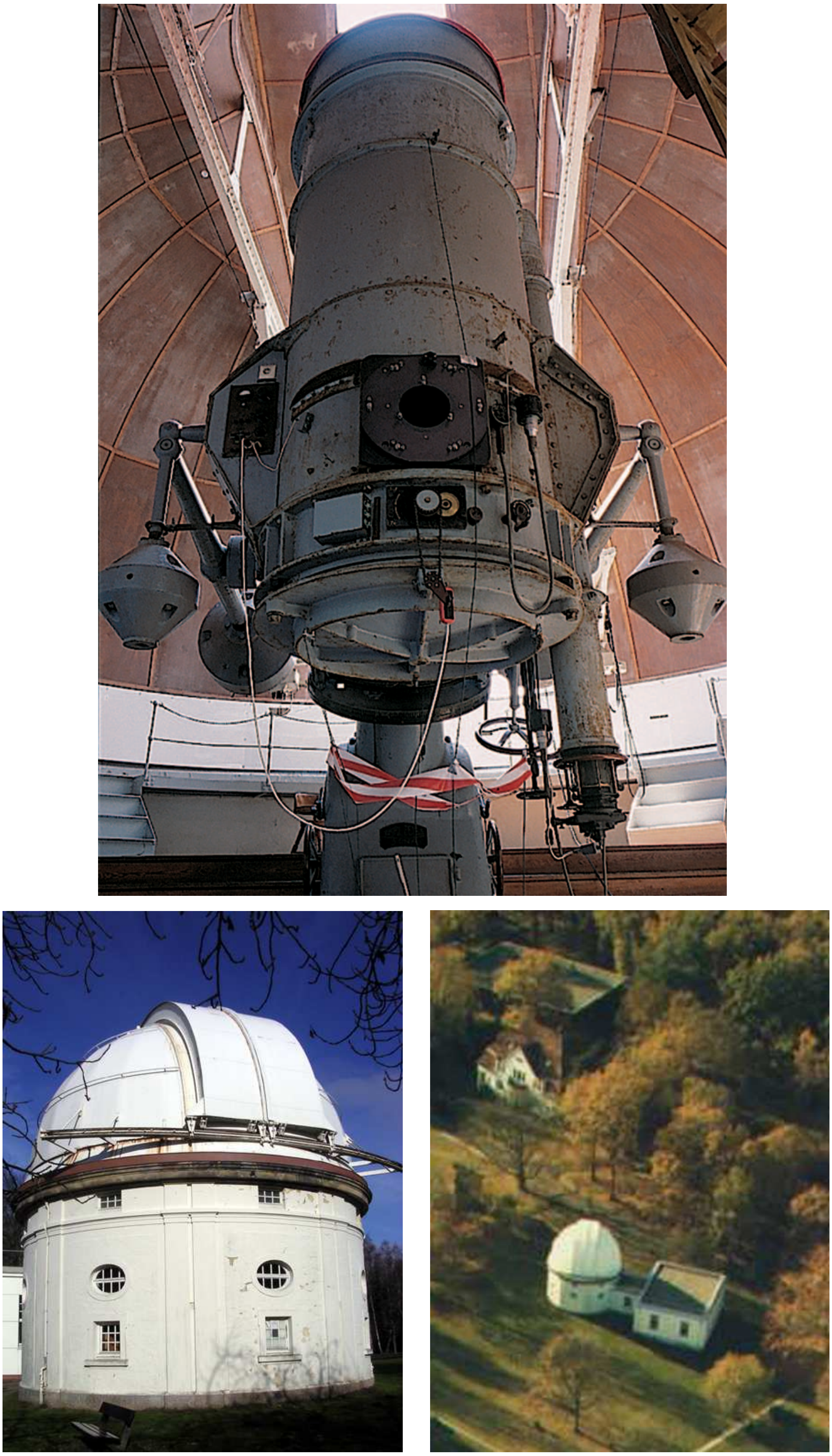


Figure 33.2: *Pictures of sections of the 1 m reflector telescope, building and aerial view. Above: The 1 m reflector telescope, view of tube with conversions and extra fittings; Below left: The dome structure of the 1 m reflector telescope. View of the slit opening; Below right: Aerial view of the 1 m reflector telescope building (Above and Below left: Beatrix Alscher; Right: Archives of Hamburg Observatory)*

33.2 The Conservation Challenge

33.2.1 The Condition of the Instrument – the Coating

The instrument is currently ready for operation, although there are some restrictions to the fine mechanics:

- The high relative air humidity has a corrosive effect on the materials (see Fig. 33.3).
- Fragile products of corrosion are hazardous to the optics and mechanics.
- Corrosion developing on the surface of the instrument also reduces the bonding of the coating.
- The aged coating and corrosion products dominate the overall impression.

The coating: Different traces of ageing of the coating are visible on the instrument.

- In the lower section of the base: very stable, still adhesive coating with large cracks developing (see Fig. 33.3A).
- In the bracket area: hard, multi-layer paint flakes that are barely bonding with the host material (see Fig. 33.3B).
- In the upper section of the tube: very fragile, flaking final coating that gives view to further corroded layers (see Fig. 33.3C).

The visual, chemical and physical examination of the coating has revealed that the instrument has been repaired with new layers of paint on an irregular basis.

The thickness of the paint in the area of the base and counterweights show thick layers with up to eight decorative sequences. The layers on the tube are far thinner, which means that more importance was given to the removal of the old layers. Therefore, the following characteristics can be proposed for the individual parts (see table 33.1, S. 298).

It can be seen that the initial oil system changes to an alkyd resin system with the application of red lead (see Fig. 33.4). Extreme brittling and cracking of the coating in some parts shows typical ageing symptoms for alkyd resins.[3]

The damage to the coating also shows that the last large-surface repair measures were conducted some time ago, which can be seen from the largely reduced binder on the coating of the counterweight of the hour axis.

The assumption that the last coat of paint was applied for the IAU Convention in the 1960s is not too far-fetched as traces of already removed technology still can be found on the final paint composure (see also Fig. 33.9).

The oil system detected in the lower layers raises the question whether it could still be the original coating applied by Zeiss.

Of particular interest in this context was the comparison[4] of the cross-section polish of the instrument in Hamburg with cross-section polishes of a further Zeiss telescope, the refractor manufactured for the Zurich Observatory in 1906. Beneath newer composures on the device in Zurich it was also possible to trace the oil-based primer found on the base of the 1 m-reflector telescope. The sequence of layers on the counterweights was also similar.

The paint systems of the base and counterweight of the hour axis should therefore be followed up further and, if necessary, be given particular relevance with regard to issues of conservation.

33.2.2 The Current Climate Situation

The instrument is mainly exposed to uncontrolled climatic conditions.
The climate situation and its effects on the materials can be outlined as follows:

High degrees of fluctuation of the relative air humidity and temperature result in strain on the material and thus lead to cracks in the coating, reduced easy movement of the construction elements, and cracks in the wood.

The mean of the relative air humidity is approx. 70–100% which can and visibly does result in microbial contamination and infestation by insects. The development of condensation water resulting from the temperature falling below the dew point activates corrosion on the metals (see also Fig. 33.3), increasing ageing of the coating and also moisture penetration of the brickwork.

The mechanics and optics are also threatened by products of corrosion. Looking at the main reflector inside the cylinder you can see that the fins slide across each another, thereby trickling corroded metal onto the remaining mechanics and surface of the reflector. When the instrument is moved these particles have an abrasive effect on the reflector (see Fig. 33.5).

33.3 The Preservation Concept

After viewing the overall ambient situation the following general requirements can be specified for the practical realization of the preservation:

Dehumidification of the building.

Stabilisation of the ambient climate, particularly after a period of observation.

Reliable corrosion protection of the instrument from corrosion.

So before thinking about conserving the instrument it should first be ensured that the building can reassume its protective function again.

33.3.1 Dehumidification of the Building

Tempering of the walls was favoured when developing a concept of stable ambient climate. This prevents condensation, convection and climate fluctuation.

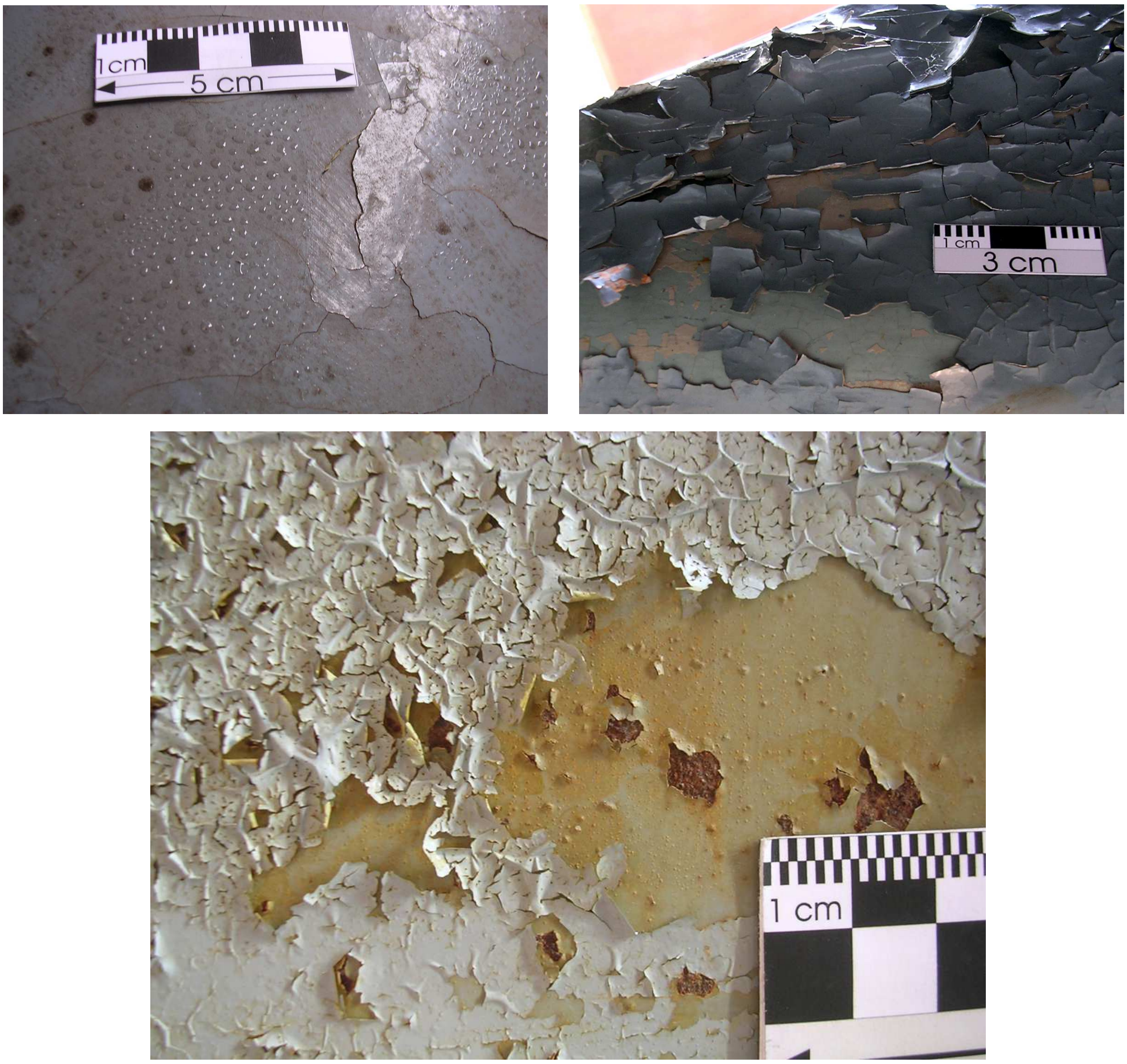


Figure 33.3: *Different traces of ageing of the coating. Above left: Condensation has resulted in surface cracks; Above right: Hard multi-layered flakes of paint with hardly any adhesion; Below: Fragile brittling and corrosive undermined coating areas (Photos: Beatrix Alscher)*

This type of tempering also protects from salt migration, damp rising from the ground and moisture penetrating resulting from rain and snow. The effect of wall tempering is exemplified again in Fig. 33.7, page 300, using the example of the 1 m-reflector telescope. The heating coils in the brickwork provide heat that wards off moisture from the ground and from outside. Climate fluctuations are toned down, convection is prevented.

33.3.2 Traces of Use

About the traces of use on the instrument:
Why? You could now ask why the instrument should not simply be overhauled and painted again using stable, state-of-the-art protection against corrosion. The question is justified and consequently brings us back to the initially commented question concerning the reason why the traces of use should be preserved with the instrument as well as maintaining its functionality and use.

As a document of history the 1 m-reflector of the Hamburg Observatory initially "only" conveys the state of technology and its importance during a particular period. According to the traces of use, however, a unique history is conveyed that, for instance, can provide details on a special purpose of use or particular characteristics of the users themselves. These indications can be found mainly on the surface, such as wear on intensively used areas, indentations that were used as aid marks or from conversions and auxiliary fittings.

The traces of use most relevant to the reflector telescope in order to build a "bridge to the past" are the special conversions and auxiliary fittings in particular that were built for the instrument during the course of its scientific use. While these still existing conversions and fittings are self-explaining, traces of removed telescope elements as well as orientation aids sketched onto the telescope surface with a pencil can also be found and are thus witnesses of these no longer existing technological components (see also Fig. 33.9, page 302).

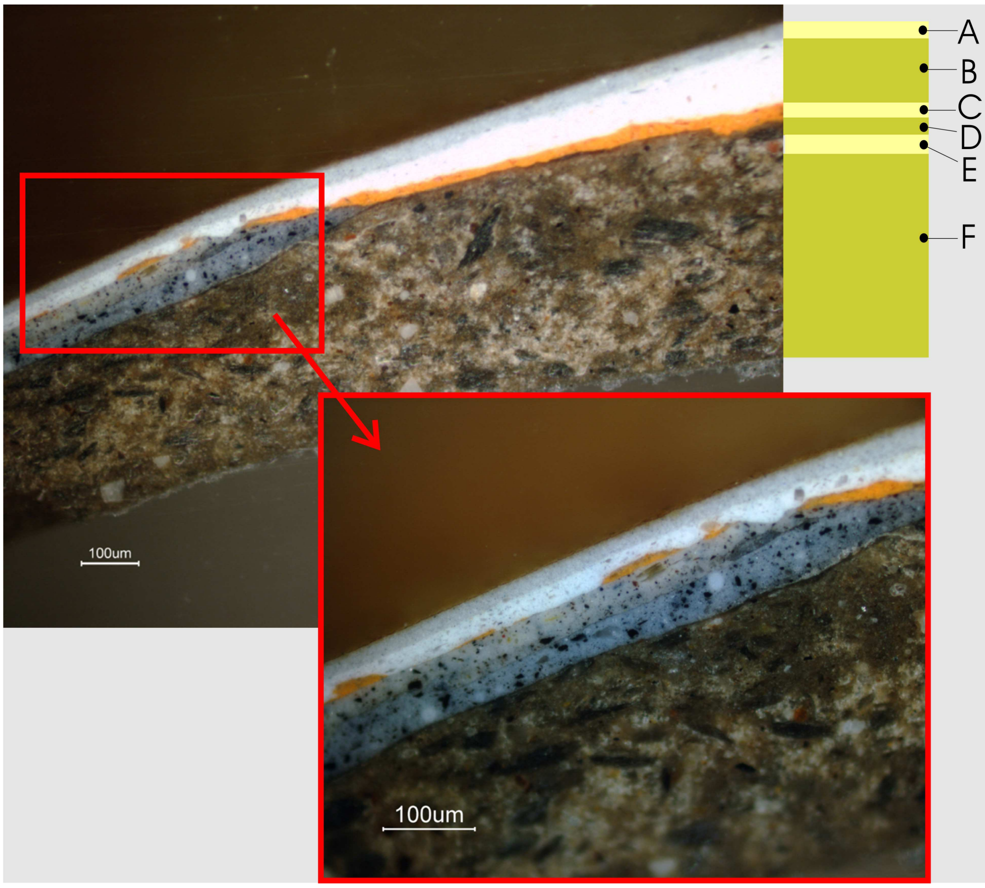


Figure 33.4: *Cross-section polish of probe 5, tube base, inner cladding A: Gray composure, fine filling materials (lithopone). B: White layer that can be interpreted as primer with rough filling materials as can be found on other polished sections of the tube. C: Red lead, on layers F and D. D: Second gray composure with coarse filling materials (lithopone portions). E: 3rd gray composure with coarse filling materials – reacts positively to basic lead carbonate analysis. While layers A, B and C are similar to the other tube composures the layers D, E and F can be found again at the counterweights and base. (Photos: Beatrix Alscher)*

33.3.3 Maintaining its Functionality?

Why preserve it and keep it fully functional?
Maintaining its functionality cannot and must not be questioned here. The device is fully operational and no interference with the aged substance is necessary to achieve this status. Taking it out of service due to worn parts would be comparable to covering up a work of art. Only if fully functional will the reflector telescope be capable of conveying its full complexity to the observer and, according to Walter Benjamin,[5] be capable of unfolding its full aura.

The actual underlying idea of the conservation concept:
Alois Riegel describes "value of age" as the feelings any person may have when looking at a monument, which allowed him to derive his maxim to prevent any "arbitrary intervention by human hand into the developed status of a monument".[6] With "historic value" he also credits the monument with the ability to document, thereby describing a particular phase in the development of human achievement.[7]

The 1 m-reflector telescope of the Hamburg Observatory, for instance, is an example of the characteristics of documentation listed by Riegl. By keeping it in working condition it will also be possible to experience it with all one's senses. Of course, only the slightest possible intervention into the "evolved condition" would form the foundation for a concept of preservation for this technical document of time.

33.3.4 The Concept of Handling the Paint

The current status of the paint, however, gives reason for discussing different approaches to preservation.

The concept of handling the paint: In his main magnum opus "The Seven Lamps of Architecture" art historian John Ruskin (1819–1900) looks into the subject of reconstructive and improving restoration. He sees the actual value of an architectural monument in the traces of its age.[8] If this idea is transferred to the 1 m-reflector telescope it is possible to critically question whether the traces of age are really conveyed by the surface, i. e. by the condition of the coating. This would entitle the coating to first degree priority of preservation.

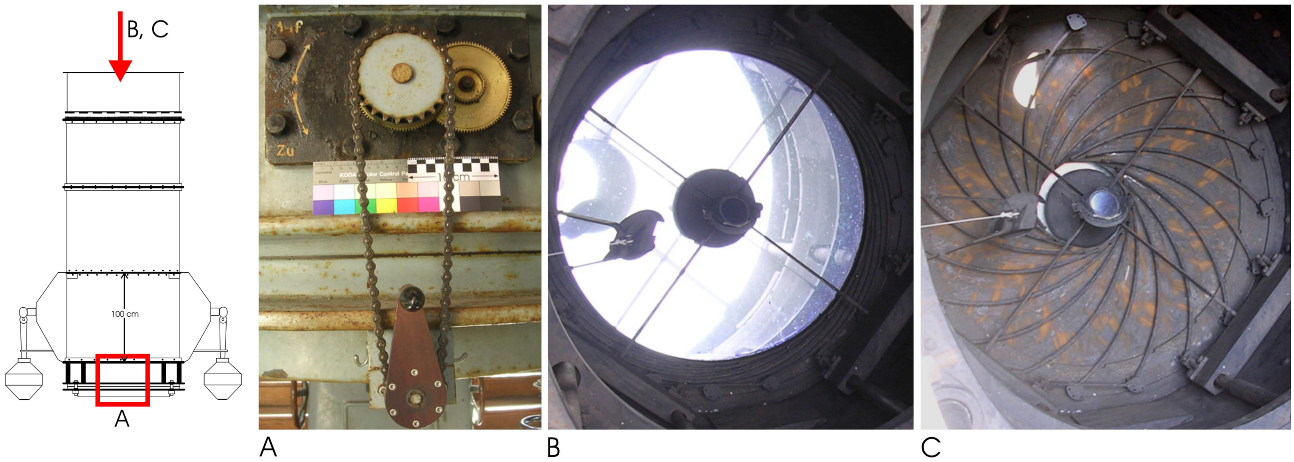


Figure 33.5: *Iris actuator system*
A: Crank handle with chain and gearwheel on outer surface of the tube
B: View of the main reflector with iris open / inside tube
C: View of main reflector with iris open and central covering / inside tube (Photos: Beatrix Alscher)

Table 33.1: *Coating characteristics at various components*

Component/Part	Surface coating characteristics
Tube	Red lead primer with state-of-the-art alkyd resin final coating
Base	System without red lead, oil-based primer, final coating based on alkyd resin, similar to tube
	Large counterweight on tube. Counterweight on hour axis. Filling similar to that of the counterweight on the hour axis.
	Lead-free anti-corrosion paint on red lead passes into alkyd resin system.
	System without red lead, oil-based primer, all coatings react positively to lead-containing filler materials; high decomposition of binder.

Could it not be so, perhaps, that there may be many traces that represent the age of the reflector telescope which, however, are concealed by the dominance of an intensively aged coating? Which historic information can the current condition of the paint still give us today?

The paint reflects the neglect of the instrument over the last decades. The flakes of paint brittling away can only give little detail on its true age, and it is not only the characteristics of ageing of the coating that give the reflector telescope its individual character.

Far more, the telescope is defined by its individual technical components and it becomes clearly visible that the authenticity of the instrument can be derived from the traces of its use. This brings up the question of how to handle the paint coating: What should it include and what is the expressive power of such a form of preservation? Let's have look to the following graphic.

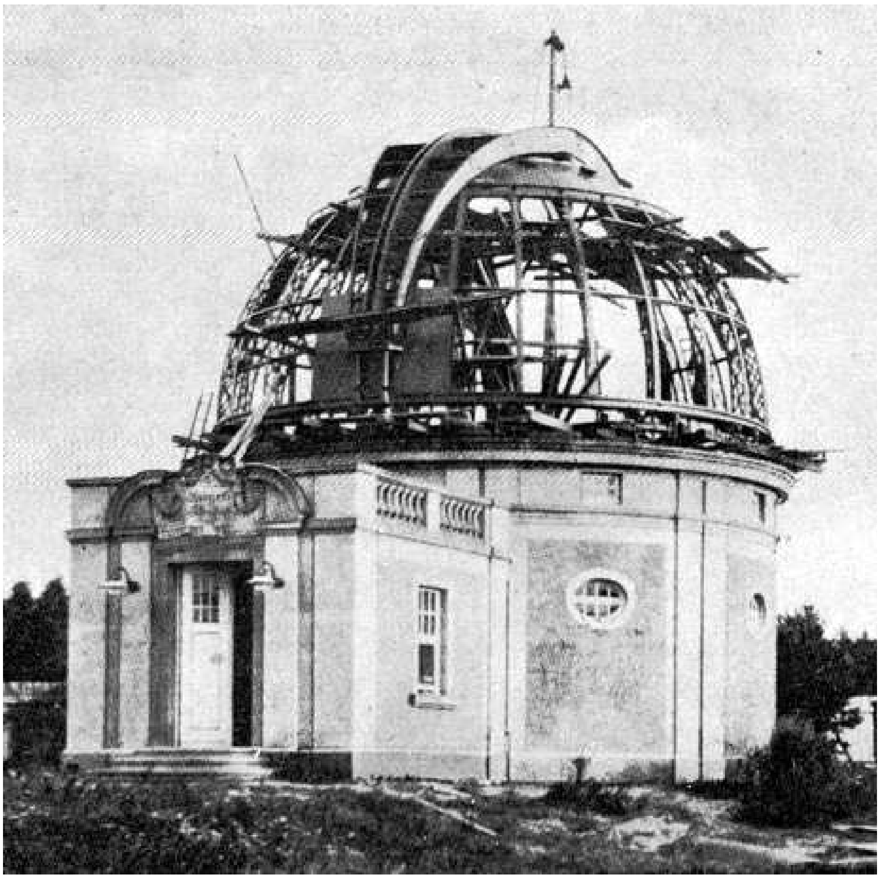
Two approaches can be argued here:

- Preserving the instrument consists of renewing or patching up the paint coat from time to time. If this tradition were to be continued and renewal of the paint coat were to be considered it would be "... the acceptance of change as an essential parameter in the process", according to Jukka Jokilehto.[9] In this case it should be evaluated as to what is an essential element of the object's "readability". If the object is mainly defined by its surface such intervention would hardly be justifiable.

- The uniqueness of the reflector telescope, however, is based on the technologically historic components as well as the conversions and additions. Therefore, a new paint coat would not impair the historical informational value of the instrument and ensure preservation of the instrument by acting as an anti-corrosion agent. This stands in contrast to preserving the wear marks on the coating as well as generally preserving all materials as required by the E.C.C.O.[10] documents.

As the functionality of the telescope is being maintained it requires reliable protection from corrosion. This initial situation also advocates a new coating to preserve the telescope in the context of the tradition of its maintenance.

To sum up: a new coating to protect the instrument while preserving its traces of use could be the ideal compromise for both approaches.



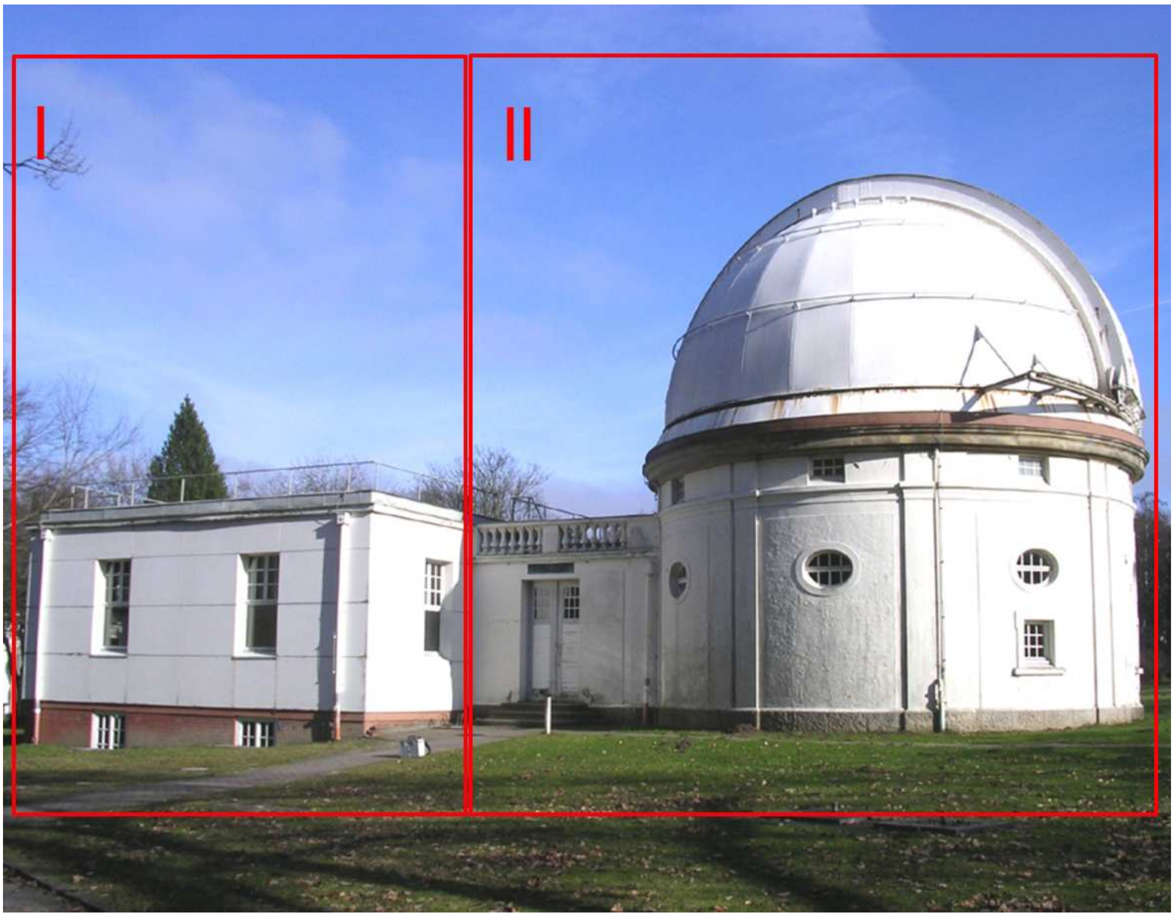


Figure 33.6: *Current and historic photos of the 1 m reflector telescope building. Above: Dome with original entrance, 1909; Below: Recent photo of the building; (I: 1926 extension, II: Dome structure of 1909) (Above: Archives of Hamburg Observatory; Below: Beatrix Alscher)*

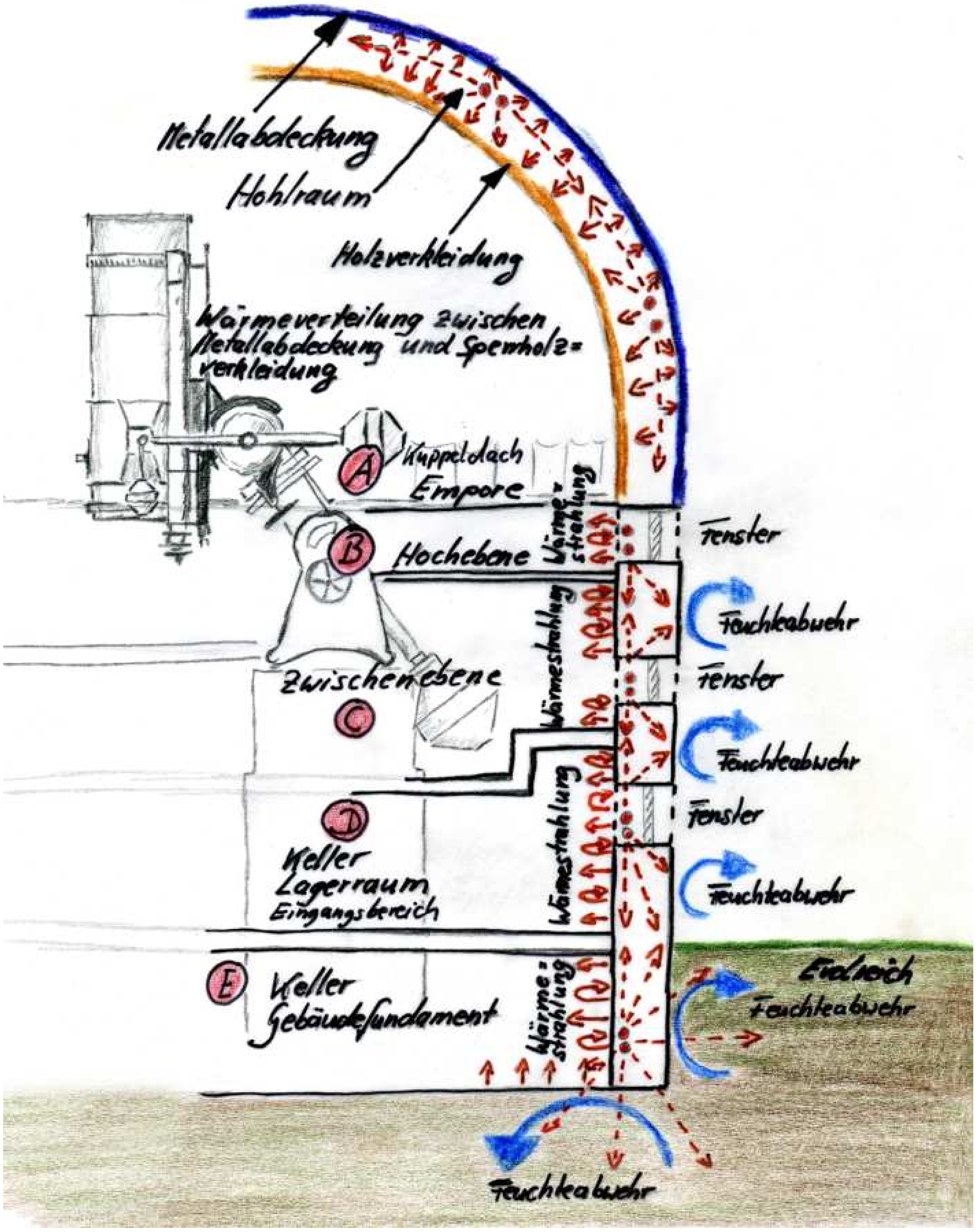


Figure 33.7: *Sketch of wall tempering mechanism on the 1m reflector telescope structure (Skizze gefertigt an Anlehnung an Skizze bei Großeschmidt 2004, S. 325.)*

33.4 Conclusion

Finally, I would like to focus on the history of the instrument once again. Here (see Fig. 33.10 above) are two very early photographs of the device.

These recordings provide interesting background information and show us that the eyepiece was gold-painted at the guide refractors. There also were windows in the dome (see Fig. 33.10A) and the rollers of the dome guide were not lined (see Fig. 33.10B).

These questions, however, should not mislead you into thinking of a restoration that would return the current instrument to such "brand new" condition. Far more it should make us envision how much history this reflector telescope has gained and how much more it still has to tell us today.

The main reflector of the telescope, manufacured in 1907 by Schott in Jena, in conjunction with the instrument, is capable of reflecting almost 100 years of history with its kinks, curbs and edges in the form of valuable traces of use, conversions and extensions.

The current condition of the 1 m-reflector telescope by Zeiss, which was entered into service in 1911, is rare, if not unique. From a perspective of preservation, how-

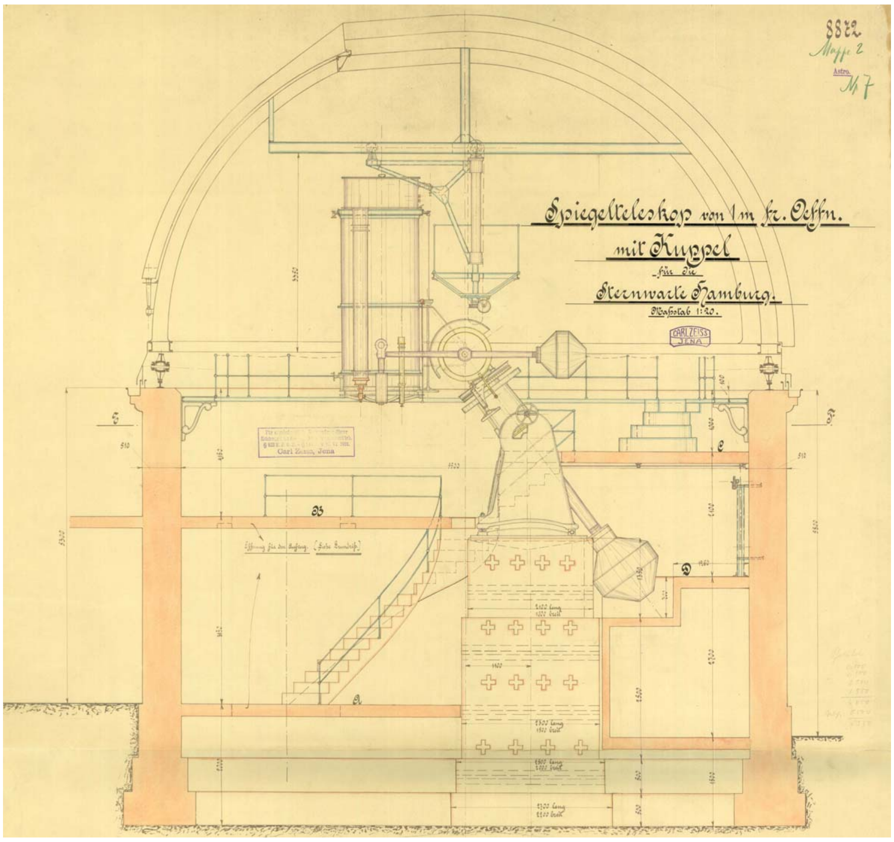


Figure 33.8: *A view with one of the large counterweights and of the overall construction with counterweights, tube and large base. Above: View with one of the large counterweights; Below: Entire construction with counterweights, tube and large base (Above: Beatrix Alscher; Below: Archives of Hamburg Observatory)*

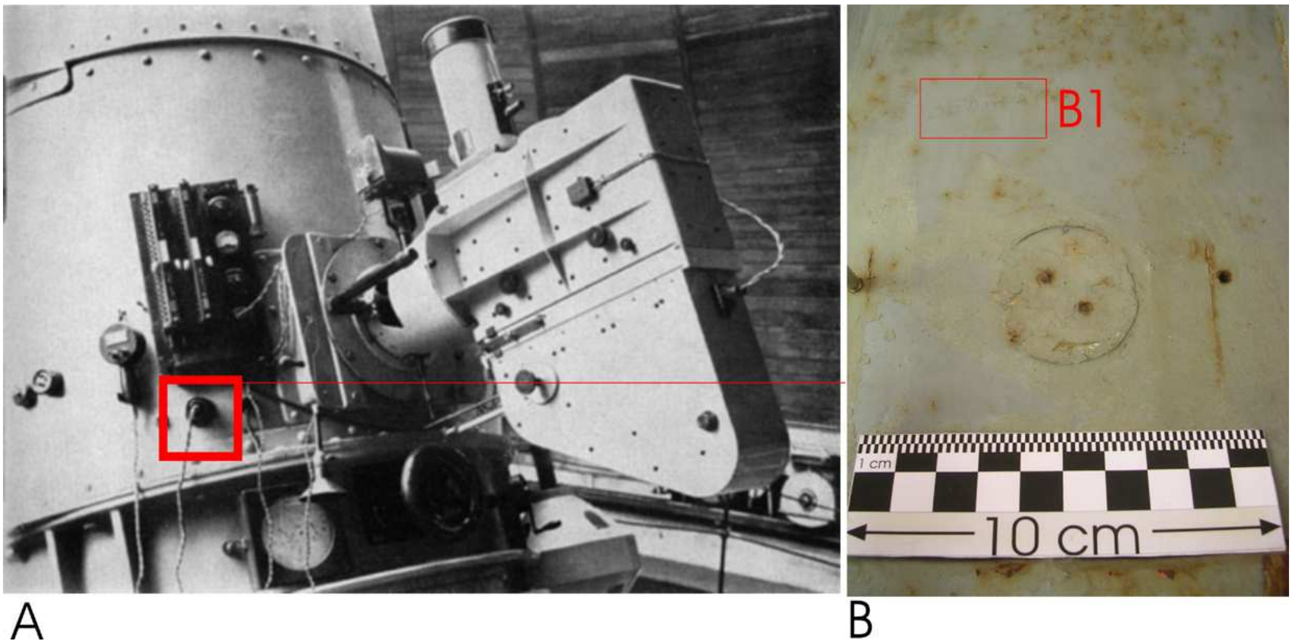


Figure 33.9: *Traces of use on tube surface A: Photograph with spectrograph, around 1953. B: The socket connection shown on picture A can still be found on the surface today. The writing in pencil can be found slightly above (B1): 350 mA (Photos: A: Mitteilungen der Hamburger Sternwarte in Bergedorf, Band 22, Nr. 237. Wellmann, Peter: Die spektrographische Einrichtung des Bergedorfer 1m-Spiegelteleskops. In: Zeitschrift für Astrophysik 33 (1953), Heft 2, S. 117, Abb. 2. B: Beatrix Alscher.)*

ever, this can only be considered an opportunity that should be put to use correctly.

33.5 Important Persons and Companies Explained

- Carl Zeiss (1816–1888): Mechanic and entrepreneur. Founder of company Carl Zeiss Jena, whose astrology department founded in 1987 built the 1 m-reflector telescope including the observation platform and dome construction. Further construction for the Hamburg Observatory in this time:
  Lippert astrograph with dome construction
  Dome and observation platform / elevator platform for the large refractor
- Otto Schott (1851–1935): Chemist and glass engineer. Founded the "Glastechnisches Laboratorium" together with Carl Zeiss and Ernst Abbe in 1884, later to become "Jenaer Glaswerk Schott & Genossen" – Schott AG.[11] Manufacturer of the main reflector and deflection mirrors of the 1 m-reflector telescope.
- Ernst Abbe (1840–1905): Physicist, optician and entrepreneur. Created the basics of modern optics together with Carl Zeiss and Otto Schott.
- Franz Meyer (1868–1933): Engineer at Carl Zeiss and developer of the load relief construction. Also involved in the construction of the Treptow refractor of 1896. First load relief construction at Carl Zeiss was the reflector telescope for the Innsbruck Observatory in 1905.
- Walter Baade (1893–1960): Significant astronomer of the 19th century. Worked on the 1 m-reflector telescope from 1920 to 1930. His observing and scientific activities represented the most prominent research period of the reflector telescope.[12]

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1. Breuninger et al. 2005, p. 2.
2. Cf. Sterne und Weltraum (2001), p. 78–83.
3. Hantschke et al. 1998, p. 182.
4. With friendly support of Prof. Dr. Christian Stadelmann, FHTW-Berlin.
5. Benjamin 1963, 15.
6. Huse 1996, 146.
7. Janis 2005, 22.
8. Janis 2005, 18.
9. Jokilehto 1999, 304.
10. European Confederation of Conservator-Restorers.
11. `http://de.wikipedia.org/wiki/Schott\_AG`.
12. Heckmann 1976, p. 204–205.

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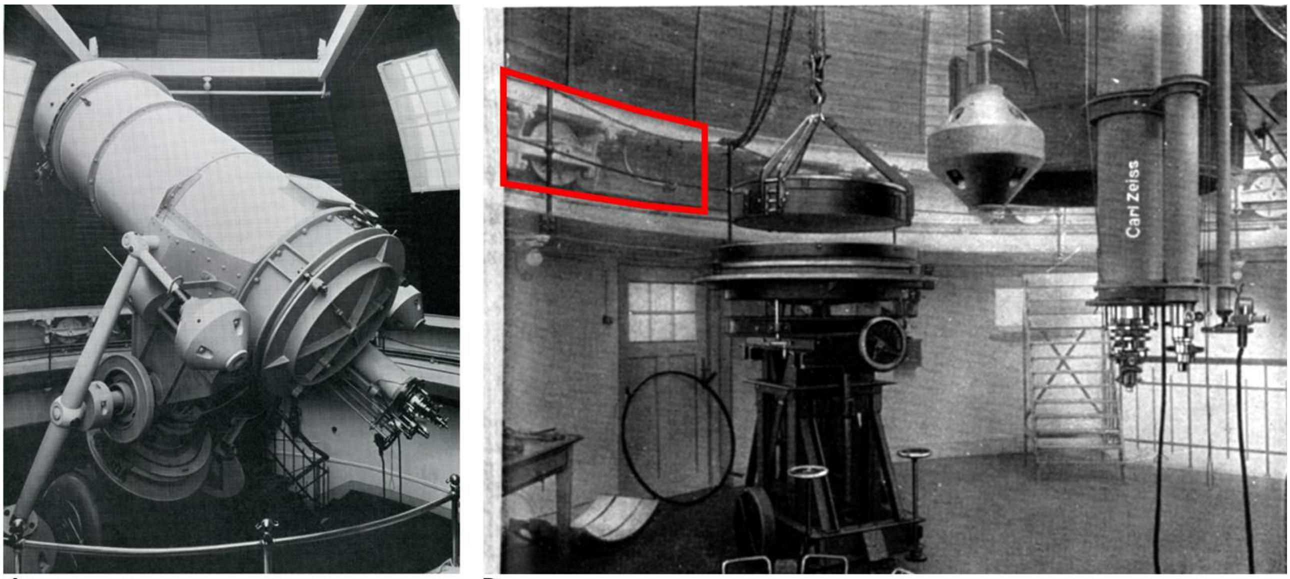

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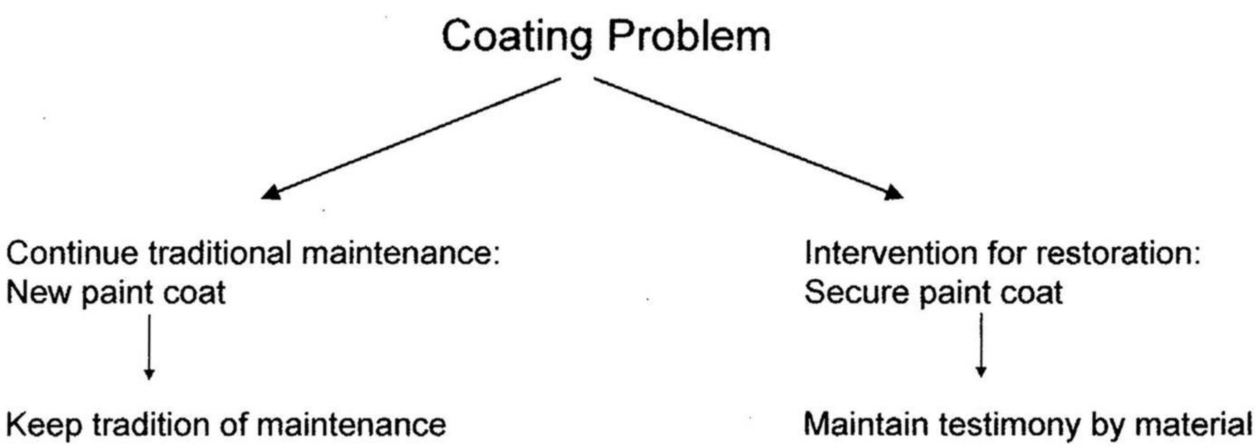

Figure 33.10: *Above: Historic photograph with dome panelling and dome wheel guide A: Historic photograph from the time when the dome still had lamellar structured wood panelling with integrated windows. The uncovered dome wheels are also visible. B: Historic photograph with uncovered dome wheel guides (highlighted by red box) Below: Coating Problem. (Photos: A: Jahresbericht der Hamurger Sternwarte 1913, S. 7. B: Carl Zeiss Katalog, 1933, p. 15, fig. 20.)*

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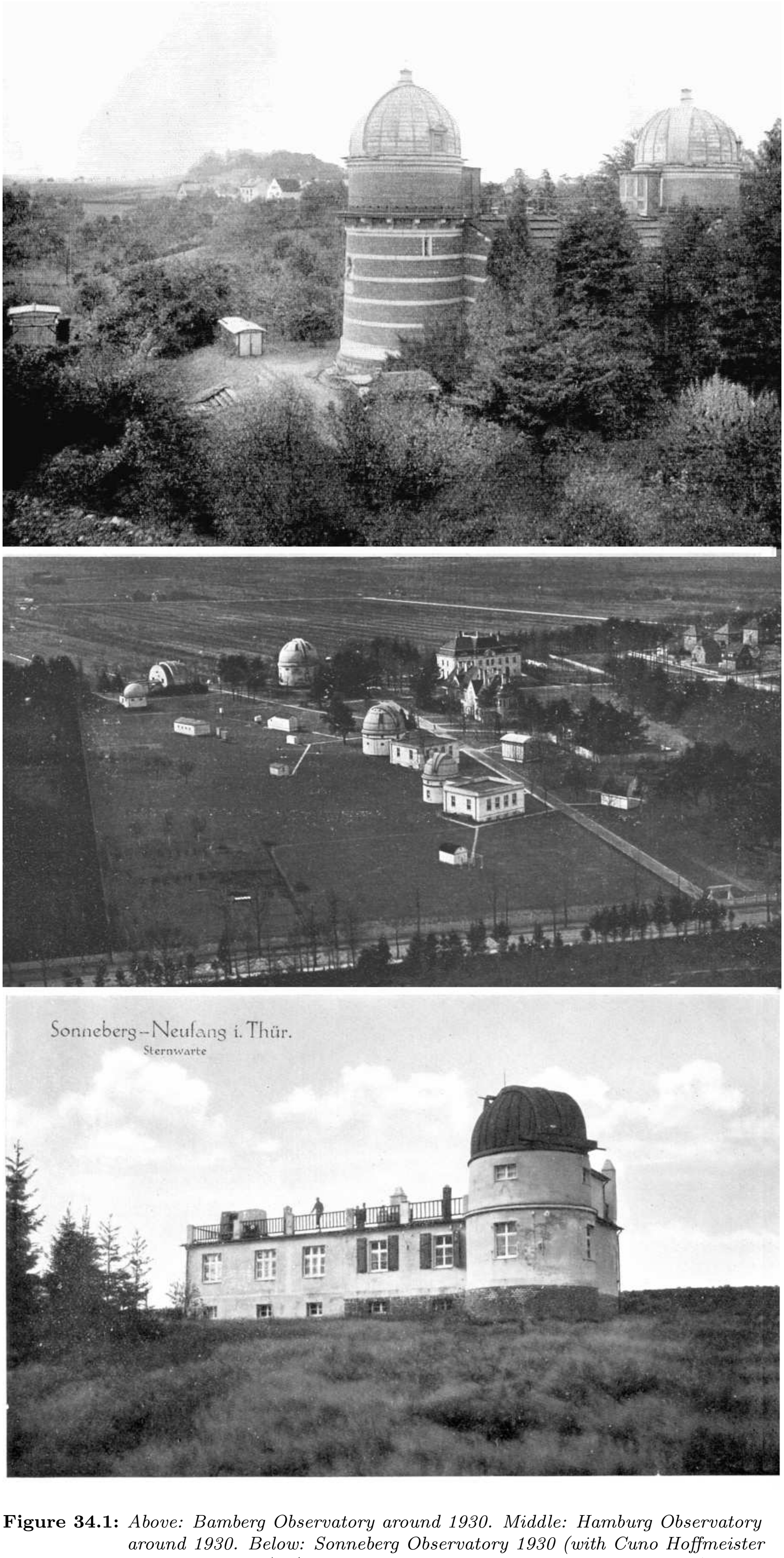

Figure 34.1: *Above: Bamberg Observatory around 1930. Middle: Hamburg Observatory around 1930. Below: Sonneberg Observatory 1930 (with Cuno Hoffmeister at the balustrade). (Bamberg Observatory, Hamburg Observatory, Archive Björn Kunzmann)*

34. Real and Virtual Heritage – Historical Astronomical Plate Archives in Sonneberg, Bamberg and Hamburg Observatories, the Evolution of Astrophysics and their Influence on Human Knowledge and Culture

Björn Kunzmann (Hamburg, Germany)

Abstract

The rise of astrophysics around 1860 introduced new instruments, methods and research areas. Of course, the increasing number of foundations of new observatories around the world starting at that time was forced by that new scientific discipline, too, but especially by the usage of photographic instruments. At the end of the 19th century the formation and development of photographic methods and techniques had reached a level of sufficient stability for productive usage in astronomy and astrophysics, their new instruments, methods and goals. The fundamental meaning of star light analysis for astrophysics by increasing discoveries of Variable Stars and the systematic search for moving Solar System objects had basically driven the beginning of large photographic sky patrols at that time, using photographic glass plates as detectors and information storages.

Sky Patrols, especially systematic long-term monitoring of the whole sky or of well defined selected areas and Sky Surveys were (and still are) an important key method that forced the evolution and progress of astrophysics. Important scientific results by famous astronomers, for example Walter Baade, Cuno Hoffmeister and Harlow Shapley depended on the analysis of photographic plates.

Today, there are around 50 photographic plate archives world-wide. Most of them, unfortunately, are in a quite poor condition and not yet digitized. Following Harvard College Observatory with an estimated total of 600,000 plates, Sonneberg observatory harbours the second largest archive world-wide (around 300,000 plates) among other large ones in Germany like Bamberg (40,000 plates) and Hamburg (35,000 plates).

These plate archives form an important heritage with a total of roughly two million direct plates and some ten or hundred thousands of spectroscopic plates. A lot of progress has been made by transforming this real heritage to a virtual one by systematic digitisation of the plates, but perhaps only 15% of them have been digitized so far. Although technical problems as the rapid changes in information technology, formats, description languages and limited life times of various storage media are not negligible the main problem remains the poor funding of different digitisation initiatives throughout the world.

34.1 Introduction

Until 1860 astronomy mainly deals with observation and calculation ofpositions and motions of celestial objects. With the rise of astrophysics at that time analysis of star light became a new task in science, starting up with our sun, the nearest star. Astrophysics uses three key methods: Spectroscopy (Kirchhoff/Bunsen 1859)[1], Photometry (Pogson[2] / Zöllner[3] 1856/1865) and Photography (Daguerre[4] 1837/39, Bond[5] 1857, Swan[6] 1871, Draper [7] 1872, Huggins[8] 1874). Photography, utilizes photographic glas plates as detectors since 1871, opened the essentiell possibility to monitor and analyse celestial objects independent of observations of astronomers at telescopes. Since the plates contain permanent pictures of the status of the sky at time of the exposure, they represent long-term collectors of historic astronomical information. The productive usage of photography (direct and spectral) in astrophysics and astronomy was introduced around 1880 – this was the beginning of the photographic revolution in astronomy and astrophysics. Large unique spectroscopic and astrometrical investigations (collecting the databases of so-called *Durchmusterungen*) were launched out. At that time systematic sky patrols were established, based on the following tasks: systematic searches for moving Solar System objects, and – mainly – the systematic search for variable stars. Variable Stars were considered peculiar until the works of Argelander,[9] who forced systematic searches, and became crucial objects of astrophysics.[10] Compared with life-time of human beings, time scales in the evolution of stars are extremly large, they undergo no evident changes. But variable stars are changing their brightness, changing their brightness, caused by geometric or – more often – intrinsic physical processes. The periods of their variability are in the range of some

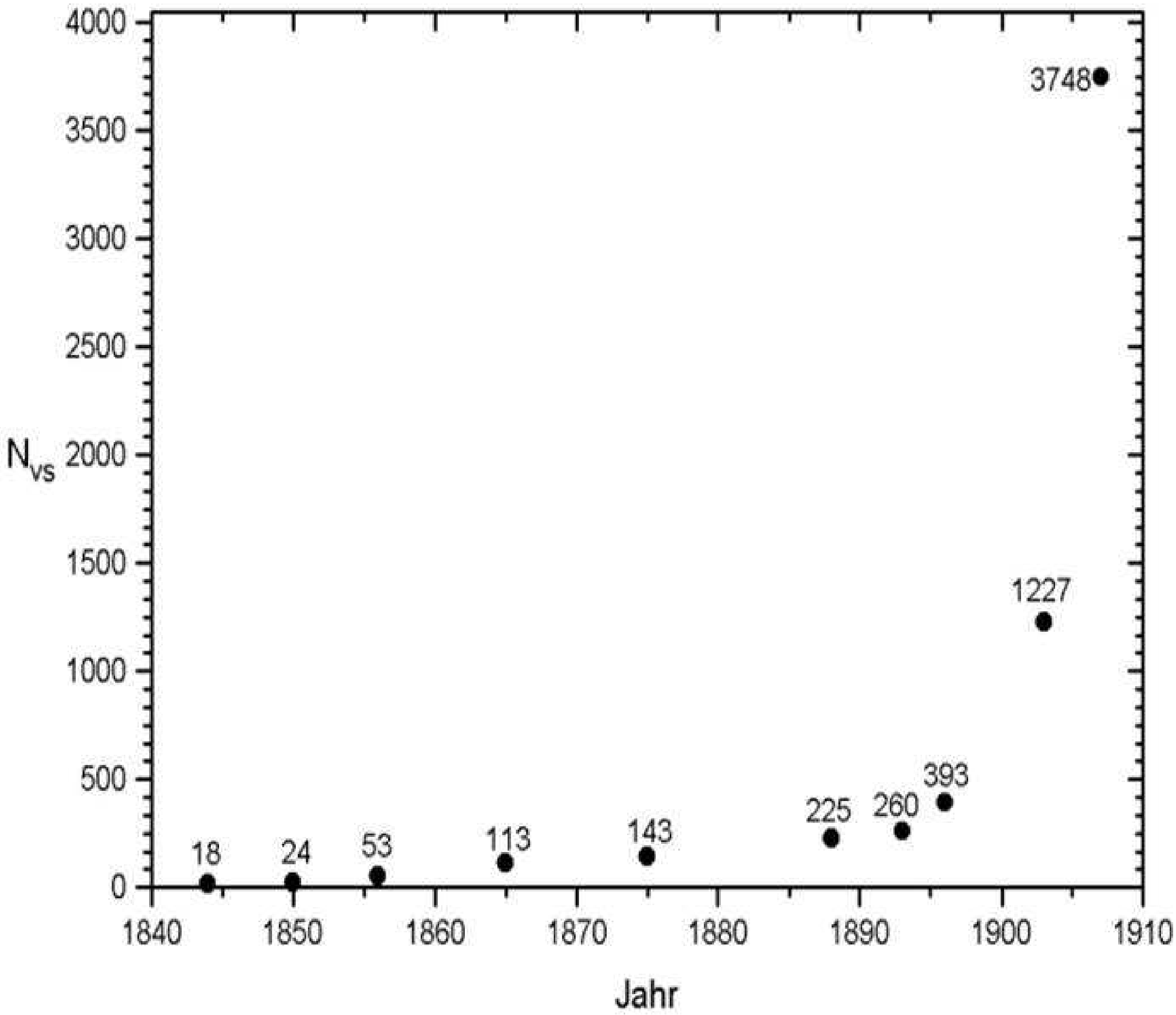

Figure 34.2: *Discoveries of Variable Stars (Diagramme compiled by Björn Kunzmann)*

minutes to some decades, mainly between 0.2 and 400 days. Thus, their varability may be detected well with the help of systematic sky patrols, covering the whole visible sky or selected areas. Caused by comprehensive photographic sky surveys discoveries of variable Stars significantly increases around 1900.

Variable stars act as physical probes, providing information about the dimensions, properties and distances of stars. In a first step, human knowledge about the structure of our galaxy, the stellar evolution and structure and cosmic distances in general depended on the information recorded in plate archives, evaluated by many famous astronomers, for example Walter Baade (1893–1960), Ejnar Hertzsprung (1873–1967), Edwin Hubble (1889–1953), Henrietta S. Leavitt (1868–1921), Cuno Hoffmeister (1892–1968), Henry Russell (1877–1957) and Harlow Shapley (1885–1972). Milestones of astrophysics are based on variable star data analysis stored on photographic plates, for example: Period-Luminosity-Relation (cosmic distances – Leavitt 1908/1912), Hertzsprung-Russell diagram (evolution of stars – Hertzsprung / Russell 1913), Analysis of globular clusters (dimensions of the galaxy – Shapley 1919), Cepheids in Spiral Nebulae (distance of M 31, Hubble 1923/25), Two-stellar-population theory and correction of period-luminosity relationship (evolution of stars, determination of distances – Baade 1944/1952).

34.2 Real and Virtual Heritage – Historical plate archives in observatories

Large direct-wide and spectral sky surveys were first performed at Harvard College Observatory (HCO) beginning in 1885, followed by many other observatories around the world. Nowadays HCO harbours 605,767 plates, Sonneberg observatory the second largest archive world-wide (around 300,000 plates) among other large ones in Germany like Bamberg (40,000 plates) and Hamburg (35,000 plates).[11] These plate archives form an important heritage, and are providing significant databases for future investigations. At present plate archives consists of an estimated total of 3,000.000 astronomical photographic plates in more than fifty observatories. The international astronomical community undergoes efforts to preserve this heritage, based on IAU Resolution B3.[12] In order to store digitised plate archives, large databases were established, for example *Wide-field Plate database* (WFPDB)[13], *Uccle Direct Astronomical Plate Archive Centre* (UDAPAC) and others. But only a fraction of the plate archives is yet digitized and only some observatories own scanning devices. The main problem remains the poor funding of different digitisation initiatives throughout the world.

34.2.1 Sonneberg Observatory

More than 11,000 galactic variable stars, being a quarter of all yet known, have been discovered on plates at Sonneberg observatory[14]. Information on this topic is presented in Peter Kroll's article *"The Plate Archive in Sonneberg – Digitisation, Preservation and Scientific Programme"*.

34.2.2 Bamberg Observatory

Bamberg observatory[15] was founded in 1889. Variable star research was its main domain for several decades, introduced by its first director, Ernst Hartwig (1851–1923). The plate archive[16] is complete and consists of around 40,000 high quality plates primarily taken for variable star research, covering time period 1913/1928 until 1982. Bamberg observatory take part in famous German sky patrol project *"Photographische Himmelsüberwachung"*[17] (Observatories in Babelsberg-Potsdam, Bamberg, Sonneberg, temporarily Wolfersdorf, Thuringia) established by Paul Guthnick[18], Cuno Hoffmeister and Richard Prager[19] in 1928. The aim of this project was to monitor variable stars in the northern hemisphere. An important southern sky project on variable stars was the *Bamberg Southern Photographic Patrol Survey* (BSPPS), covering time period 1962–1976 and taken at observation sites in New Zealand, South Africa and Argentina, with limiting magnitude 14–17. The digitisation of Bamberg's plate archive is still in progress, a catalogue is available online.

34.2.3 Hamburg Observatory

Hamburg observatory[20] plate archive harbours around 35,000 plates of northern and southern sky (direct and spectral plates), covering 1912–1999, with limiting magnitude 15–20. While Bamberg and Sonneberg plate archives primarily originate from variable star surveys, Hamburg plate archive is more heterogeneous concerning its content. Hamburg observatory performed some large projects, covering miscellaneous astrophysical, astronomical or astrometrical research areas. Earlier projects are the *"Bergedorfer Spektraldurchmusterung"* (1923–1933), determining the spectral types of stars in selected areas of the northern sky and the astrometric catalogues AGK 2 (1929–1930) and AGK 3 (1956–1964). Newer photographic projects are, for example, *Hamburg Quasar Survey* (HQS – 1980–1997, full coverage of northern extragalactic sky), *Hamburg/ESO survey* (HES – 1990–1999, full coverage of southern extragalactic sky) and the *Second Cape Photographic Catalogue* (CPC2), an astrometric, photographic catalogue covering the entire southern sky. Hamburg plate archive includes a large quantity of substantial plates of variable star research and stellar clusters, too. The archive is almost complete, a catalogue is available online. The digitisation of newer plates has already been concluded.

34.3 Virtual Heritage – concluding remarks

- Evolution and development of astrophysics substantially depends on the information we got from photographic plates, especially those of sky patrols and sky surveys.
- Historically, human knowledge about the structure and dimensions of the Milky Way, the position of the solar system, cosmic distances etc. significantly results from variable star research based on photographic monitoring projects.
- This heritage stored in astronomical plate archives contains more than a hundred years of historic information. These data are of highly scientific value and at present the only possibility to explore long-term processes.
- Some observatories, many of their buildings and instruments around 1900 were formed for photographic observation purpose. Therefore astronomical plate archives are of course an important part of cultural heritage, being worth to be preserved.

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1. Gustav Robert Kirchhoff (1824-1887) and Robert Wilhelm Bunsen (1811–1899).
2. Pogson, Norman: On Variable Stars, 1856.
3. Zöllner, Karl Friedrich: Photometrische Untersuchungen, 1865.
4. Louis Daguerre (1787–1851), inventor of photography, 1837–1839.
5. George Phillips Bond (1825–1865), first photography of a star.
6. Joseph Wilson Swan (1828–1914), inventor of photographic dry plate.
7. Henry Draper (1837–1882), first photographic stellar spectrum in 1872.
8. William Huggins (1824–1910), introduces dry plates in astrophotography in 1874.

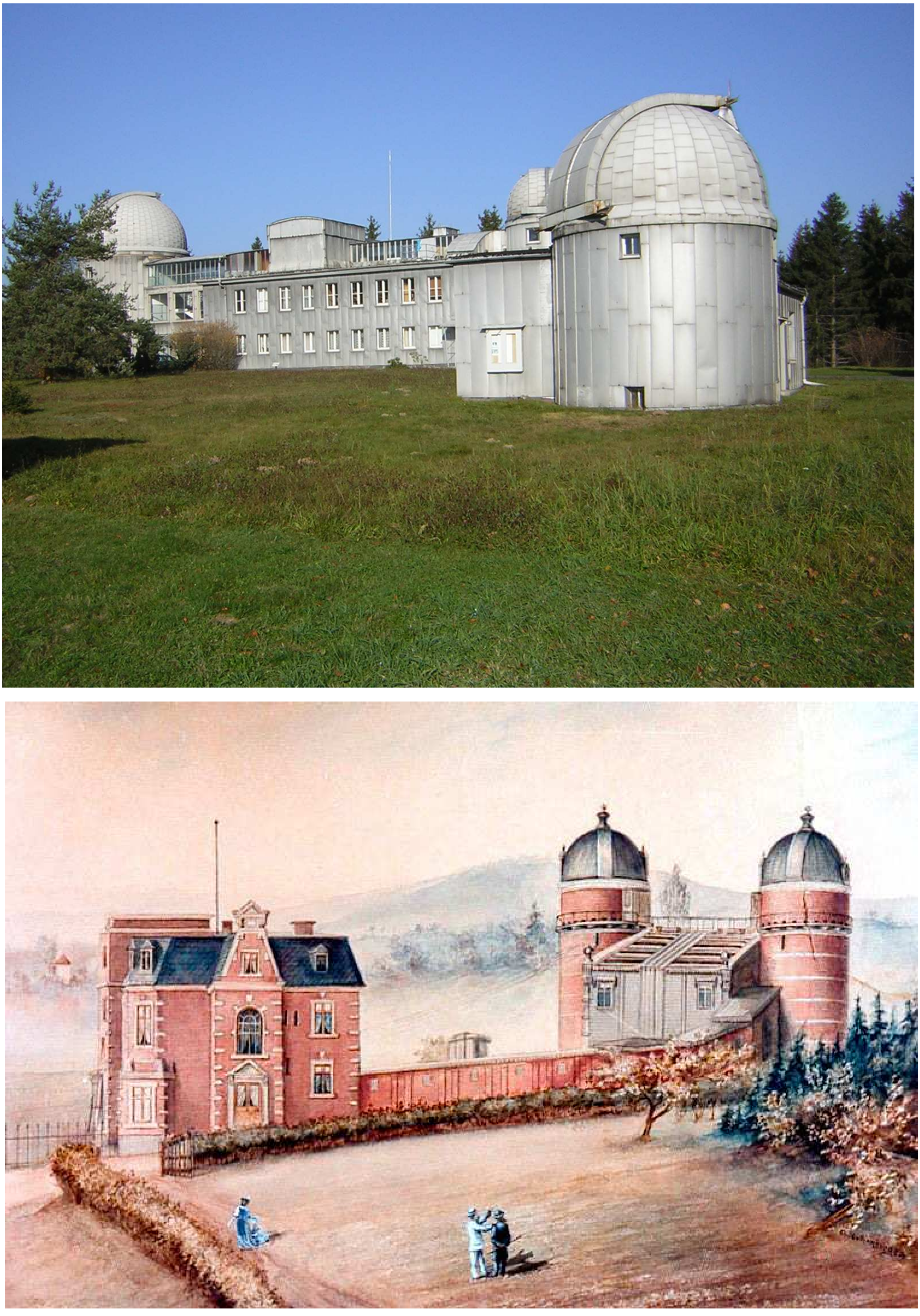

Figure 34.3: *Above: Main building of Sonneberg Observatory; Below: Dr. Remeis-Sternwarte Bamberg (Photo: Björn Kunzmann, Archiv Dr. Remeis-Sternwarte Bamberg)*

9. Friedrich Wilhelm Argelander (1799–1877), established variable star research.
10. Key papers on this topic are: Argelander 1844, Pickering 1883, Bailey 1906. For a comprehensive treatise of early Variable Star research history, see Kunzmann 2009.
11. Tsvetkov 2000, p. 613–617 and `http://www.skyarchive.org`.
12. IAU Resolution B3 (August 2000): Safeguarding the Information in Photographic Observations, `http://www.iau.org/static/publications/ib88.pdf`.
13. http://www.skyarchive.org.
14. For an introduction to observatory's history, see Kunzmann 2008, p. 205–239.
15. Wolfschmidt 2008, p. 155–191.
16. Hudec 1999, p. 33.
17. Kunzmann 2008, p. 224.
18. Paul Guthnick (1879–1947), astronomical photoelectric photometry 1912.
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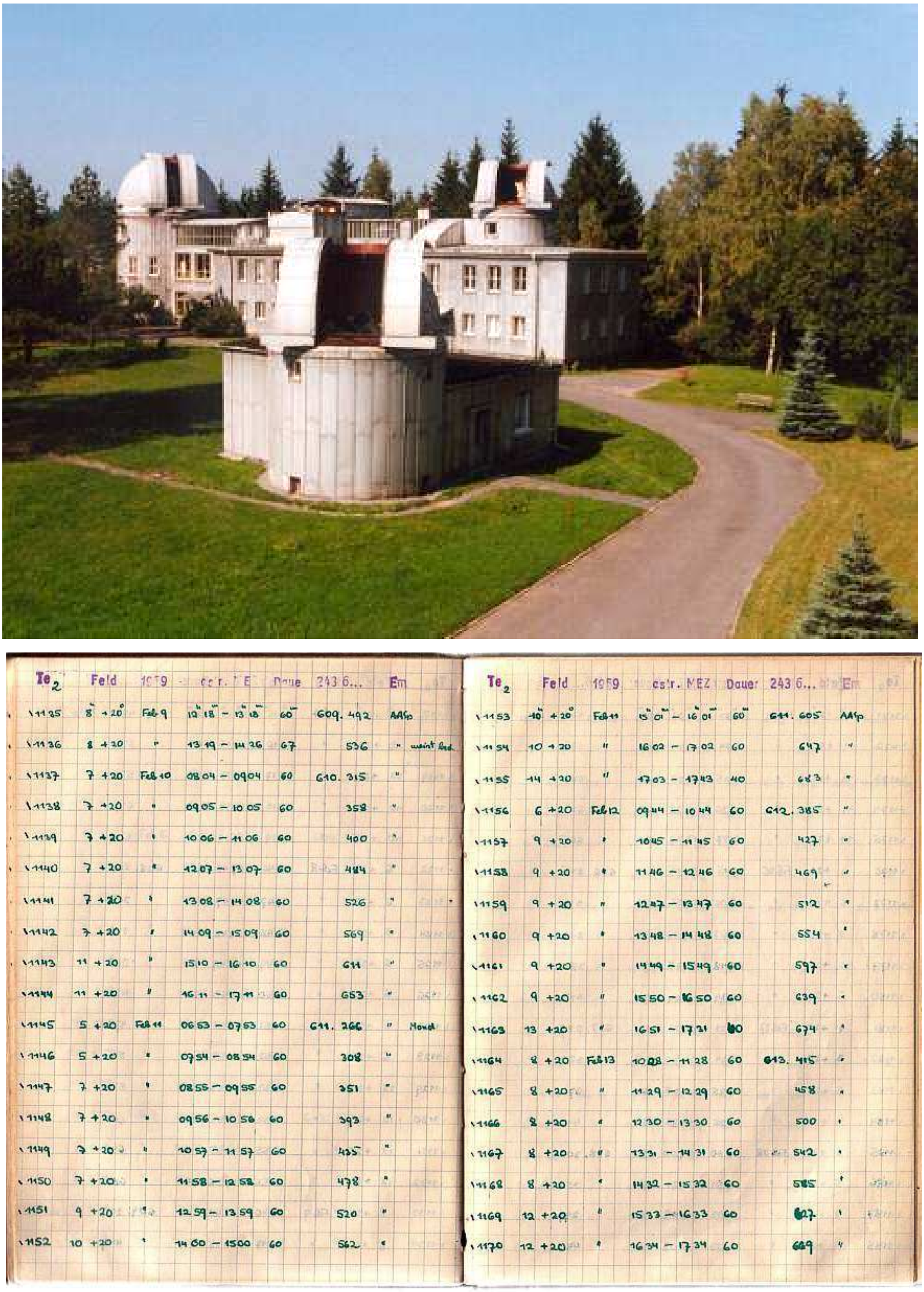

Figure 35.1: *Above: Sonneberg Observatory is a characteristic ensemble of buildings covered with aluminium sheet. Below: Log book of Tessar 2. (Photo: Peter Kroll, Sonneberg)*

35. Real and Virtual Heritage – The Plate Archive in Sonneberg – Digitisation, Preservation and Scientific Programme

Peter Kroll (Sonneberg, Germany)

Abstract

The real heritage of Sonneberg Observatory consists of several buildings with seven domes, a number of telescopes for photographic and photoelectric measurements, a plate archive – which is the second-largest in the world –, and a scientific library. While the instruments are today mainly used for public observing tours and to a limited degree for continuing sky patrol, the plate archive is systematically scanned in order to make the whole information stored in the emulsion of the plates accessible to the astronomical community and to allow the scientific study of all stars ever recorded. First pilot studies give a taste of what output can be expected from the digitized plate archive.

35.1 Brief History

Sonneberg Observatory was founded in 1925 by Cuno Hoffmeister as a municipal Observatory. In that time Hoffmeister was well-known yet for his works in variable star research. In close collaboration with the observatories in Bamberg and Berlin-Babelsberg he participated in a systematic photographic observational program, called sky-patrol, to monitor the stellar sky. In 1931, Sonneberg Observatory was affiliated to Berlin-Babelsberg Observatory.

After World-War Two the observatory became a member institute of the German Academy of Sciences. In the following decades the observatory grew significantly. Several new buildings were erected and new instruments were set up. The staff numbered up to 35.

As a consequence of German reunification the observatory became part of the Thüringer Landessternwarte Tautenburg next to Jena. However, the Ministry of Science of Thuringia decided to close the observatory within a period of three years. The observatory was closed in 1995 for nine months. Town and district of Sonneberg founded an association (so-called *Zweckverband*) to keep the observatory operational. The staff was reduced to five persons. After a few years it became more and more difficult to continue this construction.

In 2004 the observatory was handed over to a private company, 4π Systeme GmbH, of astronomy and information technology – a spin-off enterprise originating from the observatory. The company is obliged to continue observations and scientific work and to preserve the buildings, domes, and instruments. An astronomy museum founded in 1997 is operated by the association *Freunde der Sternwarte Sonneberg e. V.*.

35.2 The Real Heritage of Sonneberg Observatory

From the historic point of view the real physical heritage of Sonneberg Observatory consists of four parts: observatory buildings, astronomical instruments, plate archive and scientific library.

35.2.1 Observatory Buildings

Sonneberg Observatory is situated on top of the small hill *Erbisbühl* at 640 m above sea level on the southern rim of the Thuringian forest. The very first building, erected in 1925, was comparably small with a 5-m dome. Later, a number of wooden barracks with movable roof were set up in order to host several telescopes. Today, all these wooden buildings do not exist any more.

The first building was extended by a number of rooms and a lecture hall. In the 1950ies three dome buildings with three to four laboratory and office rooms were built. In 1960 the new main building with basement, two floors, a 8-m and 5-m dome and a movable roof for the sky patrol was erected. In the 1970ies, a separate workshop building was built.

In the late 1970ies all buildings were covered with aluminium sheet for isolation and to protect them from rainy weather. This layer gives the observatory a very characteristic appearance (Fig. 35.1 above, p. 310). Since 1994, the observatory as an ensemble of buildings is officially listed as a historic monument.

35.2.2 Astronomical Instruments

Two photographic programme have been conducted (see Bräuer et al., 1999):

1. The *Field Patrol* has monitored about 80 fields along or near the northern Milky Way (fields in higher galactic latitudes were added later) mainly with two astrographs (400/1950 and 400/1600 mm) at limiting magnitudes up to 17^{m}. A Schmidt camera (500/700/1720 mm) with a limiting magnitude of 18^{m} was mostly used for monitoring of open star clusters.
2. The *Sky Patrol* (see Fig. 35.2, p. 313) was recording the entire sky northern to $\delta \sim -30°$ in two colors (photographic (ca. B) and photovisual (ca. V)) at a limiting magnitude of 15^{m}(B) and 14^{m}(V) with 14 cameras (55/250 mm) on two mountings. The Sky Patrol is still running with 7 cameras. Due to increasing light pollution by the nearby town of Sonneberg the patrol was restricted to fields northern to $\delta \sim -10°$ in the late 1980ies.

Two Cassegrain telescopes (600/1800/4500 mm and 600/7500 mm) have been used for photoelectric multicolor measurements of variable stars. In the 1990ies, the telescopes were equipped with CCD cameras. Today, the second telescope is used for public observations. One dome of the observatory hosts a historic refractor (135/1800 mm) which was heavily used by Hoffmeister in the past, and which is today the main instrument for public guiding tours.

Table 35.1: *Principal series of Sonneberg plate archive*

Series	Instrument	Plate (mm)	Field (°)	mag_{limit}	Total	Scanned
SC	Schmidt 500/700/1720	130×130	3.4×3.4	18 (B)	8700	5200
GA/GB/GC	Astrographs 400/x	300×300	10×10	17 (B)	20300	5100
A,F	Astrographs 170/x	200×200	8×8	16 (B)	14200	0
E	Ernostar 135/240	160×160	30×30	13 (B)	22800	15000
Te	Tessars 55/250	130×130	26×26	14 (B) 13 (V)	160000	160000
others (ca.)				10...16	70000	25000
total (ca.)					296000	210000

35.2.3 Plate Archive

All plates taken at Sonneberg Observatory are stored in two protected rooms (Fig. 35.3, p. 314). The plates of each field are collected in card boxes with up to 20 plates, separated by chemically neutral paper sheets. Each box is labeled with the coordinates of the recorded field and the period of time when the plates were taken. The storage conditions in the rooms are kept at 40% to 50% relative humidity and temperatures of about 18°C to 23°C.

Each exposure is recorded in manually written log books (Fig. 35.1 below, p. 310), containing instrument name, plate number, date and time of begin and end of exposure, Julian day, emulsion type, field name oder coordinates of plate center, sky condition, and remarks. A subset of these parameters (civil date, Julian day, field name, instrument name, plate number) are also written at the upper and lower edges of every plate for clear identification and practical use.

A rough overview of the content of the plate archive gives the following table 35.1, p. 312. For details see Bräuer et al (1999).

35.2.4 Library

The library of Sonneberg Observatory consists of three parts: books (text books on astronomy, mathematics, physics; monographs, conference proceedings, etc.), periodicals, and publications series of other institutes and of astronomical organizations.

The publication series which were collected on the basis of mutual interchange of publications between about 150 astronomical institutes world-wide are probably the most valuable content of this library since periodicals and books are available in other libraries too but others institutes' publications are often not. From the observatory first days on all incoming literature was scanned for publications about variable stars – the main field of research. All these notes were collected on file cards forming the BCVS (Bibliographic Catalogue on Variable Stars). In the 1980ies these data were keypunched and sent to CDS in Strasbourg, France. Today the catalogue is available online (see Rössiger & Bräuer, 1994).

The scanning of the literature has stopped in the early 1990ies since more and more necessary periodicals and proceedings could not be acquired any more. In parallel, CDS is scanning all new literature anyway and offers this in the internet. Nevertheless, one great advantage of the file cards of the BCVS is the locally accessibility of about

Figure 35.2: *Instrumentation of Sky Patrol (image taken in the 1960ies) (Photo: Peter Kroll, Sonneberg)*

95% of the papers listed therein. In particular, papers from before around 1950 which are not yet available in the internet can be found physically in the library. Of course, this situation will change in the future making this collection more and more obsolete – from the point of view of information science.

35.3 The Virtual Heritage of Sonneberg Observatory

In parallel to the real heritage as being physically present a digital heritage has emerged in the recent years. The process of digitization has started in the early 1980ies and is still going on. Formally speaking, the photometric information in the plates of the archive is stored since the exposure took place, however only with the help of the digitization this heritage can be made accessible in a systematic way and to broad community. Coming from the buzz words around virtual observatories, telescope, archives etc. we propose to call this heritage a virtual one.

35.3.1 Log-book Data

When observing with the photographic instruments the observer writes manually all exposure data in a log-book. Each record contains instrument name, plate number, date and time of start and end of exposure, Julian day, emulsion type, field name or coordinates of plate center, weather conditions, and remarks. A subset of this information is also carefully written on the emulsion side along the upper and lower edge of each plate for identification: civil date, Julian day (plus fraction) of mid of exposure, field name, instrument name, and plate number. In the early 1980s keypunching of the log books has started. In that time, the date were stored on tape cassettes, later on floppy disks, and finally on hard disks. Currently, about 90% of the data are stored in a dBase database. This database is under migration to a modern database system with internet access.

35.3.2 Digital Plate Archive

Long before the systematic scanning of the plates was started, they were carefully cleaned. This became necessary since the plates were frequently used over decades by visual inspection for variable stars. Each investigator had to handle plate by plate, taken them out of the box, inspecting the field of interest under a microscope, and finally putting the pile of plates back to the box. By this way, many finger prints, dust grains and other impurements were found on the glass side of the plates. A few plates also show on the glass side written remarks and small frames around stars left over from the discoverers of variable stars.

The process of cleaning the plates was accomplished by checking the plate identification data against the log-book database. By this way it turned out that about 3%

Figure 35.3: *Sonneberg Plate Archive (Photo: Peter Kroll, Sonneberg)*

of all plates display some kind of erroneous identification data.

In order to get experience several experiments with different commercial and dedicated scanners have been carried out in the 1990ies. About 5,000 plates were scanned in this way. The systematic scanning of all plates started in spring, 2003. After a number of unsuccessful applications to get grants from the Deutsche Forschungsgemeinschaft or from the Ministry of Science of the state of Thuringia, the 4pi Systeme company took the investment to purchase five commercial flatbed scanners.

These scanner of HP Scanjet 7400c type are fast enough, reliable, and easily operated. In order to achieve the complete data output of 16 bit, the scanners are operated by the universal scan software VueScan. Four scanners were operated in parallel with a total throughput of 25 plates per hour. The resolution of 20μm per pixel is a compromise between photographic grain size (about 15μm), scan speed, and data volume. One sky patrol plate of size 130 mm $\times$ 130 mm yields an image of 6k $\times$ 6k pixels of 2 bytes each, thus 72 MB in total of raw data stored in files of TIFF type. By gzip-ing these files are lossless compressed to about 45 to 50 MB. After this compression up to 90...95 scan files are then stored on DVDs. Up to the present all sky patrol plates of this size have been scanned. Two of these scanners are still used to scan the older sky patrol plates of smaller sizes.

The whole-sale scanning was accompanied by a permanent assessment of the photometric and astrometric properties of the scanners. While the photometric stability is satisfying, the positional accuracy appears too poor for sophisticated astrometric studies. But owing to the relatively small plate scale of 830″/mm astrometric investigations are not feasible anyway.

For scanning the Schmidt plates of the same size but with a scale of 120″/mm astrometric investigations can be taken in consideration. For this reason, a better scanner had to be procured. A good opportunity was raised by the offer of the Maria Mitchell Observatory, Mass., USA, to sell their AgfaScan T5000 sacnner which was formerly used for scanning their plate archive (see Strelnitski & Davis, 2004). Although this scanner has several drawbacks (for the highest resolution the plates can only be scanned in two swathes) it was purchased in August 2006 and ready for operation in May 2007. Since then all the 8800 Schmidt plates have been digitized.

In order to digitize the large astrograph plates a bigger flat-bed scanner was purchased in autumn 2007. This scanner of Microtek ScanMaker 9800 XL type is able to scan a full 300 mm × 300 mm plate with 2 bytes per pixel and 20 μm resolution within about 20 minutes. Up to now, about 8000 plates have been digitized with it.

To sum up, the current virtual heritage of Sonneberg Observatory comprises about 12 TB data stored on 2600 DVDs. Scanning the whole plate archive will probably be achieved in 2011 with a total of 20 TB.

35.4 Utilizing the Virtual Heritage

The digitization of the plates does not end in itself. In the contrary, only by digitization the full astronomical content of information – so far hidden in the emulsion – can be raised.

In the recent years several studies of stellar variability based on digital data have been conducted:

- **Long-term variability** While the discovery of variable star by traditional visual inspection of photographic plates can reveal changes between two plates of at least 0.3 mag only, the analysis of stellar photometric data automatically measured on scanned plates allows to decrease the detection limit to below 0.1 mag. In particular, long trends over years in photometric variability with small amplitude can be detected only in this way. A pilot study by Vogt et al. (2004) based on scanned Sonneberg plates revealed several new types of long-term variability: cycles of about 20 years length with 0.1 to 0.4 mag amplitude, and annual trends of 0.002 to 0.005 mag with increasing or decreasing slope.
- **Variability of solar-like stars** Fröhlich et al. (2006) have studied the photometry of the solar-like star HK Lacertae on about 2000 scanned Sonneberg plates. The results were in good agreement with high-precision photoelectric data. The data from the plates yielded a prolongation of the light-curve into past by two decades. Although rather noisy, the data could be used to detect the rotational period of the star, and even a new long-term cycle was derived.
- **Variability of host stars of extra-solar planets** An interesting application of the scanned plates arises from the long-term study of stars at which extra-solar planets have been detected. Originally in order to check if the eclipse light-curve (amplitude 0.017 mag only) of the planet HD 209458B could be measured Richter (unpublished) has visually estimated the photometry of the host star HD 209458A on all available plates (ca. 2500). The eclipse light-curve could not be revealed, but the stars shows several phases of irregular variability with an amplitude up to 0.4 mag.

The whole-sale investigation of the scanned plates has still to be conducted. The above mentioned project show the potential of a systematic investigation of virtually all stars recorded in the plates. Certainly, there is a great number of suspicious objects and unknown phenomena still to be discovered.

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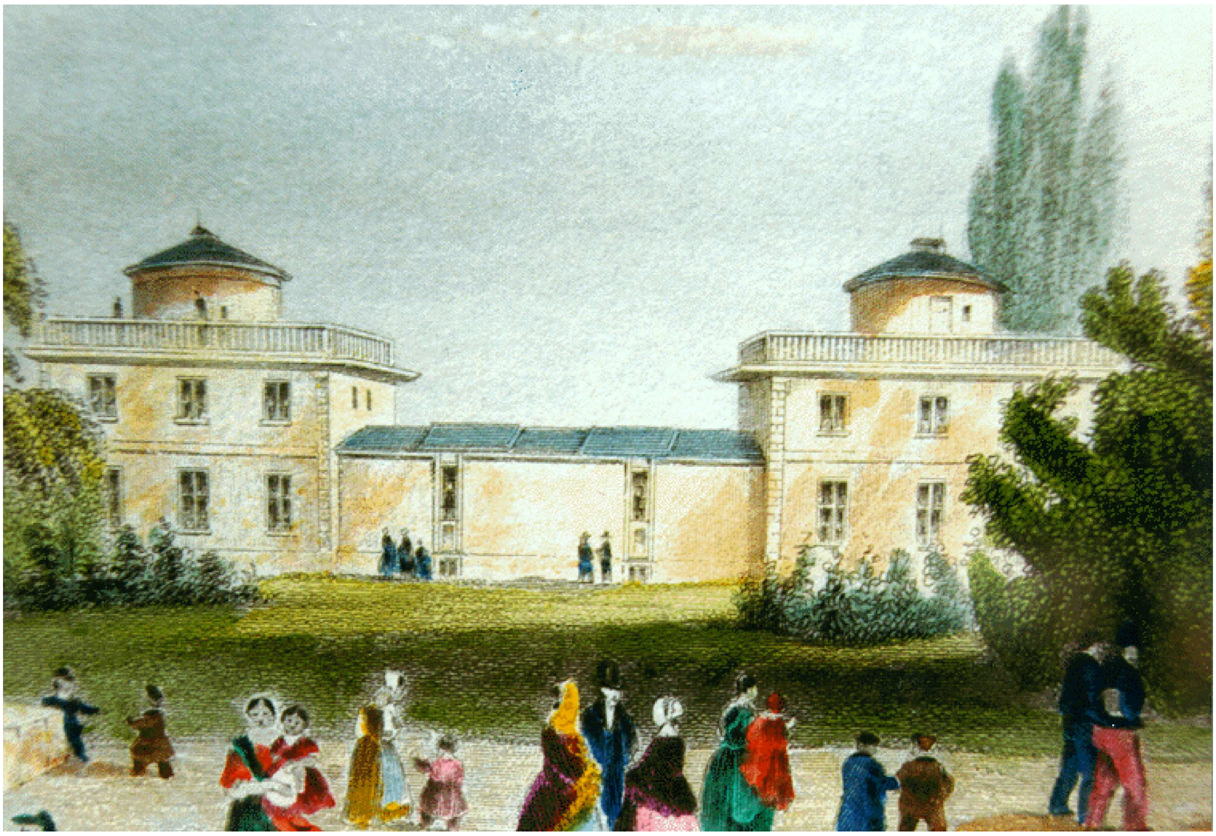

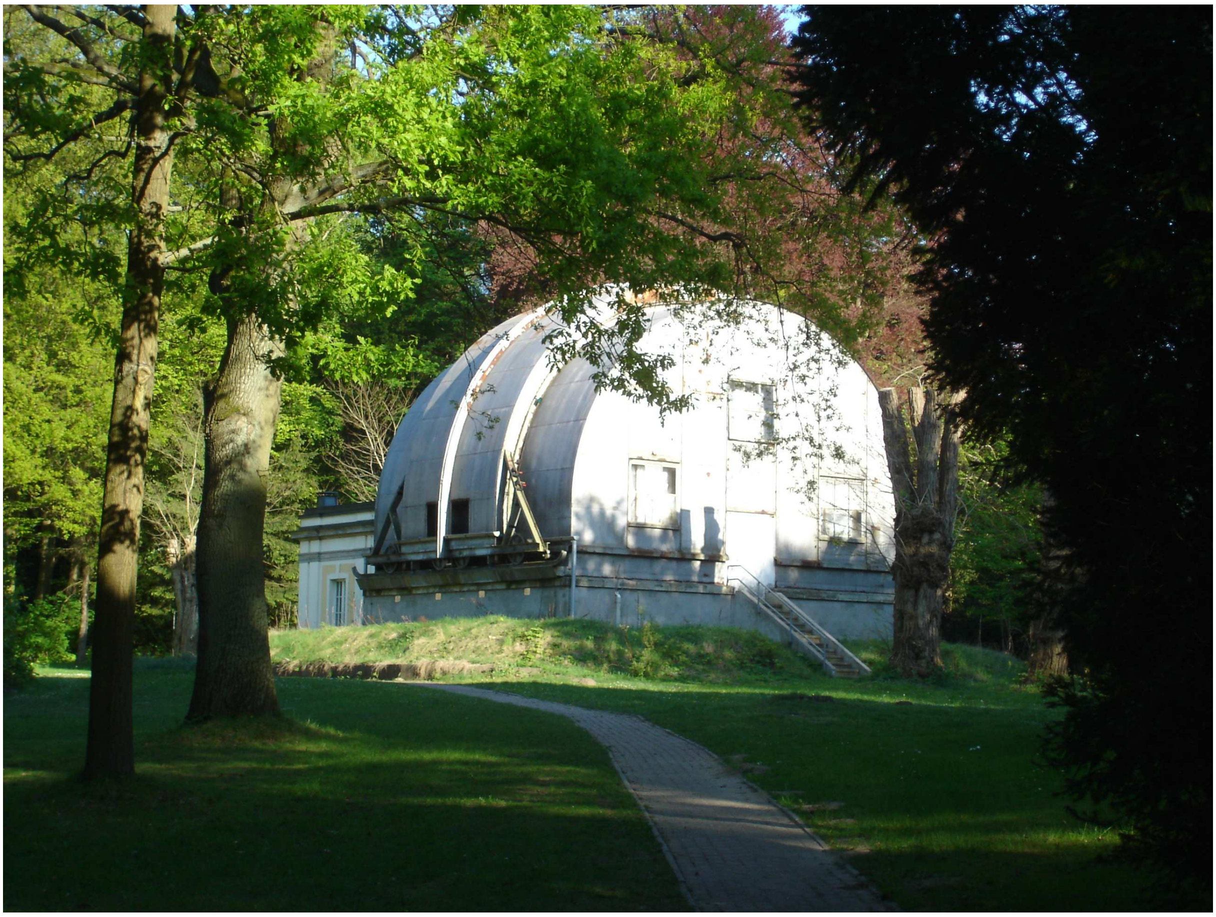

Figure 36.1: *Above: Old Hamburg observatory near Millerntor, built in 1825 Below: Hamburg Observatory in Bergedorf (1906–1912), meridian circle building (Hamburg Observatory; Photo: Gudrun Wolfschmidt)*

36. Faszination Astronomie – Die letzten zwei Jahrhunderte

Rudolf Kippenhahn (Göttingen, Germany)

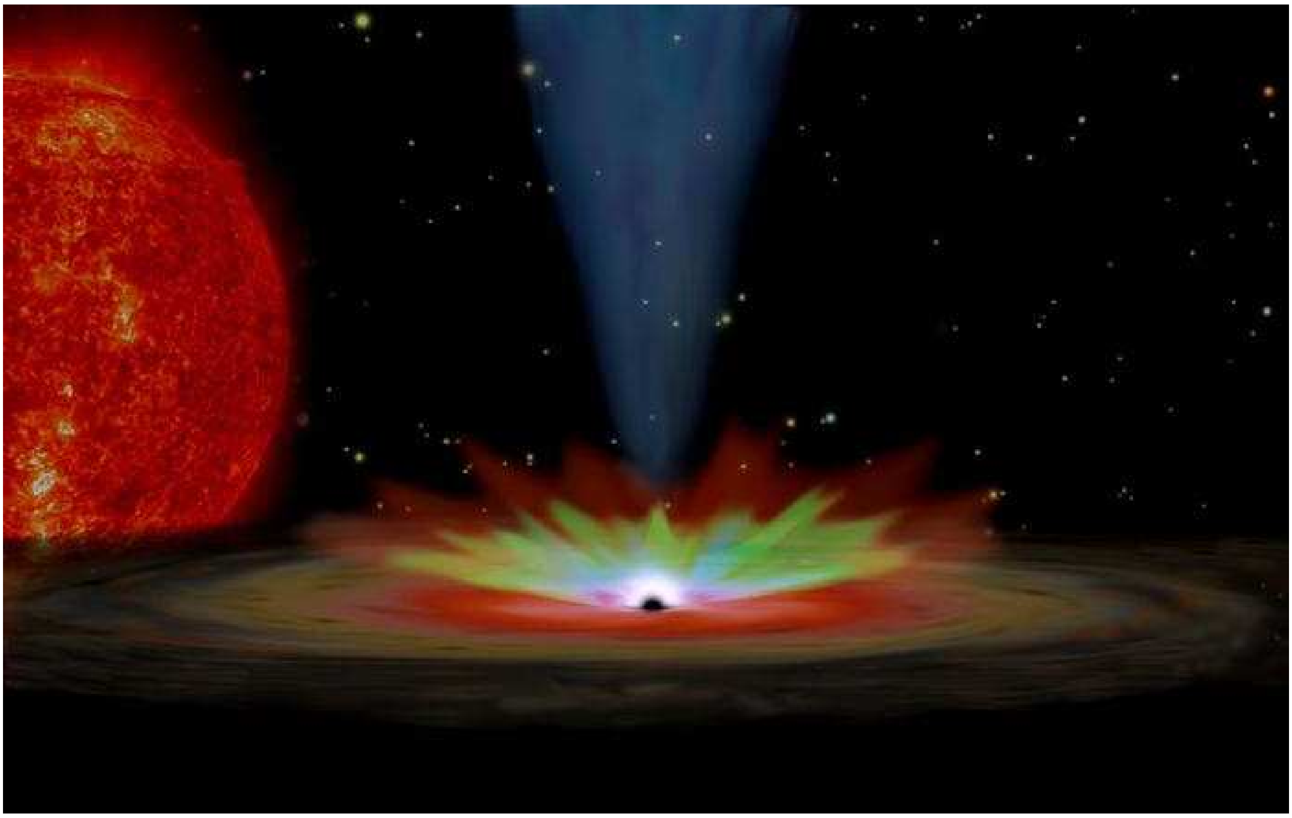

Figure 36.2: *Flashing light from the black hole in KV UMa (Max Planck Institutes for Astrophysics (MPA) and Extraterrestrial Physics (MPE))*

Der Zeitraum zwischen der Gründung der Hamburger Sternwarte (1825) und der Gegenwart umspannt den Übergang von der klassischen Astronomie zur modernen Astrophysik. Die Hamburger Astronomen sind diesem Trend ihrer Zunft gefolgt und haben selbst dazu beigetragen. Im Vortrag wurde gezeigt, wie sich durch die Entwicklung der Teleskope unser Weltbild veränderte. Man lernte, dass das Weltall expandiert und dass nicht nur Licht, sondern auch Radiowellen aus dem Weltall zu uns dringen.

Nach dem Zweiten Weltkrieg wurde den Astronomen durch die Weltraumtechnik das gesamte elektromagnetische Spektrum des Weltalls zugänglich. Man entdeckte Sterne, die Röntgenstrahlen aussenden und solche, die ihr Licht nicht gleichförmig abstrahlen, von denen das Licht vielmehr in Form von Lichtblitzen ausgeht. Radiowellen lenkten das Interesse auf gewaltige Strahlungsquellen, die sich als Zentren ferner Sternsysteme entpuppten, in die Gasmassen stürzen und strahlen, ehe sie in einem Schwarzen Loch für immer verschwinden.

Figure 37.1: *Oskar Lühning Telescope (OLT)*

37. Geschichte und Zukunft der Hamburger Sternwarte

Dieter Reimers (Hamburg, Germany)

Die Hamburger Bürgerschaft hat am 31. Oktober 1833 auf Antrag des Senats beschlossen, die bereits bestehende Sternwarte am Holstenwall als Staatsinstitut zu übernehmen.

Tatsächlich gibt es dazu eine längere, komplizierte Vorgeschichte, die mindestens bis 1802 zurückreicht, als der Gründer der Hamburger Sternwarte, Johann Georg Repsold, Oberspritzenmeister der Hamburger Feuerwehr, auf der Elbhöhe am jetzigen Stintfang ein astronomisches Observatorium errichtete. Dort wurden von ihm und von H. C. Schumacher, dem späteren Direktor der Altonaer Sternwarte und Freund von Gauß, Begründer der *Astronomischen Nachrichten* (1821, der ältesten astronomischen Zeitschrift, die noch existiert), 1809–1812 astronomische Beobachtungen gemacht.

Dann kam ein Einschnitt, der in mehrfacher Hinsicht folgenreich war für die Entwicklung der Astronomie. Die französischen Besatzer ließen 1813 die Sternwarte abreißen, weil sie freies Schussfeld haben wollten.[1]

Zurück zur Hamburger Sternwarte: Was kam nach dem Stintfang? 1819 errichtete der damalige Lehrer an der Navigationsschule auf dem Wall Charles Rümker eine kleine Privatsternwarte und führte eine große Zahl von Beobachtungen durch, die auch publiziert wurden. Den Namen Charles Rümker müssen Sie sich merken, denn er wurde später der 1. Direktor der Hamburger Sternwarte, später folgte ihm sein Sohn Georg Rümker im Amt (1867 bis 1899).

Charles Rümker, der aus Mecklenburg stammte, war zur See gefahren und von 1812 bis 1817 Offizier der britischen Kriegsmarine und Navigationslehrer an Bord des Admiralschiffes der Mittelmeerflotte. Er ging dann nach Hamburg, ab 1821 leitete er eine neugegründete Sternwarte in New South Wales (Australien).

Eine so glückliche Vereinigung astronomischen und nautischen Wissens, wie Rümker sie durch seine langjährige seemännische und astronomische Tätigkeit besaß, war später für Hamburg von großer Wichtigkeit.

Johann Georg Repsold machte zusammen mit dem Kanaldirektor J. Th. Reinke am 5.5.1820, nachdem bei den Entfestigungsarbeiten der Stadt auf dem Wall ein Gelände frei geworden war, das sich für die Errichtung einer Sternwarte eignete, eine Eingabe, in der sie, unter Beziehung auf den engen Zusammenhang zwischen Astronomie und Schifffahrt, die Wichtigkeit der Errichtung einer Sternwarte in Hamburg betonten und darum baten, dass ihnen so viel Flächenraum von der Bastion zugeteilt werde, als zu einer vollständigen Sternwarte nötig sei. Da zu dieser Zeit auch Rümker eine Erweiterung der Navigationsschule beantragt hatte, schlug der Senat vor zu überlegen, ob nicht das neu zu errichtende Observatorium mit der Navigationsschule direkt verbunden werden könnte. Schließlich bewilligte der Senat, nach einigem Hin und Her, am 22.8.1821 22.000 Mark Crt für das gemeinsame Gebäude der Navigationsschule und der Sternwarte.

Erst 1825 war das Gebäude im Wesentlichen fertig (cf. fig. 36.1, p. 316). (Es gab zwischendurch Finanzschwierigkeiten, das Gebäude wurde teurer als gedacht, und erst ein privates Legat durch einen Liebhaber der Astronomie ermöglichte die Fertigstellung – klingt alles erstaunlich modern: die Hamburger Sternwarte hat in der Vergangenheit des Öfteren von Erbschaften und Stiftungen profitiert. Zwei der Teleskope in Bergedorf:das 60 cm Lippert und das 1.2 m Oskar Lühning-Teleskop gehen auf private Stiftungen bzw. Erbschaften zurück).

Die Geschichte der Sternwarte nahm dann eine ganz unerwartete Wendung. J. G. Repsold kam am 14.1.1830 bei einem Brand ums Leben (ein Hausgiebel stürzte auf ihn). Das ergab einerseits die Möglichkeit, die Leitung der Navigationsschule und der Sternwarte in einer Hand zu vereinigen; und Karl Rümker (1788–1862) besaß in idealer Weise die Voraussetzungen. Andererseits: Die Instrumente der Sternwarte gehörten Repsold und mussten von den Erben gekauft werden. Bei der damaligen Finanzlage der Hansestadt war es schwierig, die dafür nötigen 15.000 Taler aus den laufenden Staatseinnahmen zu bestreiten.

Die Schwierigkeiten wurden jedoch durch hochherzige Stifter behoben. Eine Anzahl Hamburger Kaufleute, die seit Anfang des 18. Jahrhunderts nach Russland Geschäfte machten und sich zum “Verein der nach Archangel handelnden Kaufleute” zusammengetan hatten, hatte ein beträchtliches Kapital angesammelt. Sie beschlossen, den vorhandenen Mitteln “endlich eine dem Gemeinwesen nützliche Bestimmung zu geben und einen Teil derselben dazu zu verwenden, die Sternwarte zu Eigentum und Angelegenheit des Staates zu machen”. Es handelte sich um 17.000 preuss. Taler für die Instrumente sowie für laufende Ausgaben. Damals wie heute fanden sich in Hamburg immer wieder Kaufleute und Unternehmer, die große Teile ihres Vermögens für das

Gemeinwohl stifteten. Charles Rümker blieb Direktor bis 1862; danach wurde die Leitung seinem Sohn George Rümker (1832–1900) übertragen, der bis 1899 im Amt war.

37.1 Was waren nun die Aufgaben der Sternwarte?

Vor der rein wissenschaftlichen Tätigkeit (Beobachtung von Kleinplaneten, Kometen, Doppelsternen, ...) war die Positionsastronomie das Hauptanliegen: die Erstellung von Sternkatalogen mit genauen Sternpositionen für die Navigation.

Die apparative Ausstattung während des 19. Jahrhunderts war im Wesentlichen die von Repsold übernommen. Erst 1867 kam ein größerer Refraktor, das Äquatorial hinzu, gebaut von der Firma A. Repsold & Söhne, die im 19. Jahrhundert zur weltweit führenden Instrumentenbaufirma aufgestiegen ist, z. B. sind die großen Refraktoren von Pulkovo, Potsdam, Mailand und Hamburg-Bergedorf von der Fa. Repsold, daneben weltweit viele Meridiankreise, Heliometer usw. Das Äquatorial von 1867 kann übrigens in Bergedorf besichtigt werden.

Für die Positionsbestimmung auf See sind für die Bestimmung der geographischen Länge genaue Zeiten notwendig. Hinreichend genau gehende Uhren, die auf hoher See, d. h. auf stark schwankendem Boden, über lange Zeiten eine hinreichende Ganggenauigkeit haben, gab es erst, seit John Harrison ca. 1770 Chronometer hatte bauen können, die eine Ganggenauigkeit von $\frac{1}{3}$ sec/Tag erreichten (das sind bei einer Seereise von sechs Wochen Abweichungen von weniger als 14 sec, entsprechend auf See einer Ungenauigkeit in der Position von weniger als ca. 4 Seemeilen in geographischer Länge,die Breite wurde unabhängig durch Messung der Polhöhe bestimmt).

Eine wichtige Aufgabe der Sternwarte war deshalb die Absoluteichung der Schiffschronometer mittels eines von der Sternwarte (über Messungen mit dem Meridiankreis) kommenden absoluten Zeitsignals. Ein elektronisches Zeitsignal löste ab 1876 über ein eigens verlegtes unterirdisches Kabel den Fall eines Zeitballs am Kaiserkai aus. Der Zeitball, ein schwarzer Ball von 1.5 m Durchmesser, hing 53 m über NN und fiel 3 m tief. Abweichungen des Falls von der wahren Zeit waren typisch 0.2 sec. Nur nach Sternen navigiert heute im Zeitalter des GPS (oder davor der Kreiselkompasse) niemand mehr.

Aber: Das GPS-System hat als Referenzsystem immer noch das absolute Referenzsystem der Astronomie, das an fernen Quasaren aufgehängt ist. Warum? Die schwankende Polarachse der Erde und die nicht völlig gleichmäßige Rotation der Erde machen für hohe Genauigkeitsansprüche (1 m) die Erde zum schlechten Referenzsystem, d. h., wenn Sie heute mit GPS auf wenige Meter genau Ihren Ort auf der Erde feststellen können, dann liegt das am absoluten Referenzsystem der Astronomen, an dem die Hamburger Sternwarte im 20. Jahrhundert durch ihre Kataloge (AGK 3 für Nordhimmel, Perth für Südhimmel) einen wesentlichen Beitrag geleistet hat.

Das alles war klassische Astronomie des 19. Jahrhunderts – von Physik war dabei keine Rede. Dabei fing die quantitative Spektroskopie (qualitativ hatte Fraunhofer schon viel früher die Sonne spetroskopiert) von Sternen in den letzten Jahrzehnten des 19. Jahrhunderts an – sobald man Spektren fotografieren konnte. Dafür mussten natürlich weitaus lichtempfindlichere Emulsionen zur Verfügung stehen als für die klassische Fotografie, und man brauchte große Teleskope (Lichtsammelfläche).

In Hamburg fing das Zeitalter der Astrophysik erst mit dem Umzug nach Bergedorf an. Zwischen 1908 und 1912 wurde auf Initiative von George Rümkers Nachfolger Richard Schorr (1867–1951) in Bergedorf das zu der Zeit größte europäische Observatorium mit Reflektoren von 1 m und 60 cm, einem Refraktor von 60 cm, einem Meridiankreis sowie weiteren Instrumenten errichtet.

Bevor das hervorragende und moderne Observatorium Früchte tragen konnte, brach der Erste Weltkrieg aus, es kamen die schlimmen Jahre der Inflation etc. Aber, meine Damen und Herren, Sie wissen: die 20er Jahre waren eine Blütezeit der Wissenschaft und Kultur in Deutschland, und auch an der Hamburger Sternwarte wurden zwei bedeutende, weil in die Zukunft weisende Entdeckungen gemacht, die mit den Namen Walter Baade (1893–1960) und Bernhard Schmidt (1879–1935) verbunden sind. Direktor Schorr war hauptsächlich an Sonnenfinsternis-Expeditionen interessiert, u. a. nach Nordafrika, Lappland und auf die Philippinen – die Daten wurden allerdings nie ausgewertet.

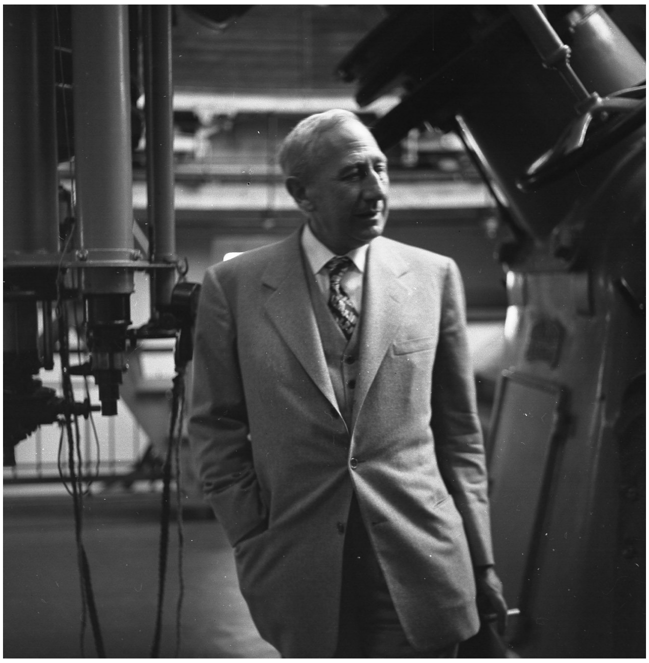

Abbildung 37.2: *Walter Baade (1893–1960)*

Walter Baade, einer der bedeutendsten Astronomen des 20. Jahrhunderts, der von 1920–1931 in Hamburg

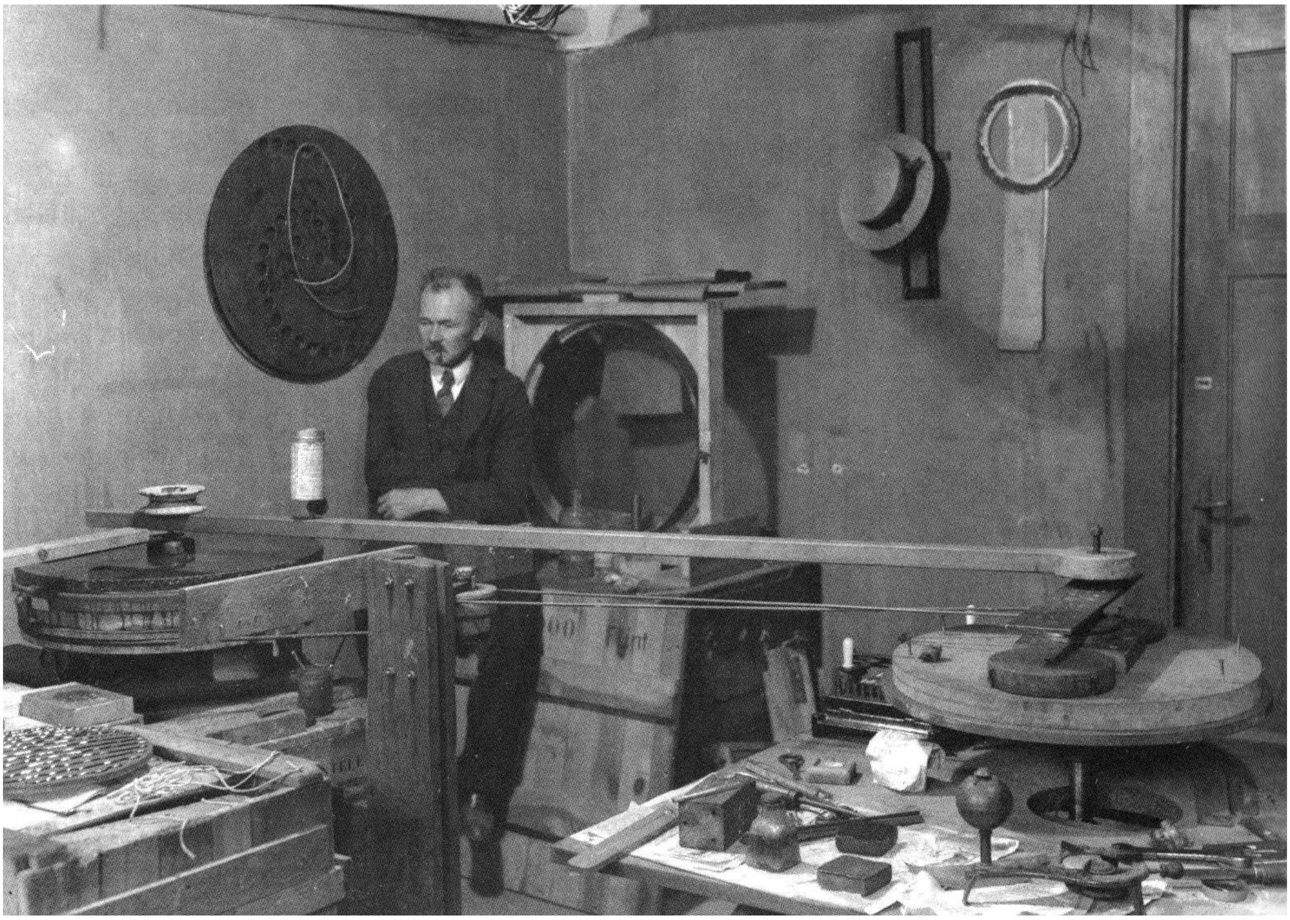

Abbildung 37.3: *Bernhard Schmidt (1879–1935) in his workshop (Hamburg Observatory)*

Observator und später außerplanmäßiger Professor war, hat in Hamburg mit dem 1 m-Teleskop seine bahnbrechenden Arbeiten zu den Sternpopulationen begonnen, die dann im Zweiten Weltkrieg in seinen Arbeiten mit dem 2.5 m-Teleskop auf Mt. Wilson über dem während des Krieges abgedunkelten Los Angeles ihren Höhepunkt hatten. Baade hat (zusammen mit Fritz Zwicky) auch als Erster den Zusammenhang von SN-Explosionen und Neutronensternen als Endprodukt postuliert. Dabei kamen ihm seine soliden physikalischen Kenntnisse und seine Diskussionen hier in Hamburg mit Wolfgang Pauli, mit dem er befreundet war, zugute (Pauli wird übrigens in einer Biografie zitiert: *"dass er oft abends zu Baade nach Bergedorf herauspilgerte und sie bei schlechtem Wetter dem Rotwein frönten"* – Baade hätte ihm das Trinken beigebracht). Baade hat später auch dem aus dem physikalischen Institut als Juden vertriebenen Rudolph Minkowski in Pasadena eine Stelle verschafft und jahrzehntelang mit ihm zusammengearbeitet.

Das zweite Highlight dieser Jahre war die Entwicklung (sowohl des Prinzips als auch seiner technischen Umsetzung) des ersten Weitwinkelteleskopes.

Die klassischen großen Reflektoren (Parabolspiegel) haben ein sehr kleines Gesichtsfeld (typisch kleiner als die Mondfläche), in dem die Sterne scharf abgebildet werden können. Bernhard Schmidt, ein Este von der Insel Naissar, der seit 1926 als freischaffender Optiker an der Hamburger Sternwarte arbeitete (er hatte nie eine Anstellung, sondern lebte von einzelnen Aufträgen; heute würde man Werkverträge dazu sagen), entwickelte eine Optik, die aus einem Kugelspiegel mit davorgesetzter Korrektionsplatte besteht, mit dem man Felder von mehr als 10fachem Monddurchmesser scharf abbilden kann. Wir haben heute ein kleines Museum auf dem Sternwartengelände, in dem man sehen kann, wie Bernhard Schmidt die Form dieser Korrektionsplatten berechnete, und man sieht auch von ihm selbst geschliffene Platten (die Abweichungen von der ebenen Platte sind so klein, dass man sie mit dem bloßen Auge nicht sehen kann) und das erste richtige Schmidt-Teleskop ("Original Schmidt").

Diese geniale Erfindung, die rasch um die Welt ging, hat B. Schmidt übrigens mit nur einer Hand realisiert – die andere hatte er als 14-jähriger Schüler bei Chemieexperimenten im Keller verloren.

Walter Baade, seit 1931 in Pasadena, wurde 1937 bei Berufungsverhandlungen auf die Direktorenstelle der Hamburger Sternwarte ein großes Schmidt-Teleskop mit mindestens 80 cm Öffnung zugesagt. Aber Baade nahm den Ruf am Ende nicht an, weil die Arbeitsbedingungen in Pasadena mit dem 2.5 m Teleskop ungleich besser waren. Auch dort wurde schon 1937 ein großes Schmidt-Teleskop (48″, 1,20 m) geplant und ca. 1948 fertiggestellt, mit dem dann die erste tiefe Ganzhimmelsdurchmusterung (Palomar Sky Atlas) durchgeführt wurde – die war für Jahrzehnte der Standard.

Hamburg hielt die ursprünglich Baade gemachten Berufungszusagen ein und ermöglichte Otto Heckmann (1901–1983), der 1941 als Schorr-Nachfolger berufen wurde – übrigens nach langem Hin und Her, Heckmann galt, zu Recht, als Vertreter der Einsteinschen Relativitätsstheorie, der musste er abschwören – ab 1951 ein großes Schmidt-Teleskop (1.20 m, 80 cm Korrektur) zu errichten, das 1954 eingeweiht wurde. Zu spät, denn die Lichtverschmutzung (Staub und helle Lichter) machte ein effektives Arbeiten mit dem Teleskop bereits unmöglich, so dass es schon 14 Jahre später auf den Calar Alto in Südspanien umgesetzt wurde. Dort, im DSAZ, hat es dann allerdings seine große Leistungsfähigkeit bewiesen; meine Gruppe hat zwischen 1983 und ca. 2000 eine Ganzhimmelsdurchmusterung nach Quasaren, den leuchtkräftigsten Objekten im Universum, machen können – mir war immer klar, dass wir am Ende das realisieren konnten, was unseren Vorgängern versagt geblieben war. Dank der sich gerade rechtzeitig entwickelnden Computer- und Speichertechnologie konnten wir die vom ganzen Himmel aufgenommenen Spektren - einige zig Millionen – digitalisieren und mit Computern auswerten; noch in den 50er bis in die 70er Jahren hatte man die Platten per Auge mit dem Mikroskop durchmustert.

Aber zurück zu Otto Heckmann, der erst nach dem Krieg (im Krieg war das Institut kriegsverpflichtet und musste Optiken zur Verfügung stellen etc.) die Wissenschaft wieder anschieben konnte.

Abbildung 37.4: *Otto Heckmann (1901–1983)*

Abbildung 37.5: *Robotic telescope of Hamburg Observatory (Photo: Gudrun Wolfschmidt)*

Neben seinen eigenen kosmologischen (theoretischen) Arbeiten, übrigens auch in Zusammenarbeit mit Pascual Jordan vom Institut für Theoretische Physik, und dem Schmidt-Teleskop gab es einige wenige "high lights":

Georg Thiessen (1914–1961) gelang es 1951 mit dem großen Refraktor erstmalig, das schwache allgemeine Hintergrund-Magnetfeld der Sonne (außerhalb der Flecken) zu messen, gleichzeitig mit Sonnenphysikern auf Mt. Wilson. Die Arbeiten kamen leider zu einem abrupten Ende, als Thiessen bei einem Autounfall ums Leben kam.

Weitere Projekte mit internationalem Impact waren die Astrometrischen Kataloge AGK 2 und AGK 3, große Kataloge mit in Hamburg gemessener Sternposition, die noch heute Grundlage der Fundamentalkataloge sind. Um 1970 herum wurde der große Meridiankreis mit einer Expedition nach Perth, Westaustralien, zur Vermessung des Südhimmels gebracht. Das lieferte die erste exakte Vermessung des Südhimmels. Wie schon erwähnt, hat das nicht nur für die Astronomie Bedeutung, wenn sie einen Stern wiederfinden wollen, sondern solche Daten sind die Basis für das GPS System, das Sie alle in Ihrem Navigationssystem im Auto verwenden.

Otto Heckmann betrieb seit den 50er Jahren zusammen mit Baade, Oort u. a. die Gründung einer europäischen Südsternwarte (ESO) und war von 1962–1968 deren erster Direktor, mit der Zentrale in Bergedorf. Sie wissen sicher alle, dass die ESO sich mit ihren Teleskopen in Chile zum leistungsfähigsten Observatorium der Welt (4×8 m Spiegel) entwickelt hat. Leider hat Hamburg nicht die nötigen Schritte unternommen, um die ESO-Zentrale in Hamburg zu halten. Sie ist heute in Garching bei München.

1968 wurde die Hamburger Sternwarte Universitätsinstitut (bis dahin war sie Staatsinstitut). Zu der Zeit musste sie ihre Rolle nicht neu definieren, denn sie hatte sich schon zu einem Institut, das Grundlagenforschung betreibt, entwickelt. Mit den Berufungen von Alfred Weigert (1927–1992) 1968 und Sjur Refsdal (1935–2009) 1972 wurden 1.) zwei exzellente Theoretiker berufen und 2.) die Grundlage für zwei florierende Arbeitsgebiete geschaffen: Theorie der Sternentwicklung und Theorie der Gravitationslinsen; Sjur Refsdal (1935–2009) hat dieses Gebiet begründet, auf dem heute weltweit einige 100 Astronomen arbeiten.

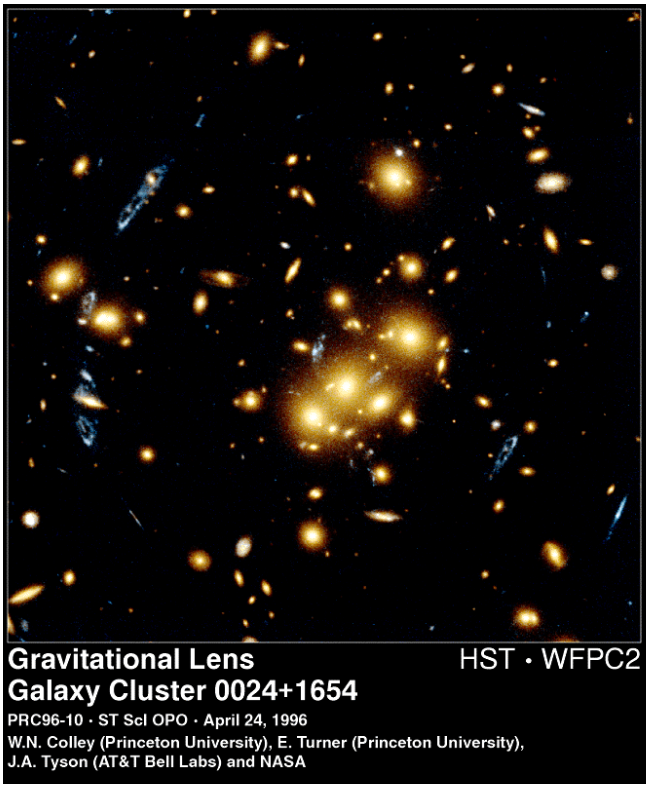

Abbildung 37.6: *Gravitationslinse, Hubble Space Telescope (HST), 1996 (© W.N. Colley and E. Turner (Princeton University), J.A. Tyson (Bell Labs, Lucent Technologies) and NASA)*

37.2 Zukunft der Sternwarte?

Es ist ziemlich riskant, über die Zukunft der zu sprechen. Die Zukunft hat die ihr eigene Eigenschaft, dass sie offen und unbekannt ist. Aber man kann natürlich nicht ein Forschungsinstitut betreiben, ohne sich über die Zukunft Gedanken zu machen, ohne ein Minimum an Planung. Zum Beispiel: Was steht in den nächsten 10 Jahren an? Was sind die Probleme? Wo sind Fortschritte möglich und zu erwarten? Ich will einfach mal eine Reihe von offenen Fragen/Problemen in den Raum werfen:

- Die Natur der dunklen Materie und der dunkelen Energie: 95% des Inhalts de Universums sind unbekannt, nur 5% sind normale Materie
- Die Physik der extremsten Objekte und Ereignisse im Kosmos: Schwarze Löcher, Supernova-Explosionen, Gammastrahlenausbrüche
- Die Bildung und Entwicklung von Milchstraßensystemen: Die Bildung und Entwicklung der ersten Generation von Sternen im Universum
- Die Bildung von Stern- und Planetensystemen (ab 1997 bis heute sind ca. 300 Systeme entdeckt worden) und am Ende der Ursprung des Lebens und "wie passen wir da hinein?"

Dies sind mit die fundamentalsten Fragen in den Naturwissenschaften mit einem breiten öffentlichen Interesse: Denn: Jeder in diesem Raum denkt ab und zu über die Wunder des Himmels nach, fühlt sich als Teil des Universums, teilt mit anderen Menschen den Wunsch, dieses Universum und seine Herkunft zu verstehen.

Und die Hamburger Sternwarte, wie wird sie dazu beitragen?
Als physikalisches Institut, das der Grundlagenforschung gewidmet ist und sich mit den großen Problemen von der Kosmologie über Schwarze Löcher und Supernova-Explosionen bis zu Planetensystemen beschäftigt.

Womit? Die Astronomie ist ja wie die Hochenergiephysik längst Großforschung. Wir beobachten zu 99% an den internationalen Sternwarten (ESO, Calar Alto, LOFAR) und im Weltraum (HST, Röntgenteleskope) und in Zukunft mit FIRST, SOFIA, Planck).

Am Boden sind im Bau ALMA (ein Radiointerferometer bei mm-Wellenlängen, das aus ca. fünfzig 12 m Radioteleskopen besteht, auf einer Hochebene in 5000 m Höhe in Chile, durch die ESO) und das ELT (42 m), das vermutlich wiederum von der ESO ab ca. 2011/2012 gebaut wird (jeweils ca. 1 Mrd.).

Wir leben in einem goldenen Zeitalter der Astronomie!

Wir von der Hamburger Sternwarte können diese vom Bund mitfinanzierten Großgeräte (wie im Weltraum) kostenlos benutzen (bei der ESO/Chile kriegt man sogar das Flugticket) und sind dadurch im weltweiten Wettbewerb konkurrenzfähig und manchmal sogar führend. Die historische Sternwarte in Bergedorf ist ohne uns eine leere Hülse.

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1. Ebenfalls verursacht durch die französische Besatzung begab sich 1808 ein 15jähriger Gymnasiast namens Friedrich Georg Wilhelm Struve auf die Flucht vor der französischen Zwangsrekrutierung. Er war Sohn des damaligen Rektors des Altonaer Gymnasiums (Christianeum) Jakob Struve und floh zu seinem Bruder nach Dorpat (Estland), der dort Professor an der Universität war, begann Astronomie zu studieren, wurde mit 20 Jahren außerordentlicher Professor und

Abbildung 37.7: *European Southern Observatory, La Silla, Chile and Very Large Telescope (VLT) (©ESO)*

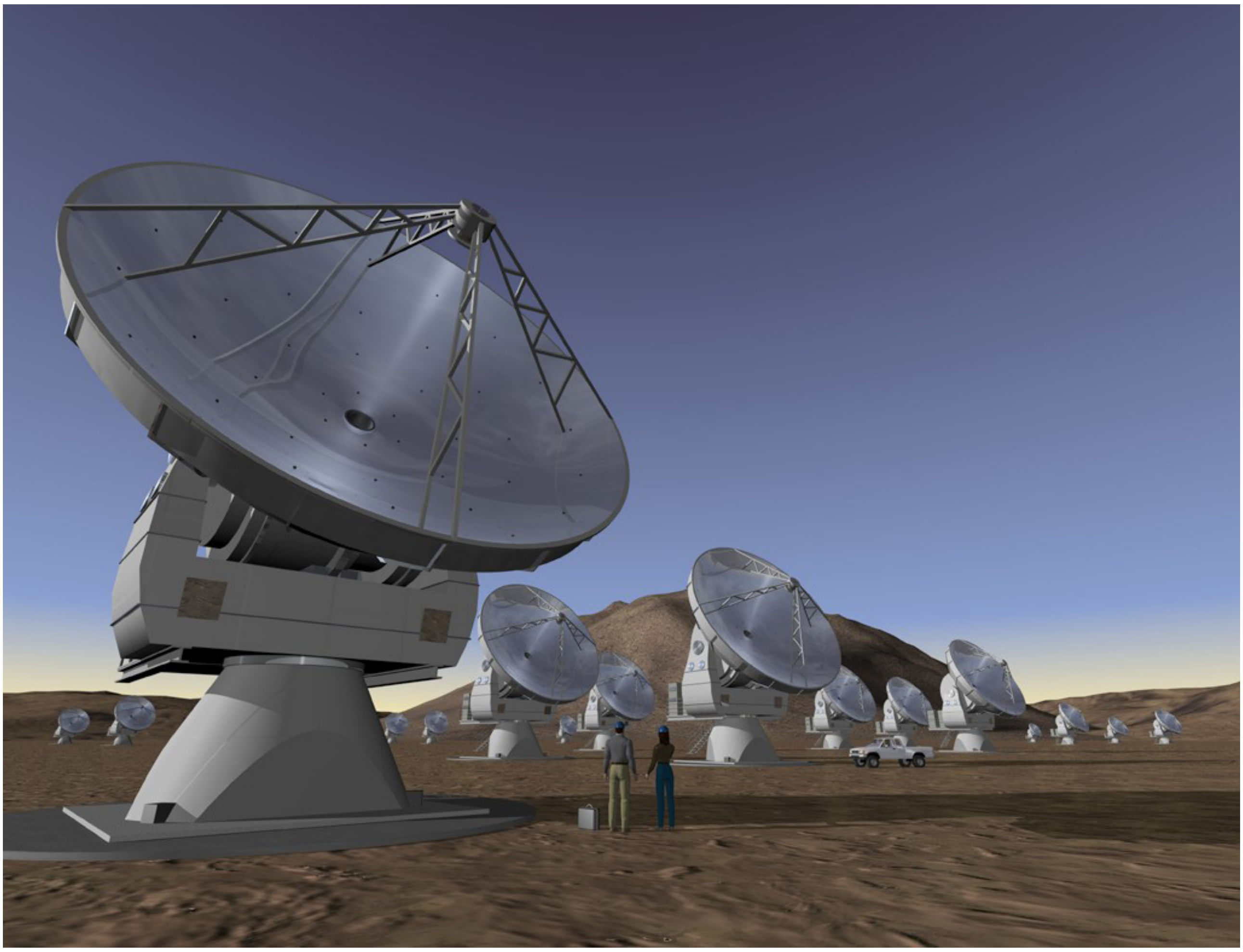

Abbildung 37.8: *Atacama Large Millimeter Array (ALMA) Chile 2011 (©MPIfR Bonn)*

schließlich einer der bedeutendsten Astronomen des 19. Jahrhunderts. Wilhelm Struve hat 1838, gleichzeitig mit Bessel in Königsberg und Henderson in Südafrika, erstmalig die Entfernung eines Sterns gemessen. Er hat 1839 das russische Hauptobservatorium Pulkovo bei St. Petersburg gegründet und wurde Gründervater einer bedeutenden Dynastie von Astronomen über vier Generationen, deren letzter Vertreter sein Urenkel Otto Struve war (später ein bedeutender US amerikanischer Astronom), der in einem Buch beschreibt, wie er 1912 als 15jähriger Schüler zusammen mit seinem Vater Ludwig (der Astronomieprofessor in Charkow war) an der Einweihungsfeier der Hamburger Sternwarte in Bergedorf teilgenommen hat.

Figure 38.1: *Observing chair of the Equatorial Telescope (Hamburg Observatory)*

38. The Hamburg Observatory – A Cultural Monument of National and International Importance

Agnes Seemann (Hamburg, Germany)

At the beginning of the 20th century, when the disturbances caused by diffused light, smoke, vibrations and noise from the harbour, the industry and the city had become too severe, reliable measurements could no longer be taken at the site of the old Hamburg observatory at the Millerntor. Therefore, in 1901 after considerable resistance the senate and parliament of the Free and Hanseatic City of Hamburg voted in favour of a transferral of the observatory to Bergedorf.[1] Richard Schorr, then director of the observatory, was successful in convincing the Hamburg authorities to give generous funds for a new technical instrumentation. Consequently, at the beginning of the 20th century one of the most up-to-date and largest contemporary observatories in Europe was erected in Bergedorf.

To this day the Hamburg observatory has been completely preserved, both as far as the grounds with their historic buildings and furnishings and the optical apparatuses and their technical details are concerned. Therefore, in 1996 the observatory was inscribed in the monument list of the Free and Hanseatic City of Hamburg as an ensemble on the basis of its relevance for the town's history as well as its cultural and scientific history.

However, this observatory, which at the beginning of the 20th century was among the most modern and largest observatories in Europe, was not only important for Hamburg. Besides the observatory in Heidelberg-Königstuhl it is the only historic observatory in Germany to have been erected as a modern group of buildings, as was realised for the first time between 1879 and 1886 on Mont Gros near Nice. While the Hamburg observatory is still largely complete, the complex in Heidelberg-Königstuhl, erected from 1896–1900 and then already much smaller than the observatory in Hamburg, is nowadays severely altered.

Apart from the architectural complex the outstanding importance of the Hamburg observatory lies most of all in the instrumental equipment. At the end of the 19th century a great change took place in astronomy with the transition from classical astronomy to modern astrophysics. The Hamburg observatory was equipped with excellent instruments for both exploratory focuses, both with a large refractor and with reflecting telescopes.

To this day the large refractor with a lens diameter of 60 cm and a focal distance of nine metres is one of the largest refractors in Germany. It is the last instrument to have been built by the renowned company Repsold and the second largest still existing. The hoisting platform developed and realised by Carl Zeiss considerably facilitated the operation of this large refractor; in addition it was the first of its kind to be realised on the European continent.

When it was put into service in 1911 the Hamburg one-metre reflecting telescope was the world's fourth-largest reflecting telescope (after Mt. Wilson: 1.52 m, Paris: 1.20 m, Lowell-Obs. Flagstaff: 1.07 m). As far as the aperture is concerned, until 1920 and again from 1946 to 1960 it was the largest telescope in Germany. With its ZEISS load relief construction, which apart from Hamburg was realised only for two other large reflecting telescopes, the reflecting telescope of the Hamburg observatory – incidentally also the first large Zeiss telescope – is considered one of the most unusual telescope constructions. Furthermore, with the aid of this instrument one of the most important astronomers of the 20th century, Walter Baade, managed to make a number of spectacular discoveries.

By means of the Bergedorf meridian circle constructed by the Repsold company with a lens of 19 cm diameter and 2.30 m focal distance the world-famous *Bergedorfer Sternenkataloge* were compiled until the 1960s. To this day, they form the basis for the still used coordinate system in the sky. Moreover, for decades the instrument was used to set the time.

Besides these large old instruments the still functioning equatorial from 1867 with its equally old wooden observation seat can certainly be considered to be among the most important historic documents for the history of astronomy in Germany. Originally, the telescope had especially large divided circles for direct determinations of positions outside the meridian. It was the largest equatorial ever to have been constructed for this purpose.

Among the modern instruments the Oskar Lühning telescope with Ritchey-Chretien system and an aperture of 1.20 m and a focal distance in the Cassegrain focus of 15.60 m was the largest telescope of the Hamburg observatory and at present it is the second largest telescope in Germany. Recently, this instrument was upgraded so that it can now be operated and used via internet. Thus the astronomical institute at Hamburg University has continued the history of developing important astronomical instruments, which saw its first highlight with the invention of the so-called "Schmidt-Spiegel" in 1930 by the Hamburg astronomer Bernhard Schmidt.

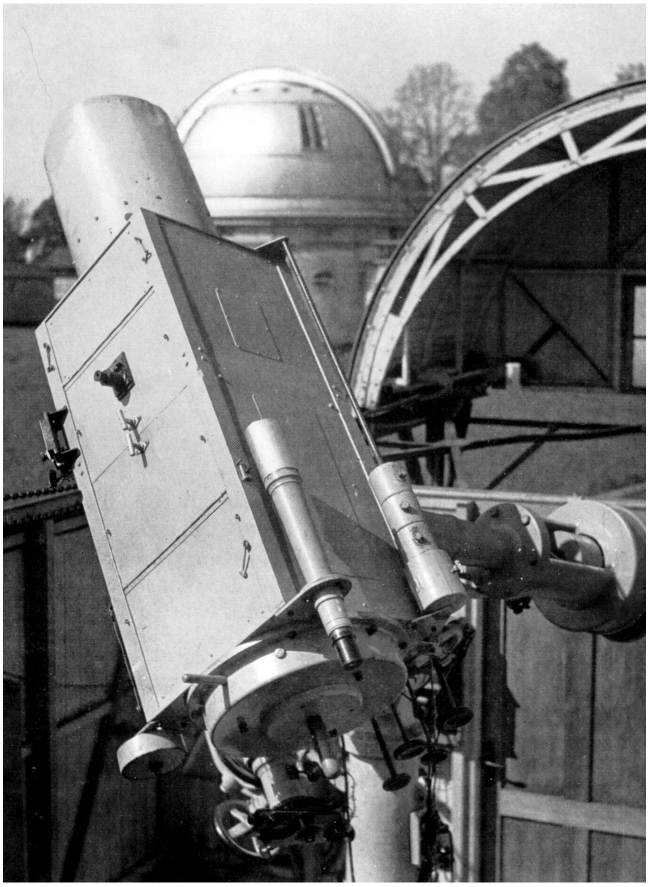

Figure 38.2: *The first Schmidt Telescope (Hamburg Observatory)*

In summary, one can say like hardly any other in the world the Hamburg observatory documents the technical development of telescope technology from 1850 to the present that went along with the development of astronomical science: The equatorial and the meridian circle stand for the astronomy of the 19$^{\text{th}}$ century with its focus on the determination of the position and visual observation. The large refracting telescope and the one-metre reflecting telescope represent the competition between the two types of construction at the beginning of the 20$^{\text{th}}$ century and the transition to photographic observation technology. Modern telescope technology is represented by the Oskar Lühning telescope and its modern upgrade, including modern computer and CCD technology. Different construction types of reflecting telescopes (Cassegrain, Nasmyth, Ritchey-Chretien, Schmidt) exist. The Hamburg observatory is not only the "birthplace" of the "Schmidt-Spiegel"; here one can also find the world's first instrument of this type. Finally, there is also a collection of other, sometimes historically relevant smaller instruments (solar eclipse expedition equipment, AG astrograph, Zeiss prism spectrograph, various smaller apparatuses).

Even if there is no doubt that there are other important historic observatories worldwide, the Hamburg observatory is special for the transition from the 19$^{\text{th}}$ to the 20$^{\text{th}}$ century in its combination of various levels of meaning, i. e. of modern layout, prestigious architecture, instrumental equipment, relevance for research and state of conservation. Based on our current state of knowledge, this combination is quite unique. As a monument to the history of science and architecture, Hamburg's observatory is therefore of national and international importance.

38.1 German version: Die Hamburger Sternwarte – Ein Kulturdenkmal von nationaler und internationaler Bedeutung

Anfang des 20. Jahrhunderts, als am Standort der alten Hamburger Sternwarte am Millerntor keine sinnvollen Messungen mehr durchgeführt werden konnten, weil die Behinderungen durch Streulicht, Rauch, Erschütterungen und Lärm von Hafen, Industrie und Stadt zu groß geworden waren, stimmten Senat und Bürgerschaft der Freien und Hansestadt Hamburg nach langem Sträuben im Jahre 1901 einer Verlegung nach Bergedorf zu. Richard Schorr, der damalige Direktor der Sternwarte, verstand es in der Folgezeit, die Hamburger Behörden zu einer wirklich großzügigen Neuausstattung zu bewegen. Dies führte dazu, dass Anfang des 20. Jahrhunderts in Bergedorf eine der modernsten und größten zeitgenössischen Sternwarten Europas entstand.

Bis heute ist die Hamburger Sternwartenanlage nahezu komplett erhalten. Das gilt für das Sternwartengelände mitsamt der historischen Gebäude und ihrer Ausstattung ebenso wie für die optischen Geräte und die technischen Details. 1996 wurde die Sternwarte daher als denkmalschutzwürdige Gesamtanlage aus stadt-, kultur- und wissenschaftshistorischen Gründen in die Denkmalliste der Freien und Hansestadt Hamburg aufgenommen.

Aber nicht nur für Hamburg ist diese Sternwarte, die Anfang des 20. Jahrhunderts zu den modernsten und größten zeitgenössischen Sternwarten Europas zählte, von Bedeutung. Neben der Sternwarte in Heidelberg-Königstuhl ist sie die einzige historische Sternwarte in Deutschland, die als moderne Gruppenanlage errichtet wurde, wie sie erstmals 1879–86 auf dem Mont Gros bei Nizza verwirklicht worden war. Während die Hamburger Sternwarte aber nahezu komplett erhalten ist, stellt sich die 1896–1900 errichtete Anlage in Heidelberg-Königstuhl, die schon zur Bauzeit sehr viel kleiner und bescheidener als die Hamburger Sternwarte war, heute stark verändert dar.

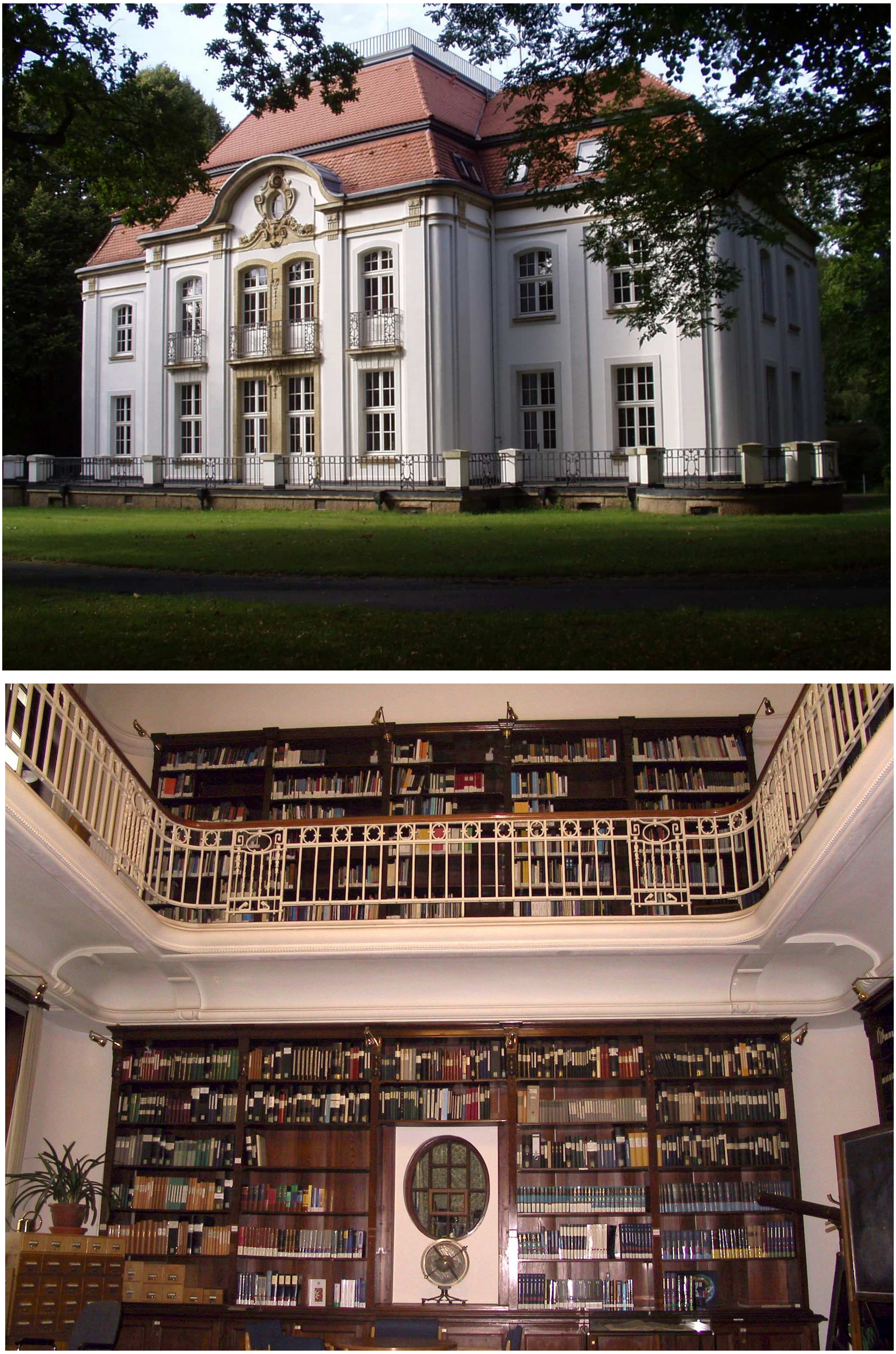

Figure 38.3: *Main building and library (Hamburg Observatory)*

Neben der Anlageform ist aber vor allem auch die instrumentelle Ausstattung der Hamburger Sternwarte von außerordentlicher Bedeutung. Gegen Ende des 19. Jahrhunderts vollzog sich in der Astronomie mit dem Übergang von der klassischen Astronomie zur modernen Astrophysik ein großer Umbruch. Die Hamburger Sternwarte wurde mit herausragenden Instrumenten für beide Forschungsschwerpunkte ausgestattet, sowohl mit einem Großen Refraktor als auch mit Spiegel-Teleskopen.

Abbildung 38.4: *Main Building, Coat of arms of the Free and Hanseatic City of Hamburg (Photo: Gudrun Wolfschmidt)*

Der Große Refraktor mit einem Objektivdurchmesser von 60 cm und einer Brennweite von 9 m zählt bis heute zu den größten Refraktoren Deutschlands. Es ist das letztgebaute Instrument der bedeutenden Firma Repsold und das zweitgrößte, das noch vorhanden ist. Die von Carl Zeiss entworfene und verwirklichte Hebebühne, die den Betrieb dieses großen Refraktors wesentlich erleichterte, ist zudem die erste ihrer Art, die auf dem europäischen Kontinent verwirklicht wurde.

Der Hamburger 1 Meter-Spiegel war bei seiner Indienststellung 1911 das viertgrößte Spiegelteleskop der Welt (nach Mt. Wilson: 1.52 m, Paris: 1.20 m, Lowell-Observatory Flagstaff: 1.07 m). Der Öffnung nach war es bis 1920 und wiederum von 1946 bis 1960 das größte Teleskop in Deutschland. Mit seiner Zeiss-Entlastungsmontierung, die außer in Hamburg nur noch an zwei weiteren großen Spiegelteleskopen verwirklicht wurde, zählt das Spiegel-Teleskop der Hamburger Sternwarte, das zugleich das erste große Zeiss-Teleskop darstellt, zudem zu den ungewöhnlichsten Konstruktionen des Fernrohrbaus. Schließlich gelangen mit Hilfe dieses Instruments durch einen der bedeutendsten Astronomen des 20. Jahrhunderts, durch Walter Baade, zahlreiche Aufsehen erregende Entdeckungen.

Mit dem von der Firma Repsold gefertigten Bergedorfer Meridiankreis mit einem Objektiv von 19 cm Durchmesser und 2,30 m Brennweite wurden bis in die 1960er Jahre die weltberühmten "Bergedorfer Sternenkataloge" erstellt, die die Grundlage der noch heute verwendeten Koordinatensysteme am Himmel bilden. Darüber hinaus diente das Instrument jahrzehntelang der Zeitbestimmung.

Neben diesen großen alten Instrumenten gehört das funktionsfähige Äquatorial aus dem Jahre 1867 zusammen mit seinem ebenso alten hölzernen Beobachtungsstuhl sicherlich zu den bedeutendsten historischen Dokumenten der astronomischen Wissenschaftsgeschichte in Deutschland. Ursprünglich besaß das Teleskop besonders große Teilkreise für direkte Positionsbestimmungen außerhalb des Meridians. Es war das größte jemals zu diesem Zweck hergestellte Äquatorial.

Von den modernen Instrumenten ist das Oskar-Lühning-Teleskop mit dem Ritchey-Chretien-System mit einer Öffnung von 1.20 m und einer Brennweite im Cassegrain-Fokus von 15.60 m das größte Teleskop der Hamburger Sternwarte und gegenwärtig das zweitgrößte Teleskop in Deutschland. Dieses Instrument wurde zudem in jüngster Zeit so aufgerüstet, dass die Bedienung und Beobachtung per Internet möglich ist. Damit hat das astronomische Institut der Hamburger Universität die Geschichte der bedeutenden astronomischen Instrumentenentwicklung, die 1930 mit der Erfindung des "Schmidt-Spiegels" durch den Hamburger Astronomen Bernhard Schmidt seinen ersten Höhepunkt erreicht hatte, fortgeführt.

Zusammenfassend ist festzuhalten, dass die Hamburger Sternwarte wie kaum eine andere Sternwarte auf der Welt die technische, mit der astronomischen Wissenschaft einhergehende Entwicklung der Teleskoptechnik von etwa 1850 bis zur Gegenwart dokumentiert: Das Äquatorial und der Meridiankreis repräsentieren die Astronomie des 19. Jahrhunderts mit Schwerpunkt auf Positionsbestimmung und visuelle Beobachtung. Der Große Refraktor und der 1-Meter-Spiegel stehen stellvertretend für den Wettstreit zwischen beiden Bauformen am Beginn des 20. Jahrhunderts und für den Übergang zur fotografischen Beobachtungstechnik. Die moderne Teleskoptechnik ist mit dem Oskar-Lühning-Teleskop und seiner modernen Aufrüstung, einschließlich moderner Computer- und CCD-Technik vertreten. Verschiedene Bauformen des Spiegeltelekops (Cassegrain, Nasmyth, Ritchey-Chretien, Schmidt) sind vorhanden. Zudem ist die Hamburger Sternwarte nicht nur die "Geburtsstätte" des Schmidt-Spiegels, hier ist sogar das weltweit erste Instrument dieses Typs noch vorhanden. Schließlich gibt es noch eine Sammlung weiterer, z. T. historisch bedeutsamer kleinerer Instrumente (Sonnenfinsternisexpeditions-Ausrüstung, AG-

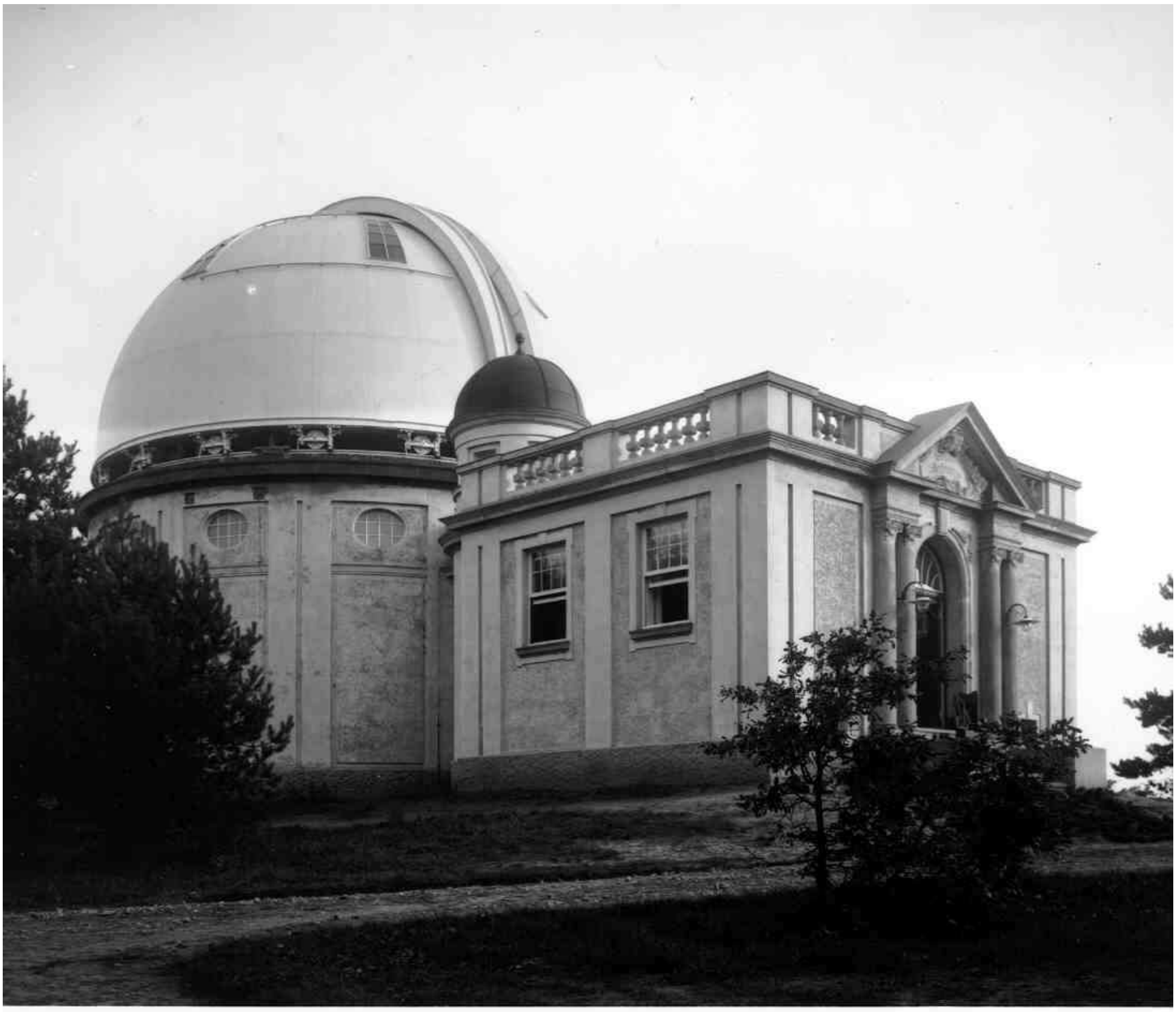

Abbildung 38.5: *Large refractor building of Hamburg Observatory (Hamburg Observatory)*

Astrograph, Zeiss-Prismenspektrograph, diverse kleinere Geräte)

Auch wenn es auf der Welt ohne Zweifel andere bedeutende historische Sternwarten gibt, stellt die Hamburger Sternwarte für die Zeit der Wende vom 19. zum 20. Jahrhundert in der Kombination der unterschiedlichen Bedeutungsebenen von moderner Anlageform, repräsentativer Architektur, instrumenteller Ausstattung, Bedeutung für die Forschung und ihres Erhaltungsgrades eine Besonderheit dar, die, nach heutigem Kenntnisstand, in dieser Kombination einzigartig ist. Die Hamburger Sternwarte stellt daher ein wissenschafts- und architekturgeschichtliches Kulturdenkmal von nationaler und internationaler Bedeutung dar.

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1. Weigert, Alfred: Hamburger Sternwarte 1833–1983. In: 150 Jahre Hamburger Sternwarte. uni hh Forschung, Nr. XVI (1983), p. 8.

Figure 39.1: *Restoration of the 1m-reflector building (Photo: Gudrun Wolfschmidt)*

39. Restoration Activities of the Observatory Buildings – Past and Future

Gudrun Wolfschmidt and Henry Schlepegrell (Hamburg, Germany)

39.1 Restoration Work on the Initiative of the *Förderverein Hamburger Sternwarte e. V.*

Fortunately, the ensemble of the observatory, including the historic buildings and their furnishings as well as the optical apparatuses and the technical details, have been preserved practically complete and in their original state. The relevance as concerns the architecture and the history of science and technology is correspondingly great. Therefore, on 12 June 1996 the entire observatory ensemble, including the historic buildings and their furnishings as well as the optical apparatuses and the technical details, was inscribed on the Hamburg monument list as item no. 1089.

The preservation of this cultural monument of international rank is threatened nonetheless: The environmental conditions, the change of research projects and enhanced observation possibilities abroad or with satellites are responsible for the fact that the observatory is not used as much as in former times by scientists of the university. Due to the lack of use in several buildings no measures for the upkeep have been carried out for years. Consequently, the fabric of these buildings is severely damaged. The *Förderverein Hamburger Sternwarte e. V.* (founded in January 1998) and its chairperson Prof. Gudrun Wolfschmidt have been advocating the restoration of the buildings for years. In cooperation with the press and through many activities the *Förderverein Hamburger Sternwarte* has drawn the public's attention to the imminent decay and to possibilities of saving the Hamburg Observatory.

When the *Deutsche Stiftung Denkmalschutz* decided in 1998 to raise funds for the upkeep, stabilisation and restoration of the meridian circle building on the occasion of a charity gala, the activities of the *Förderverein* were an important criterion for this decision. By now relevant stabilisation works on the foundations and the porch of the meridian circle building have been carried out with funds from the *Deutsche Stiftung Denkmalschutz*.

Furthermore, the *Förderverein* used its own funds and the support from conservation institutions to restore the Salvador building in 2003 and the Equatorial building in 2004 and 2005.

In order to be able to cover the expenses of ca. 42,000 euros the *Förderverein*, apart from using its own resources of 19,000 euros, received several private donations, donations from the Bergedorf-Stiftung and a grant from the Stiftung Denkmalpflege Hamburg. Moreover, for 2006 the Förderverein managed to raise European funds (ESF-Fond) for small restoration measures (doors and windows).

For its many years of commitment, especially concerning the restoration works but also with regard to various kinds of public events, the *Förderverein Hamburger Sternwarte e. V.* was awarded the *Deutscher Preis für Denkmalschutz* (National award for monument protection) in November 2006 in Weimar. As due to the lack of use of several buildings no measures for the upkeep have been carried out for years, severe damages to the fabric have developed. However, the university restorated the most important offices for the astronomers, the main building, including the library and administration rooms, and the so-called civil servant's house.

In spring 2008, as the result of an application of the *Förderverein* made on the basis of an evaluation of the Hamburg monument conservation department, the Hamburg Observatory was declared a cultural monument of national importance.

39.2 Restoration of the One-Metre Reflector Telescope Building

Among the impressive large telescopes of the Hamburg Observatory in Bergedorf the one-metre reflector telescope is probably historically the most important. It is largely in its original state and stands for a historic turning point in astronomical research. As the first large reflector telescope by the company Carl Zeiss it is also an important monument of the history of technology. Owing to the already executed restoration measures the means of the Förderverein are now almost entirely exhausted so that for other urgently necessary restoration works it can no longer fall back upon its own funds. Sadly, especially the impressive, historically valuable

Figure 39.2: *Building of the Meridian Circle (2000) (Photo: Gudrun Wolfschmidt)*

one-metre reflector telescope is in a bad state: this applies also to the related domed structure and the annex with flat roof added in 1925. The idea is therefore to restore the building in two stages first and then to restore the valuable instrument in a third stage. The Förderverein already has a cost estimate from ArchitekturContor which intends to repair the damages to the building in two construction stages.

For the first construction stage costs of 160,000 euros have been estimated. After first funds were promised, construction work on the building could begin on 1 July 2008. The second construction stage, for which costs of 180,000 euros have been estimated, is to begin in 2009. During the restoration the 1960s slab cladding on the annex is to be removed.

For the total costs of c. 340,000 euros funds could be raised from the Federal Ministry of Culture's programme for cultural monuments of national importance, from the Stiftung Denkmalpflege Hamburg, the Reemtsma Foundation and the *Deutsche Stiftung Denkmalschutz*. Fortunately, Hamburg University will also share the costs.

The next step will be the restoration of the one-metre reflector telescope. For this, a detailed study on the instrument's relevance for the history of science and technology, prepared by Beatrix Alscher (2006) as a diploma thesis[1] and supervised by Prof. Dr. Gudrun Wolfschmidt and Prof. Dr. Ruth Keller-Kampus (Berlin FHTW, Restaurierung / Konservierung von Technischem Kulturgut) will be useful. Funds for carrying out this restoration can probably not be raised before 2010.

39.3 Restoration of the Meridian Circle Building

The next big restoration project in the astronomy park is meant to be the meridian circle. Providing museum conditions in order to return the meridian circle from the Deutsches Museum in Munich implies much more than just the restoration of the building. Additional costs for the return transport of the meridian circle[2] and its restoration must also be taken into account. Here we have a very positive development: half a million euros from the Hamburg economic stimulus package are provided by the university for the restoration of the observatory, earmarked especially for the meridian building. Thus, the building can be prepared for the return of the instrument.

Figure 39.3: *Restoration of the equatorial telescope building (2004–2005) (Photos: Gudrun Wolfschmidt, Photo (middle): Henry Schlepegrell)*

Figure 39.4: *Restoration of the 1m reflector building (2008–2009) (Photo: Gudrun Wolfschmidt)*

39.4 Perspective

Furthermore, the district of Bergedorf is allocating an investment sum of 500,000 euros for the construction of a multi-functional building (including a lecture hall).

More needs to be done in the future: the Lippert telescope building and the large refractor also show damages, even if their condition is not quite as alarming as that of the buildings described above.

An important date projected for the completion of the crucial restoration measures is the 100th anniversary of the Hamburg Observatory in Bergedorf in 2012. With these comprehensive restoration measures of the most relevant buildings the observatory should be well prepared for an application as UNESCO World Heritage site.

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1. Alscher, Beatrix: *Das 1m-Spiegelteleskop der Hamburger Sternwarte – Konzept der Erhaltung.* diploma thesis 2006, supervisors: Ruth Keller-Kempas and Gudrun Wolfschmidt.
2. The meridian circle was in Australia and no longer used scientifically. No institution in Hamburg was willing to cover the costs for a return transport. Fortunately, the Deutsches Museum was planning a new permanent exhibition on astronomy with the assistance of Gudrun Wolfschmidt. Thus, as part of a rescue operation the meridian circle could be transported to the museum in Munich, where it is stored today.

Figure 39.5: *Details of the restoration of the 1 m reflector building – telescope, dome and slit (2008–2009) (Photo: Henry Schlepegrell and Gudrun Wolfschmidt)*

Figure 40.1: *12 observatories aiming for a serial trans-national application for inscription in the UNESCO World Heritage List*

40. Summary and Results Cultural Heritage of Astronomical Observatories From Classical Astronomy to Modern Astrophysics

Gudrun Wolfschmidt and Frank Pieter Hesse (Hamburg, Germany)

On the occasion of the 175th anniversary of the Hamburg Observatory as a State institute the international ICOMOS symposium "Cultural Heritage: Astronomical Observatories (around 1900) – From Classical Astronomy to Modern Astrophysics" was held from 15 to 17 October 2008 in Hamburg-Bergedorf in the Haus im Park of the Körber Foundation and inside the Observatory itself. The symposium was organised by the Institute for the History of Science at the University of Hamburg, by the Conservation Department Hamburg as well as by ICOMOS Germany, with support from the University of Hamburg, the Senatskanzlei Hamburg, the Bezirksamt Bergedorf, the Buhck Foundation, the Körber Foundation, and the Bergedorfer Zeitung. It was prepared and chaired by Prof. Dr. Gudrun Wolfschmidt (University of Hamburg / Institute for History of Science).

The objective of the symposium was to discuss the relevance of modern observatories for the cultural heritage of humankind and to win partner observatories, which due to the time of their erection or to their architectural or scientific importance are comparable to the Hamburg Observatory, as international cooperation partners for a serial trans-national application. Such a trans-national serial application corresponds to the "global strategy for a credible, representative and balanced World Heritage List" as has been pursued since 1994 by the World Heritage Centre (WHC) and the World Heritage Committee of UNESCO in order to fill existing regional, geographical and thematic gaps, as defined in 2004 by ICOMOS International with its action plan "Filling the Gaps".

For Hamburg the symposium was the start of the "International Year of Astronomy 2009", which was decided by the General Assembly of the United Nations in 2007. The conference was carried out in accordance with the initiative of the World Heritage Centre (WHC) of UNESCO, which since the 32nd session of the World Heritage Committee in 2004 has been attending to the topic "Astronomy and World Heritage". The person responsible for this initiative in the WHC was invited to the conference; as she could not attend her contribution was read out.

The following representatives either attended the scientific conference (introducing observatories or other topics) or provided an abstract for the booklet:

Argentina: Sofia A. Cora, Dr. Juan Carlos Forte (La Plata Astronomic Observatory)

Austria: Dr. Anneliese Schnell (University Observatory of Vienna)

Brasil: Prof. Dr. Marcus Granato (Polytechnic Observatory Rio de Janeiro/Museu de Astronomia e Ciências afins)

Czech Republic: Prof. Dr. Martin Šolc (Observatories of Prague and Ondrejov)

England: Dr. Gloria Clifton, London (Royal Observatory Greenwich, London)

Estonia: Reet Mägi (Tartu, Old Observatory)

France: Dr. Suzanne Débarbat (Observatory of Paris and Meudon), Dr. Françoise Le Guet Tully, Nice, and Dr. Hamid Sadsaoud, Algiers (Observatory of Nice, Observatory of Algiers), Dr. James Caplan (Observatory of Marseille), Dr. Jean Davoigneau, Paris (University Observatory of Strassburg), Dr. Christophe Benoist (University Observatory of Kandili in Istanbul/Turkey)

Germany: Prof. Dr. Gudrun Wolfschmidt (development of astrophysics in international comparison), Dr. Matthias Hünsch and Henry Schlepegrell (Hamburg Observatory), Dipl.-Phys. Björn Kunzmann and Dr. Peter Kroll (Observatories in Sonneberg, Bamberg and Hamburg), Prof. Dr. Ruth Keller-Kempas and Beatrix Alscher, FHTW Berlin (restoration), Dr. Peter Müller, Cologne (observatory architecture compared internationally), Frank P. Hesse, Dr. Agnes Seemann, Conservation Department Hamburg, Ilka von Bodungen, Authority for culture, sports and the media, Hamburg, Prof. Dr. Rudolf Kippenhahn, Göttingen, and Prof. Dr. Dieter Reimers (Hamburg Observatory)

Hungary: Prof. Dr. Lajos G. Balász and Magda Vargha (Konkoly Observatory, Budapest)

India: Dr. Shylaja B.S., Bangalore (Kodaikanal Solar Observatory of the Indian Institute of Astrophysics, Kodaikanal and other Indian Observatories around 1900)

Italy: Dr. Ileana Chinnici, INAF Palermo (various observatories and collections of instruments in Italy) Dr. Paolo Brenni, Florence (scientific instruments on observatories)

Portugal: Pedro Raposo, Oxford (Observatório Astronómico de Lisboa)

Romania: Prof. Dr. Magda Stavinschi, CÆtÆlin Mosoia (Bucharest Observatory)

Russia: Prof. Dr. Viktor Abalakin (Nikolas Central Astronomical Observatoy Pulkovo, St. Petersburg)

Turkey: Gaye Danisan and Füsun Limboz (Observatories of Istanbul)

Venezuela: Pedro Chalbaud Cardona (Observatory of Cagigal – a copy of Hamburg)

USA: Dr. Brian D. Mason (US Naval Observatory/USNO, Washington)

Furthermore, lectures were given by Prof. Dr. Rajesh Kochhar, Chandighar/India, Org Secy IAU Commission 41 "History of Astronomy" and Prof. Dr. Michael Petzet, Munich, ICOMOS. In addition other guests from Germany participated as well. Dr. Inga Elmqvist Söderlund, Sweden, and Dr. Vidar Enebakk, Oslo, Norway took part as chairpersons.

The conference was extremely fruitful, especially with regard to the information and findings on the history of the observatories presented and in combination with their individual equipment and the persons decisive for the development of astronomical science and instruments. Although many papers dealt with the building history and architectural features of the observatories, a detailed description of the buildings and an analysis of their architectural relevance and urbanistic disposition, as well as an evaluation of the inherent artistic and aesthetic values of the various observatories remain a desideratum. At similar or thematically more focussed meetings these aspects should be followed up. However, it needs to be emphasised that several papers addressed the conservation of the buildings and instruments either with the observatory still in regular use or with it being used as a museum or for continuing education. A comparative survey on the architecture of the observatories around 1900 was given by Dr. Peter Müller as a possible basis for a "comparative study", as needs to be provided for a World Heritage application.

It also became clear that the urbanistic complex, the buildings and their architecture, the quality of instruments, the scientific archives (collections of photographic plates, chronicles, observation books, correspondence, star catalogues, etc) as well as the scientific/intellectual achievements, inventions and discoveries made by the persons related to the individual observatory are all to be understood as categories of the cultural heritage (also in terms of scientific heritage). This corresponds to the four main categories according to which the "outstanding universal value" of the observatories will have to be evaluated: historic, scientific, and aesthetic. Explicit reference is made to the "Operational Guidelines" of the WHC , where under section 77 the criteria for the "outstanding universal value" are named and according to which criteria ii, iv and vi are relevant:

The Committee considers a property as having outstanding universal value (see paragraphs 49–53) if the property meets one or more of the following criteria. Nominated properties shall therefore:

ii. exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;

iv. be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;

vi. be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria).

After consultation between the representatives of ICOMOS, the Conservation Dept. of Hamburg and the University of Hamburg / Institute for the History of Science it was proposed to invite 11 additional observatories for a serial trans-national application for inscription in the World Heritage List. This first proposal is based on the criteria of a comparability of the presented observatories in terms of the urbanistic complex and the architecture, the scientific orientation, equipment of instruments, authenticity and integrity of the preserved state, as well as in terms of historic scientific relations and the historic relevance of the persons who worked at the observatories. A significant fact was also that among these observatories there were some which are parts of an already existing World Heritage site, but which would nonetheless be of advantage in the separate nomination process for a series of observatories as World Heritage. The following observatories were recommended:

Algeria: Observatoire d'Alger

Argentina: La Plata Astronomic Observatory (proposed to lead this application)

Brasil: Polytechnic Observatory Rio de Janeiro/Museu de Astronomia e Ciências afins)

England: Royal Observatory Greenwich (component of WH 795 "Maritime Greenwich")

Estonia: Tartu, Old Observatory (component of WH 1187 "Struve Geodetic Arc")

France: Observatoire Paris-Meudon, Observatoire de la Côte d'Azur, Nice

India: Kodaikanal Observatory of the Indian Institute of Astrophysics

Portugal: Observatório Astronómico de Lisboa

Russia: Nikolas Central Astronomical Observatory Pulkovo, St. Petersburg (component of WH 540 "Historic Centre of Saint Petersburg and Related Groups of Monuments"

USA: US Naval Observatory (USNO), Washington D.C.

It became clear that endeavours to nominate these above-listed "observatories around 1900" need to be combined with the UNESCO initiative "Astronomy and World Heritage". This initiative is meant to be managed by an international steering committee made up of the National Focal Points and other protagonists. Therefore, the UNESCO World Heritage Centre has asked for an up-to-date list of national focal points referring to this initiative. The World Heritage Centre has already taken note of this conference.

Hence, it was suggested that Prof. Dr. Gudrun Wolfschmidt (University of Hamburg, Institute for History of Science) chairs a national focal point in Hamburg (as far as Hamburg is concerned together with the Conservation Department Hamburg). In correspondence with the UNESCO initiative the focal point will not be able to focus exclusively on "observatories around 1900". Instead it will have to look at the entire spectrum of historic institutions of astronomical research in Germany. The compilation of a well-founded survey of such sites on the national level is the indispensable precondition for a promising justification of the application. For this compilation Hamburg offers excellent conditions. Therefore, it would be necessary that the University of Hamburg, the authority for science and research or the authority for culture, sports and the media respectively provide the accordant resources. This would increase the chances for a successful application of the Hamburg Observatory together with other observatories.

The participants of the conference belonging to the recommended observatories were asked to confer with their local authorities, especially with the institutional sponsors and the responsible conservation authorities as well as with their national committees of ICOMOS, and to get acquainted with the "Operational Guidelines" of the WHC. They were invited to report on the steps taken by their institutions and authorities.

It is planned to intensify the network of observatories, institutions and authorities set up at the conference and to consult the national committees of ICOMOS. Prof. Petzet also pointed out that the topic of the next "International Day for Monuments and Sites" on 18 April 2009, "Science Heritage", could and should be used for more activities at the observatories.

At present, for Hamburg the first priority will be to install a national focal point for the initiative "Astronomy and World Heritage" at the University of Hamburg / Institute of the History of Natural Sciences. For this purpose, the necessary resources need to be made available and ICOMOS Germany and the Germany UNESCO Commission need to be consulted. The Hamburg Conservation Department will give an account of these activities at the next meeting of the heads of the Federal Conservation Departments at the beginning of December and suggest a cooperation via the European Heritage Heads Forum (EHHF).

We wish to thank all organisers, lecturers, participants, supporters and helpers in the background for making this such a fruitful and unobstructed conference.

Hamburg, October 18, 2008

Frank Pieter Hesse
Hamburg Conservation Department

Gudrun Wolfschmidt
Institute for History of Science, University of Hamburg

http://www.math.uni-hamburg.de/spag/\\ign/events/icomos08.htm

Figure 40.2: *End of the ICOMOS Symposium (Photo: Yang-Hyun Choi)*

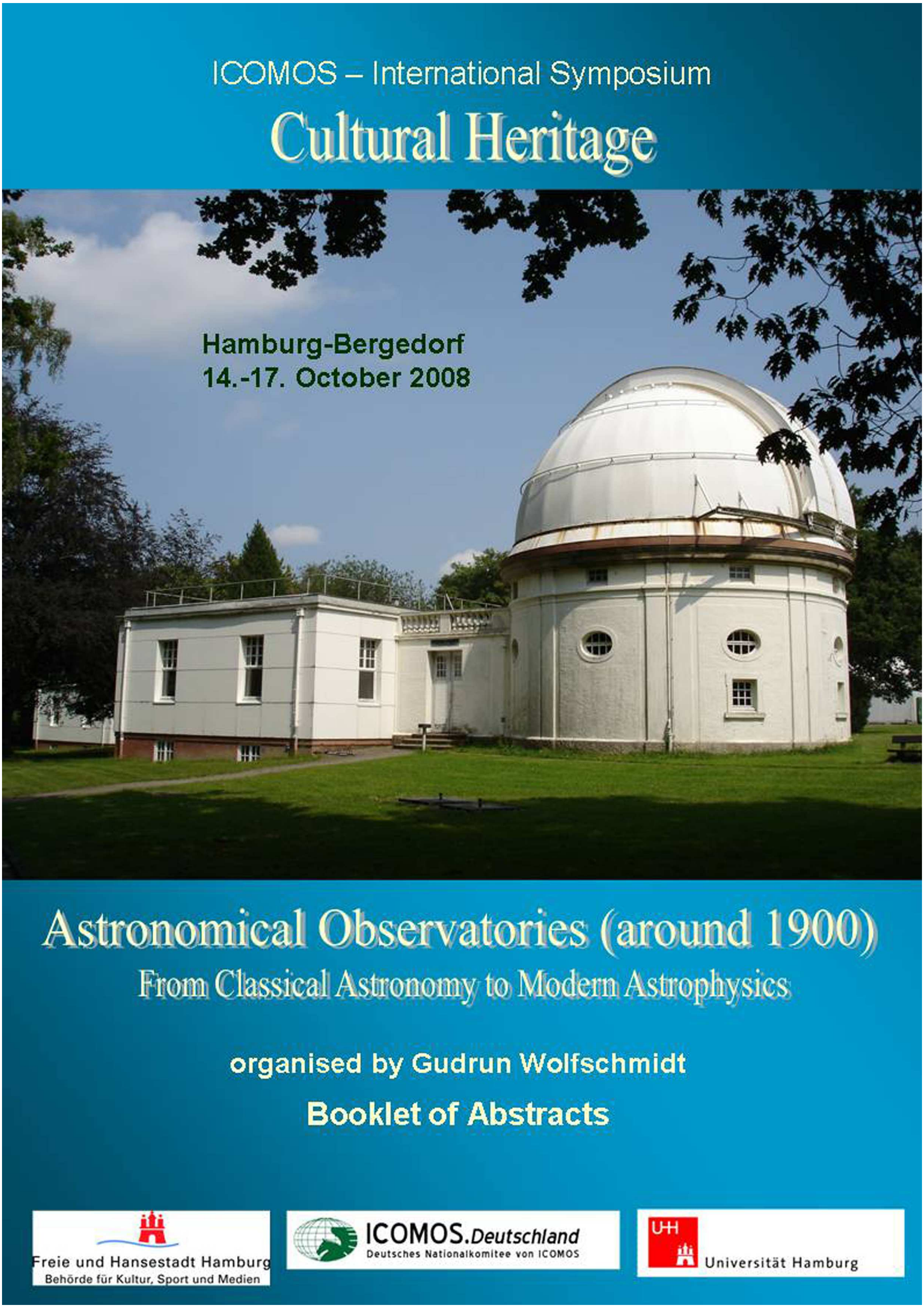

Figure 41.1: *Cover of the booklet of abstracts of the ICOMOS symposium Oct. 2009*

Programme of the Symposium: Cultural Heritage of Observatories

Gudrun Wolfschmidt

ICOMOS.Deutschland
Deutsches Nationalkomitee von ICOMOS

Scientific Committee

- Prof. Dr. Michael Petzet,
  Präsident ICOMOS Germany
- Prof. Dr. Monika Auweter-Kurtz,
  Präsidentin der Universität Hamburg
- Prof. Dr. Karin von Welck,
  Senatorin für Kultur, Sport und Medien
  der Freien und Hansestadt Hamburg
- Frank Pieter Hesse,
  Denkmalpfleger der Freien und Hansestadt Hamburg,
  Denkmalschutzamt
- Prof. Dr. Gudrun Wolfschmidt,
  Institute for History of Science, Hamburg University
- Förderverein Hamburger Sternwarte e. V. (FHS)
- Prof. Dr. Jürgen Schmitt,
  Hamburger Sternwarte, Universität Hamburg

Freie und Hansestadt Hamburg
Behörde für Kultur, Sport und Medien

Universität Hamburg

Funding for the Symposium was provided by

- Behörde für Kultur, Sport und Medien
- Behörde für Wissenschaft und Forschung
- Hamburg University
- Senatskanzlei Hamburg
- Bezirksamt Bergedorf
- Bergedorfer Zeitung
- Körber-Stiftung
- Buhck-Stiftung

buhck Stiftung

BERGEDORF

Figure 41.2: *Participants of the ICOMOS symposium Oct. 2009 (©: Gudrun Wolfschmidt)*

Tuesday, 14. October 2008 – Evening 19 h

Rathaus Bergedorf (Spiegelsaal) – Welcome address
Get together party – Ratskeller Bergedorf

19.00	Grußworte (Welcome address) Bezirksamtsleiter Dr. Christoph Krupp Grußworte (Welcome address) Staatsrat Bernd Reinert Grußworte (Welcome address) Prof. Dr. Gudrun Wolfschmidt

Wednesday, 15. October 2008
Haus im Park in Bergedorf

1. Opening of the symposium – Eröffnung des Symposiums

Chairperson: Gudrun Wolfschmidt (Hamburg)

10.00	Eröffnung des Symposiums Grußworte (Welcome address) Senatorin Dr. Herlind Gundelach, Präses der Behörde für Wissenschaft und Forschung Grußworte (Welcome address) Frank Pieter Hesse Leiter des Denkmalschutzamtes Hamburg Anna Sidorenko-Dulom, Paris, UNESCO World Heritage Centre ? Coordinator Thematic Initiative „Astronomy and World Heritage"' Introduction: Prof. Rajesh Kochhar (IAU, C 41), India *Astronomical Heritage: Towards a global perspective and action* Opening lecture: Prof. Dr. Michael Petzet, München, Präsident des Deutschen Nationalkomitees von ICOMOS
12.00–14.00	Reception

2. From Classical Astronomy to Modern Astrophysics

Chairperson: Gloria Clifton, Greenwich, UK

14.00	Gudrun Wolfschmidt, Hamburg, Germany: *Cultural Heritage of Observatories and Instruments – From Classical Astronomy to Modern Astrophysics*
14.30	Viktor Abalakin, St. Petersburg, Russia: *The Pulkovo Observatory on the Centuries' Borderline*
15.00	Suzanne Débarbat (Paris, France) *At the Belle Epoque, astronomy and astrophysics at the Observatoire de Paris*
15.30	Pedro Chalbaud, Mérida, Venezuela: *The Truncated Modernization (1950–1959): Eduardo Röhl and the Observatories of Cagigal and Hamburg – A look from the outside*

Wednesday, 15. October 2008
Hamburg Observatory in Bergedorf

3. Observatories as Universal Heritage

16.00	Grußwort (Welcome address): Prof. Dr. Jürgen Schmitt, Director of Hamburg Observatory
	Guided tour through the observatory (Förderverein Hamburger Sternwarte) (English: M. Hünsch, G. Wolfschmidt) (German: A. Seemann, H. Schlepegrell, W.-D. Kollmann) There are different options: Architecture, Instruments, Restauration:
	Agnes Seemann: *Architecture of Hamburg Observatory* Henry Schlepegrell: *Restauration activities of the observatory buildings – past and future*
18.00– 18.30	Peter Müller, Köln, Germany: *The Observatory of Hamburg-Bergedorf,* *compared with other Observatories about 1900*
	Guided tours through the observatory (German) Coffee break
 19.30	Panel discussion *Observatories as Universal Heritage* *(Der Weg zum Weltkulturerbe?)* Prof. Dr. Michael Petzet, München, Präsident des Deutschen Nationalkomitees von ICOMOS Prof. Dr. Karin von Welck, Senatorin für Kultur, Sport und Medien Prof. Dr. Monika Auweter-Kurtz, Präsidentin der Universität Hamburg Annette Liebeskind, Deutsche Stiftung Denkmalschutz Moderation: Ulf-Peter Busse, Bergedorfer Zeitung
21.00	Reception in the observatory

Thursday, 16. October 2008
Haus im Park in Bergedorf

4. Astronomical Observatories around 1900

Chairperson: Suzanne Débarbat, Paris, France

9.00	Pedro Raposo, Oxford / Lisbon: *The material culture of nineteenth-century astrometry,* *its circulation and heritage at the Astronomical Observatory of Lisbon*
9.30	Christophe Benoist, Nice, France / Istanbul: *Two observatories in Istanbul:* *from the late Ottoman Empire to the young Turk Republic*
10.00	Marcus Granato, Rio de Janeiro, Brazil: *Heritage and the observatories in Brazil around 1900, a brief review*
	Coffee Break

Chairperson: Ileana Chinnici, Palermo, Italy

11.00	James Caplan, Marseille, France: *The Marseille Observatory: the final move.* *A case study in the conservation of astronomical heritage.*
11.30	Anneliese Schnell, Vienna, Austria: *The University Observatory Vienna*
12.00	Lajos G. Balázs and Magda Vargha, Budapest, Hungary: *The first 50 years of Konkoly Observatory*
12.30– 14.00	Lunch Break

Thursday, 16. October 2008
Haus im Park in Bergedorf

5. Cultural Heritage of Observatories

Chairperson: Viktor K. Abalakin, St. Petersburg, Russia

14.00	Magda Stavinschi and Catalin Mosoia, Bucharest, Romania: *Considering heritage as part of astronomy –* *100 years of Bucharest Observatory*
14.30	Gloria Clifton, Greenwich, UK *The Royal Observatory, Greenwich, London:* *presenting a small observatory site to the public*
15.00	Reet Mägi, Tartu, Estonia: *The Heritage of the 200-year-old University Observatory in Tartu*
	Coffee Break

Chairperson: James Caplan, Marseille, France

16.00	Juan Carlos Forte and Sofía A. Cora, La Plata, Argentina: *La Plata Observatory*
16.30	Françoise Le Guet Tully, Observatoire de la Côte d'Azur, Nice, France and Hamid Sadsaoud, Observatoire d'Alger, Algeria: *Astronomical heritage sites: two early "mountain" observatories* *on the Mediterranean coast*
17.00	Brian Mason, Washington, D.C., USA: *U. S. Naval Observatory*

6. "175 Years Hamburg Observatory"
City Hall (Rathaus) in Hamburg

19.00	Grußworte (Welcome address) Staatsrat Bernd Reinert, Behörde für Wissenschaft und Forschung Grußworte (Welcome address) Prof. Dr. Monika Auweter-Kurtz, Präsidentin der Universität Hamburg
	Lecture by Prof. Dr. Rudolf Kippenhahn (Göttingen): *Faszination Astronomie – Die letzten zwei Jahrhunderte*
	Short Lecture by Prof. Dr. Dieter Reimers (Hamburg) *Geschichte und Zukunft der Hamburger Sternwarte*

Senatsempfang im Rathaus Hamburg – (State Reception in the City Hall Hamburg)

Friday, 17. October 2008
Haus im Park in Bergedorf

7. Instruments, restoration and virtual heritage

Chairperson: Vidar Enebakk, Oslo, Norway

09.00	Jean Davoigneau, Strasbourg, France: *The architectural and instrumental heritage of the Strasbourg university observatory*
09.30	Ileana Chinnici, Palermo, Italy: *Italian Astronomical Observatories and their historical instruments collections*
10.00	Martin Šolc, Prague, Czech Republic: *Prague and Ondřejov Observatory*
	Coffee Break

Chairperson: Inga Elmqvist Söderlund, Stockholm, Sweden

10.30	Shylaja B. S. (Bangalore, India) *Advent of Astronomical Instruments and their impact – the Indian context*
11.00	Matthias Hünsch, Hamburg, Germany: *The telescopes of Hamburg Observatory – history and present situation*
11.30	Ruth Keller-Kempas, Berlin, Germany: *Possibilities and strategies for the conservation of technical objects like telescopes*
12.00	Beatrix Alscher, Berlin, Germany: *The 1m-Reflector – an object of technical heritage and a concept of its restoration / preservation*
12.30–14.00	Lunch Break

Friday, 17. October 2008
Haus im Park in Bergedorf

8. Instruments, restoration and virtual heritage

Chairperson: Gudrun Wolfschmidt

14.00	Paolo Brenni, Florence, Italy *Non astronomical research* *in astronomical observatories*
14.30	Björn Kunzmann, Hamburg, Germany and Peter Kroll, Sternwarte Sonneberg: *Real and Virtual Heritage –* *Digitized Photographic Plate Archives* *in Astronomical Observatories*
15.00	Closing remarks: Frank Pieter Hesse, Denkmalschutzamt Hamburg
	End of the conference

Additional offer:

Gudrun Wolfschmidt:
Guided tour through Hamburg to places of interest in respect to history of astronomy
(Altona Meridian line, place of old Hamburg and Altona observatory, Repsold monument, etc.)

Closing dinner.

Figure 41.3: *The coordinates of Hamburg (Photo: Gudrun Wolfschmidt)*

Figure 41.4: *Participants of the ICOMOS symposium 2009 (©: Gudrun Wolfschmidt)*

Authors

Prof. Dr. Viktor K. Abalakin (St. Petersburg, Russia)

Viktor K. Abalakin ist am 27. August 1930 in Odessa, Ukraine, geboren. 1953 hat er die I. I. Metschnikoff-Staatsuniversität Odessa im Fach *Astronomie* absolviert; 1953 bis 1955 hat er am Institut für Geophysik der UdSSR Akademie der Wissenschaften zu Moskau gearbeitet; 1955 bis 1957 arbeitete Abalakin am Institut für Theoretische Astronomie der UdSSR AW zu Leningrad; 1957 bis 1961 ist er ein Aspirant an der I. I. Metschnikoff-Staatsuniversität Odessa im Fach *Himmelsmechanik* gewesen; 1961 bis 1964 arbeitete Abalakin an der Universitäts-Sternwarte Odessa und an der Abteilung *Astronomie* der I. I. Metschnikoff-Staatsuniversität Odessa; 1964 bis 1985 ist Abalakin der Leiter der Ephemeridenabteilung des Instituts für Theoretische Astronomie der UdSSR AW gewesen; 1983 bis 2000 bekleidete Abalakin den Direktorposten an der Hauptsternwarte der UdSSR (Russischen) AW zu Pulkowo.
Zur Zeit (seit dem Jahre 2000) ist er ein Berater der Russischen Akademie der Wissenschaften an der Hauptsternwarte Pulkowo der RAS sowie der Leiter des Sektors für Geodynamik daselbst. 1961 war er für seine Dissertation *Über periodische Bewegungen von Sternen in ellipsoidalen Sternensystemen* zum Kandidaten der physikalischen und mathematischen Wissenschaften promoviert; 1978 wurde ihm ein akademischer Grad des Doktors der physikalischen und mathematischen Wissenschaften für seine Dissertation *Über Methoden für Berechnung der astronomischen Ephemeriden für extraterrestrische Beobachtungen* zuerkannt; 1982 wurde Abalakin sowie seinen anderen Kollegen der UdSSR Staatspreis für die kollektive Arbeit *Eine einheitliche Relativitäts-Theorie der Bewegung von großen Planeten des Sonnensystems* verliehen. Seine wissenschaftlichen Interessen liegen im Bereich der Himmelsmechanik, der Stellardynamik, der Geosowie Selenodynamik und der Astronomiegeschichte.
Mehr als 250 Monographien und Artikel sind von Abalakin veröffentlicht worden. Zu seinen wisseschaftlichen Veröffentlichungen zählen u. a. *Das n-Körperproblem in Himmelsmechanik und Kosmogonie* (die Übersetzung aus dem Russischen eines von H. F. Chilmy verfassten Buches (die Mitverfasser E. P. Aksjonow, W. G. Djomin, E. A. Grebenikow, J. A. Rjabow, 1972), *Theory of Artificial Earth Satellites Motion* (1974), einige weitere russische Bücher (1979), (1982), (2005), (die Mitverfasser I. I. Krasnorylow und J. W. Plachow, 1996).
Viktor K. Abalakin ist ein Mitglied der Internationalen Astronomischen Gesellschaft (seit 1967) und der Astronomischen Gesellschaft (seit 1970), ein korrespondierendes Mitglied der Russischen Akademie der Wissenschaften (seit 1987), ein Mitglied der International Academy of Ecology, Man and Nature Protection Sciences (seit 1997), ein Ehrenmitglied der Akademie für Kosmonautik (seit 1998) und der Russischen Akademie der Naturwissenschaften (seit 2006). Abalakin ist ein Ehrenbürger von Tucson, Staat von Arizona, die VSA. Der Kleinplanet 2722 Abalakin ist nach ihm benannt worden.

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Dr. B S Shylaja obtained Masters (Physics) from Bangalore University, India. Later she obtained Ph D in astrophysics observing binaries with Wolf – Rayet components. The other fields of her interests are novae and cataclysmic variables, chemically peculiar stars, comets and asteroids. Of late, she has been interested in history of astronomy. Her publications include study of stone inscriptions, temples and development of astronomy in the colonial period in India. She has authored several books as part of her work at the Jawahralal Nehru Planetarium in Bangalore, where she is actively engaged in teaching undergraduates and popularising astronomy along with research. The book *Eclipse – the Celestial Shadow Play* co authored with H. R. Madhusudana has an extensive coverage of the historical and cultural aspects.

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His main interests are two-folded: astrophysics and history of science. In astrophysics he is involved in projects related to cosmology and large scale structures of the Universe. In history of science he is studying the development of astronomy in the Ottoman Empire and more generally the astronomical developments made in the Islamic world and their relationships with European astronomy.

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James Caplan (BS in physics, University of Chicago; PhD in astronomy, Northwestern University; docteur d'état, université de Provence) is an *astronome* at the Observatoire de Marseille (as it was called before 2000), now the *Laboratoire d'Astrophysique de Marseille*, a division of the OAMP (*Observatoire Astronomique de Marseille-Provence*). He works in the Interstellar Medium group, where he has specialised in the use of Fabry-Perot interferometry for the study of H II regions. He is currently interested in the history of astronomical instruments, and is in charge of the heritage programme of the OAMP.

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After the University degree in Physics (thesis on History of Astronomy), she has spent one year at the Paris Observatory, working on the Carte du Ciel archives.
She is currently Coordinator of the INAF Museum Service and Chair of the IAU C41 Working Group on Archives.
She is author of several publications on 19th century History of Astronomy, especially concerning instruments and archives.

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Dr. Gloria Clifton (Greenwich, UK)

Gloria Clifton is Head Curator of the Royal Observatory, Greenwich, part of the National Maritime Museum, London. Her interest in instruments began in 1989 when, after completing a Ph. D., she became a Research Officer for three years at Imperial College, London, working under Professor Gerard L'Estrange Turner on the development the British scientific instrument making trades. The results of this research were published in 1995 by the National Maritime Museum as the *Directory of British Scientific Instrument Makers c. 1550–1851*, by which time she had moved to the Museum as Curator of Navigational Instruments. Since then she has also published, amongst other things, 'Globe making in the British Isles', in E. Dekker, *Globes at Greenwich. A Catalogue of the Globes and Armillary Spheres in the National Maritime Museum, Greenwich* (1999) and 'The London Mathematical Instrument Makers and the British Navy, 1700–1850', in *Science and the French and British Navies, 1700–1850*, ed. Pieter van der Merwe (2003).

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Dr. Sofía A. Cora obtained her Ph. D. in Astronomy in 1999 at the Faculty of Astronomical and Geophysical Sciences (La Plata National University, Argentina). She had postdoctoral positions at the Faculty of Astronomical and Geophysical Sciences (1999–2001) and at the Max-Planck Institute for Astrophysics (Garching by Munich, Germany, 2001–2003). She has been a Research Scientist of the National Reasearch Council (CONICET) since 2002. Her research work involves the study of galaxies and intergalactic medium in different environments, mainly based on the use of numerical techniques. She had several Assistanships at the Faculty of Astronomical and Geophysical Sciences since 1992. In 2007 she obtained a Professor position (Relativistic Astronomy).

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Dr. Suzanne Débarbat (Paris, France)

SD's carrier, that took place entirely at the Observatoire de Paris, began in 1953 when she joined the staff as a part time calculator, being at the same time a student in astronomy at La Sorbonne. From 1955, she was successively assistant, aide-astronome, astronome adjoint and astronome titulaire, which were at that time the four levels for such a carrier. She is *Docteur d'Etat* and she was, from 1985 to 1992, director of the research group *Systèmes de référence spatio-temporels* of the *Centre national de la recherche scientifique*, and of the *Département d'Astronomie fondamentale* of the *Observatoire de Paris*, now named *Systèmes de référence temps-espace* (SYRTE), of which she is an *Associé* since her retirement.
From 1975, after being asked by historians of astronomy, she worked – and is still doing so – on the history of the Observatoire de Paris, its astronomers, their instruments, works, discoveries, ...
After publishing papers and one book (with B. Guinot), in her field of research as an astronomer, she has written quite a number of articles in various magazines, dictionaries, encyclopedies, ... and she has, still in preparation, three books concerning the *Observatoire de Paris.*
She is a member of the *Académie internationale d'histoire des sciences* and of the International Astronomical Union (commission 41, History of astronomy of which she was president, 1991/1994).

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MA in Business administration and MA in the History of Art.
Curator at the Observatory museum in Stockholm since 1996. With previous experience from several museums and exhibitions in the Stockholm region. Specifically interested in the material culture of the history of astronomy and the intersection of the arts and sciences. At present concluding the PhD thesis Taking possession of astronomy: The role of frontispieces and illustrated title-pages in books on astronomy during the 17th century at Stockholm university.
Various publications on the history of the old observatory of Stockholm (in the printed series Observatoriemuseets skriftserie). One article available on the internet: http://www.ep.liu.se/ecp/030/015/ecp0830015.pdf.

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Prof. Dr. Ian S. Glass (Cape of Good Hope, South Africa)

Ian Glass was born in Ireland in 1939 and received his B. A. degree from Trinity College, Dublin. He holds a PhD in Physics from the Massachusetts Institute of Technology (MIT). He has held posts at MIT, the California Institute of Technology, the Royal Greenwich Observatory and the South Astronomical Observatory and has been a visitor at several other institutions.
His main field has been infrared astronomy and he has published over 200 papers in this field. More recently he has specialised in astronomical history. He is currently an Astronomical Research Associate at the South African Astronomical Observatory and an Adjunct Professor at James Cook University, Queensland, Australia.
He has written four books: *Victorian Telescope Makers: the Lives and Letters of Thomas and Howard Grubb*, IOPP, Bristol and Philadelphia, 1997; *Handbook of Infrared Astronomy*, CUP, Cambridge, 1999; *Revolutionaries of the Cosmos: the Astrophysicists*, OUP, 2006 and *Proxima – the Nearest Star (Other than the Sun)*, Mons Mensa, Cape Town, 2008.

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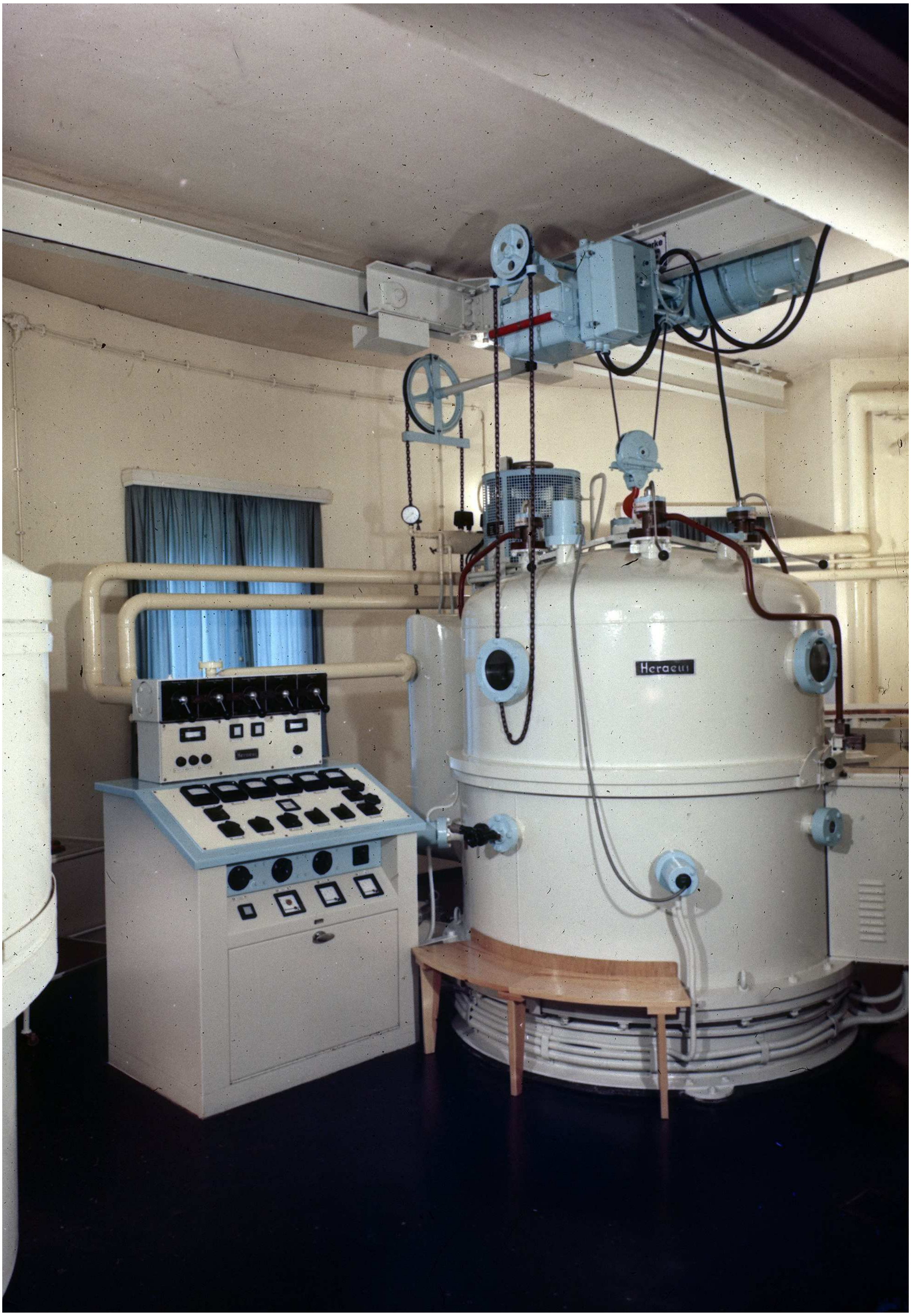

Figure 42.1: *Mirror coating facility: On the telescope mirror a layer of highly reflective aluminum is applied in a vacuum chamber with a diameter of 153 cm with a pressure of* 5×10^{-5} *Torr (Spiegelbedampfungsanlage), Hamburg Observatory*

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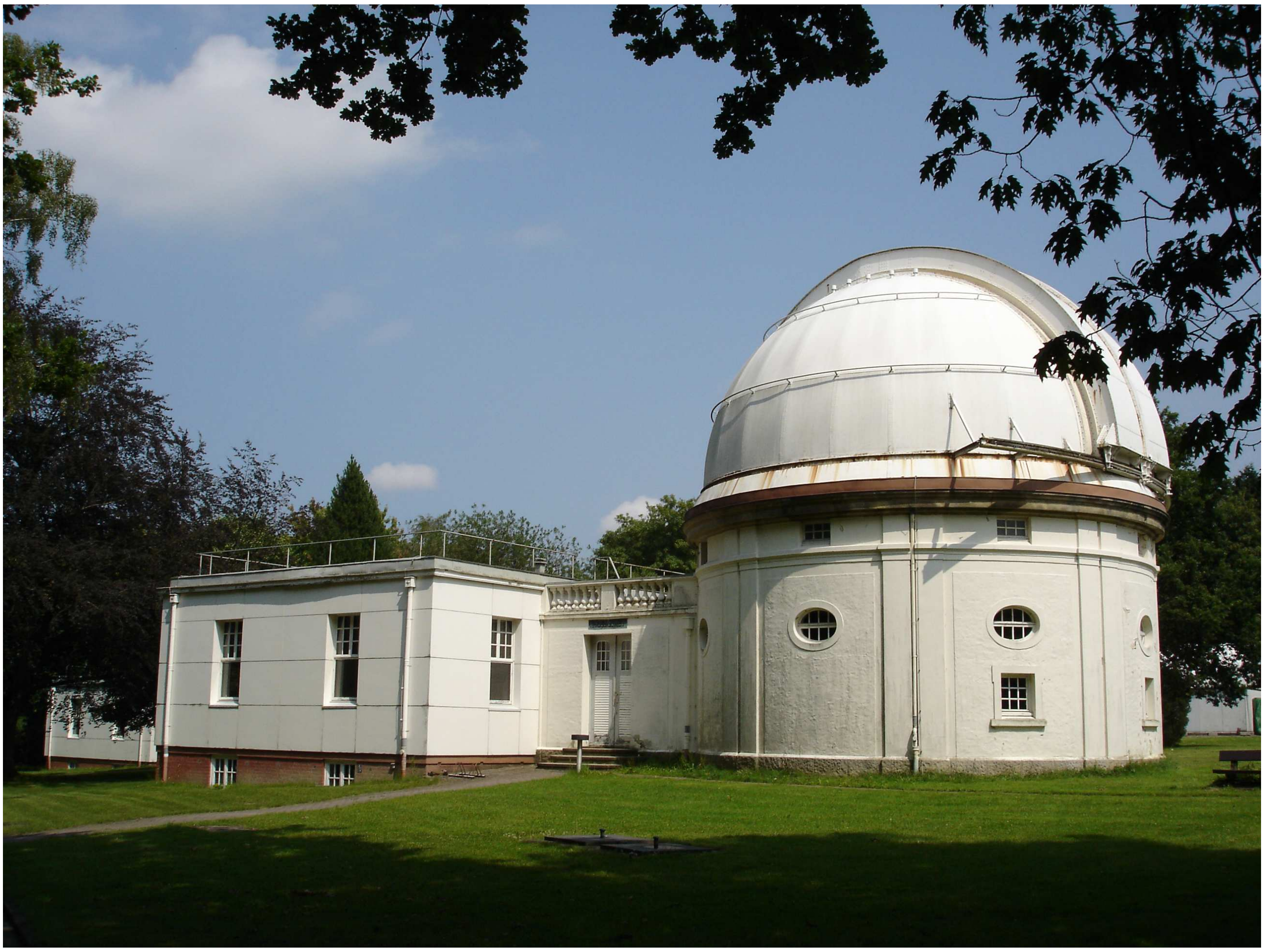

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