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

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

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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 20th 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 19th 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)*

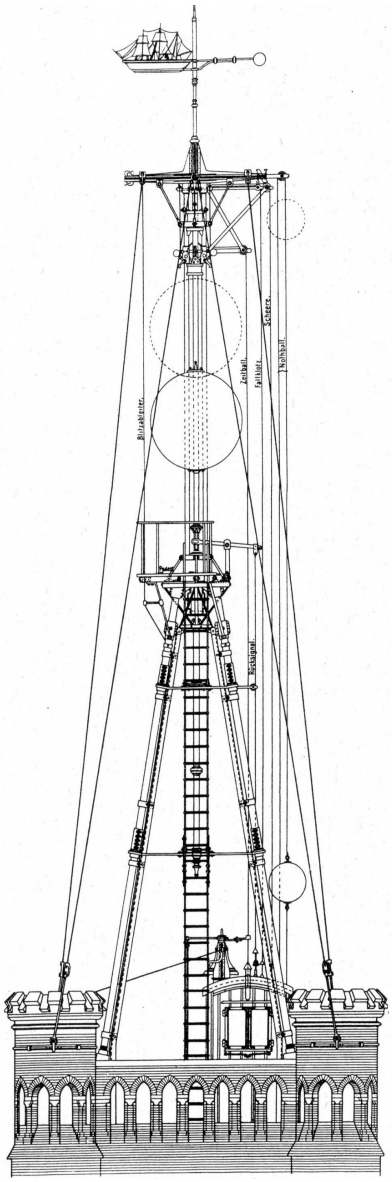

Figure 5.5: *Hamburg time ball, Carl Bamberg of Berlin (1876) used until 1934 (Photo: Gudrun Wolfschmidt)*

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 19th 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]

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)*

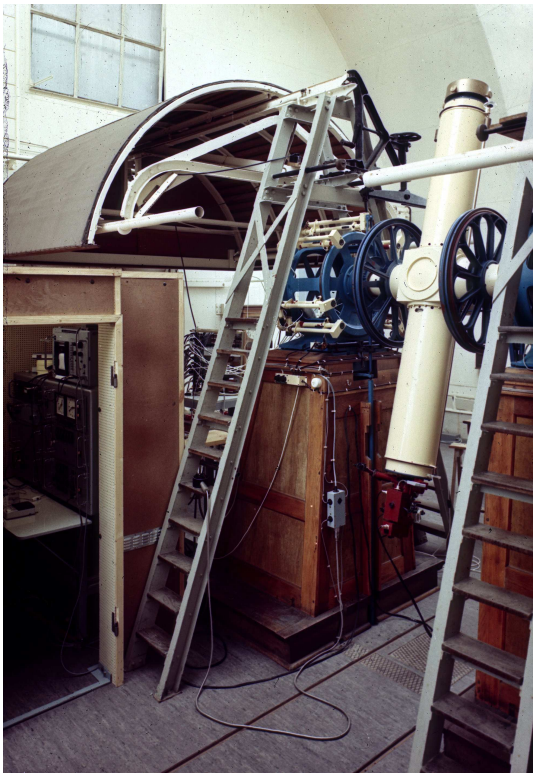


Figure 5.7: *Meridian circle of Hamburg-Bergedorf observatory, A. Repsold & Söhne, Hamburg, 1909 (Photo right: Gudrun Wolfschmidt, Photo left: Hamburg Observatory)*

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

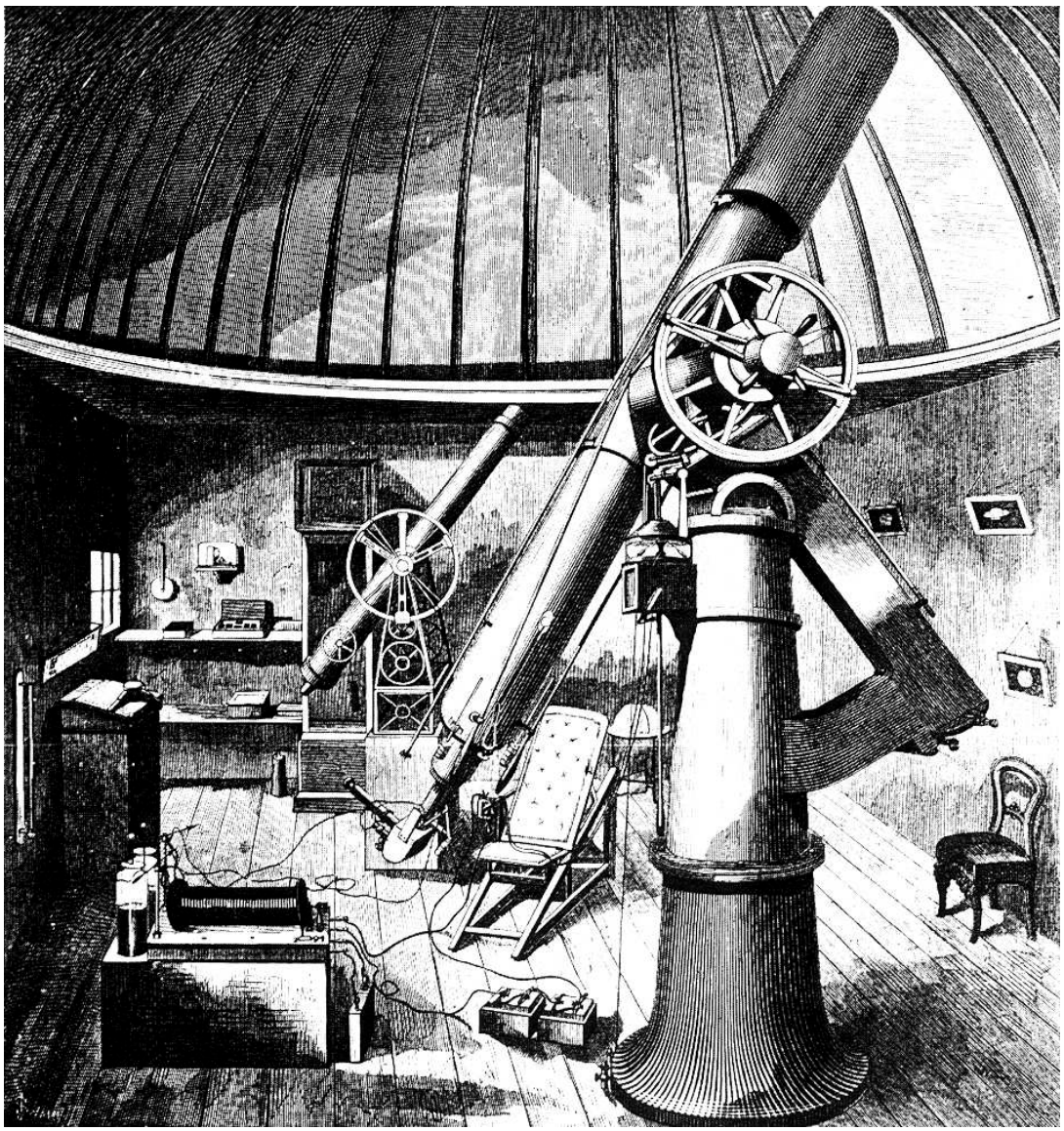

Figure 5.9: *Observatory Tulse Hill near London, Sir William (1824–1910) and Lady Margaret Lindsay Huggins' (1848–1915), 8″ refractor and prism spectroscope, 1860/68 (Huggins 1899, p. 4.)*

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^{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).

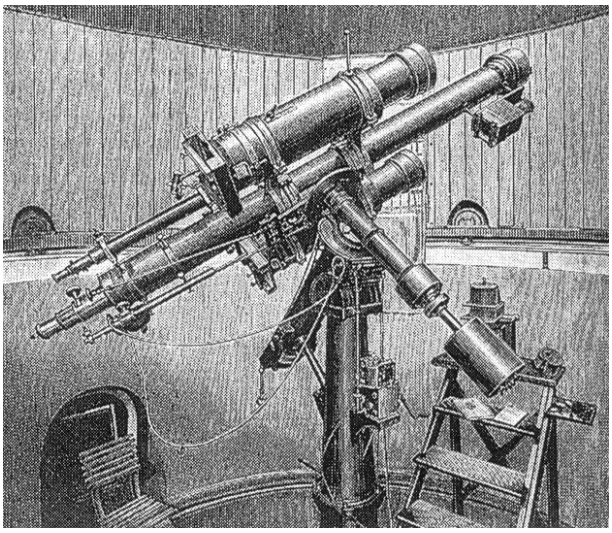

Figure 5.10: *Astrophotography: portrait objectives of Max Wolf, Heidelberg*

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.

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.

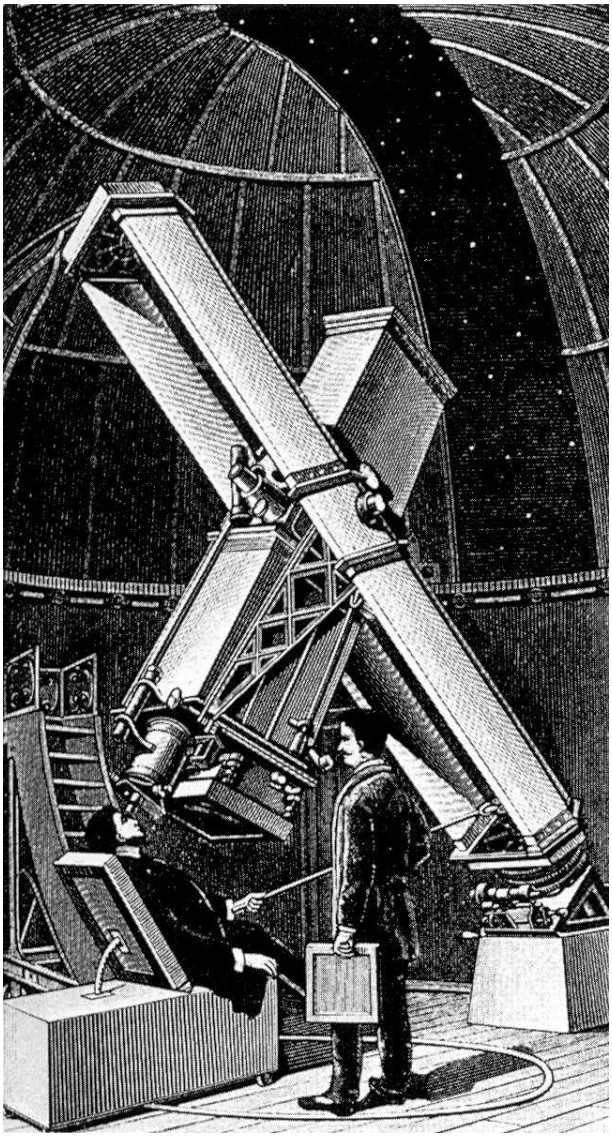

Figure 5.11: *Astrophotography: Henry standard astrograph, Paris 1887*

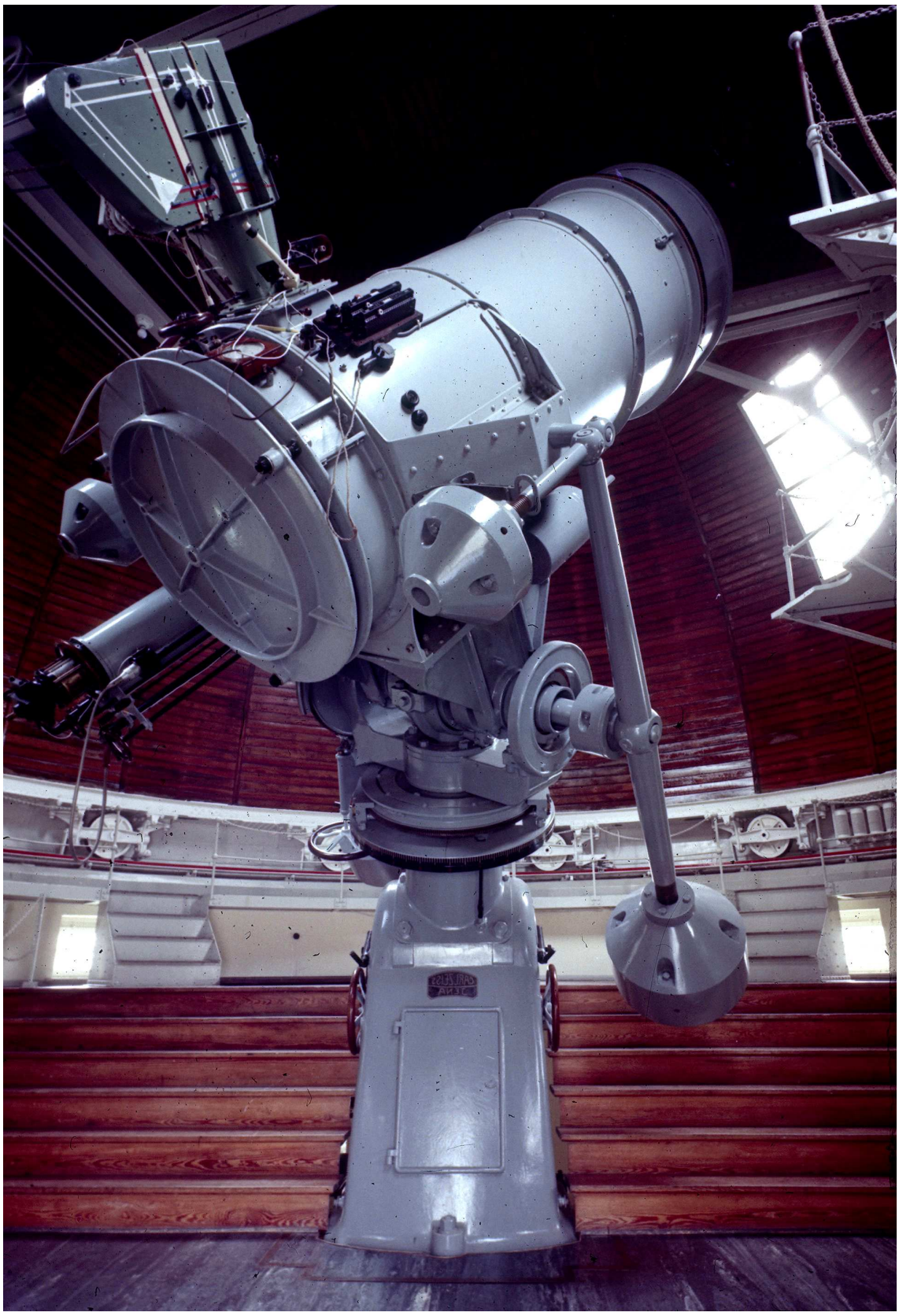

Figure 5.12: *1m-reflector Hamburg, Zeiss of Jena (1911), with three prism spectrograph, load relieving mounting by Franz Meyer (1868–1933) (Hamburg Observatory)*

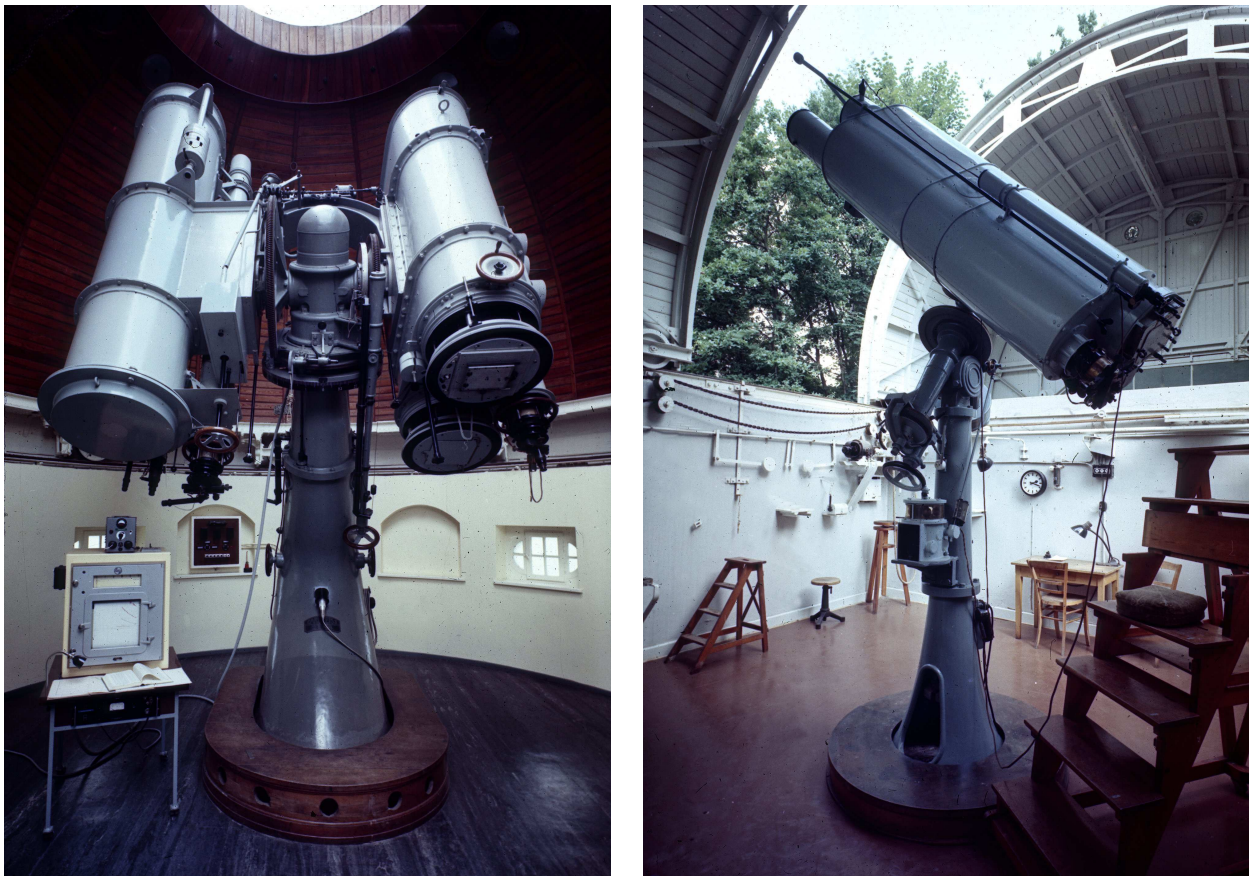

Figure 5.13: *Astrographs of Hamburg Observatory. Left: Lippert Astrograph and Double Astrograph with an object lens prism, Carl Zeiss of Jena, 1911/1914; Right: AG-Zonen-Astrograph, Carl Zeiss Jena, 1924 (Hamburger Sternwarte)*

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 19$^{\text{th}}$ to 20$^{\text{th}}$ 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 19$^{\text{th}}$ 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-

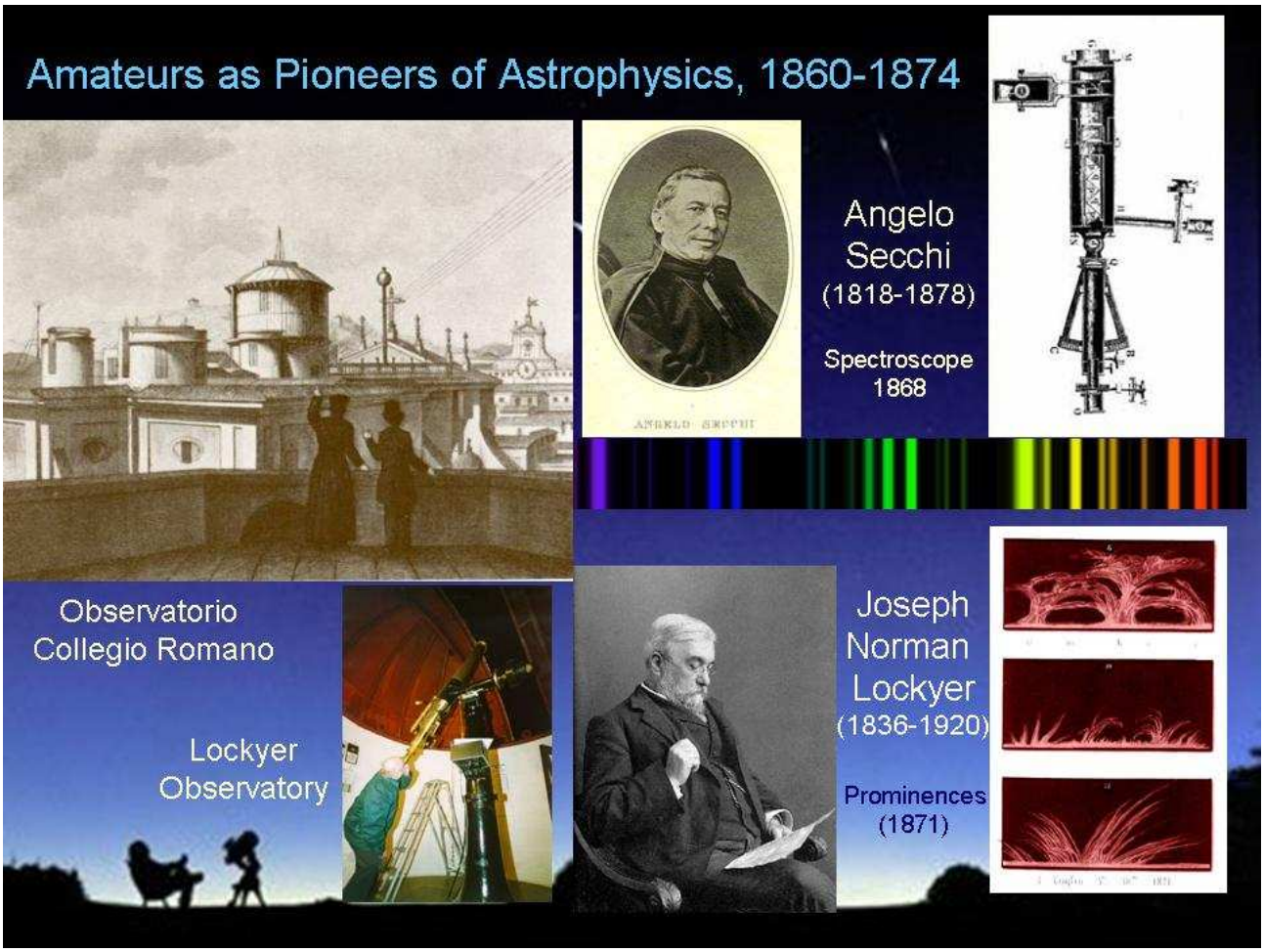

Figure 5.15: *Spectroscopists: Angelo Secchi (1818–1878) in Rome, Joseph Norman Lockyer (1836–1920) in England*

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.

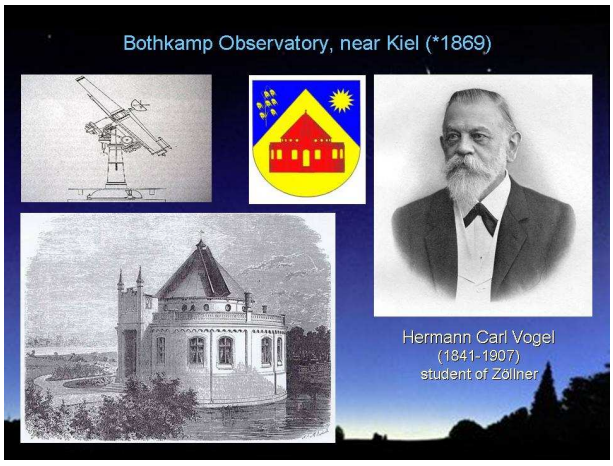

Figure 5.16: *Bothkamp Observatory (1869), Friedrich Gustav chamberlain (Kammerherr) von Bülow*

- 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

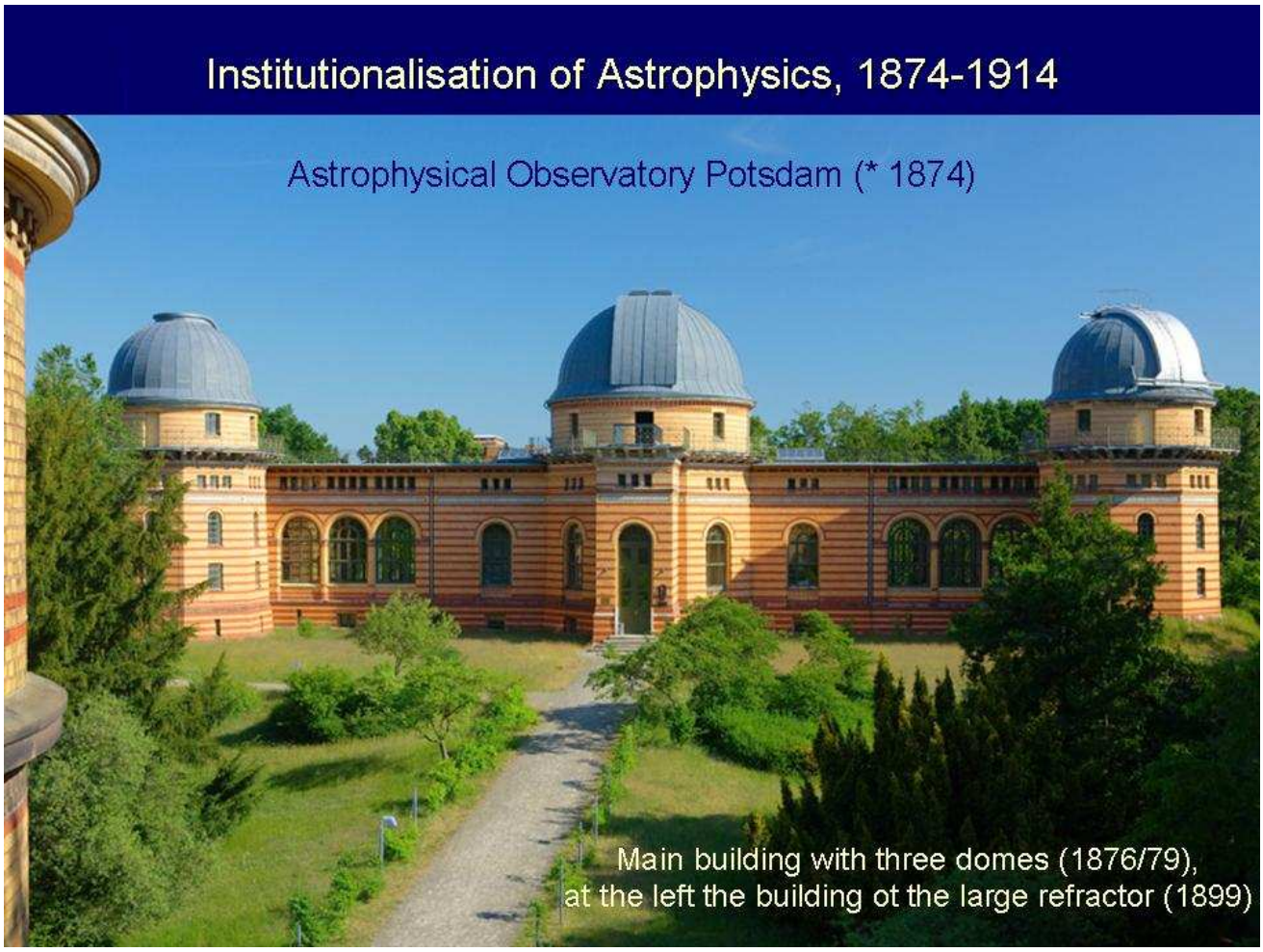

Figure 5.17: *Astrophysical Observatory Potsdam (1874), building 1876–1879, large refractor 1899*

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-

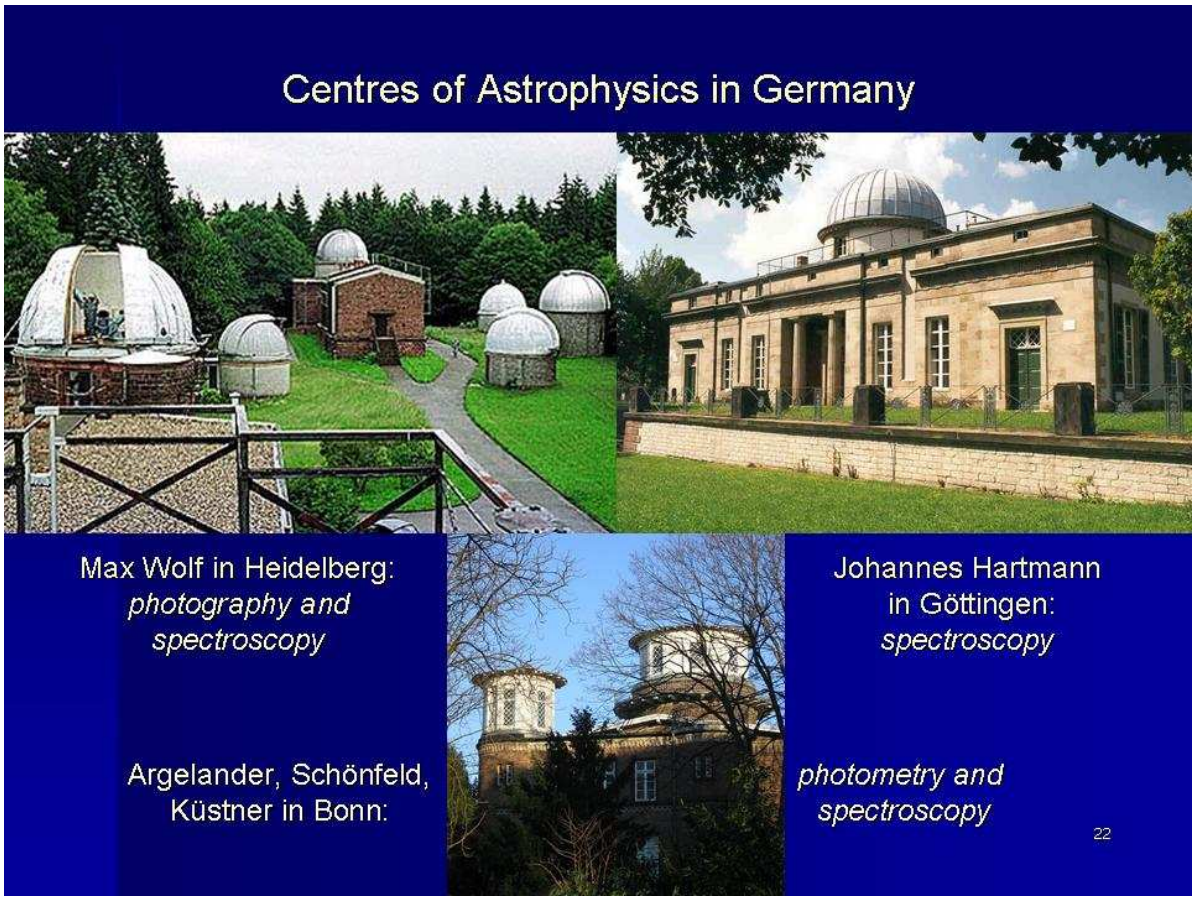

Figure 5.18: *Centres of Astrophysics in Germany: Max Wolf in Heidelberg, Karl Schwarzschild and Johannes Hartmann in Göttingen, Argelander, Schönfeld and Küstner in Bonn*

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$^{\text{th}}$ to the 20$^{\text{th}}$ 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`.

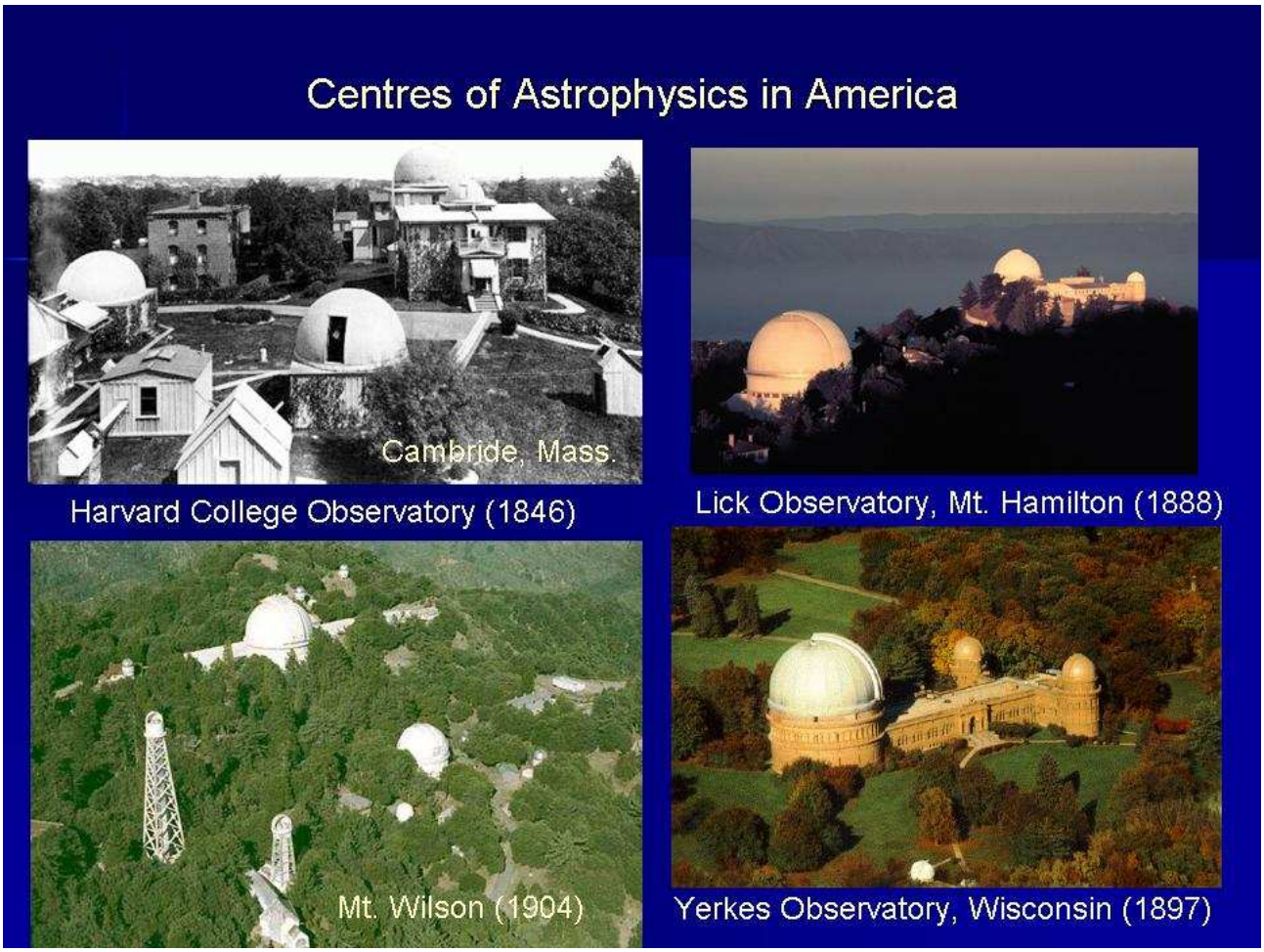

Figure 5.20: *Centres of astrophysics in the USA: Harvard College Observatory (1846), Lick Observatory, Mt. Hamilton (1888), Yerkes Observatory, Wisconsin (1897), Mt. Wilson (1904)*

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.

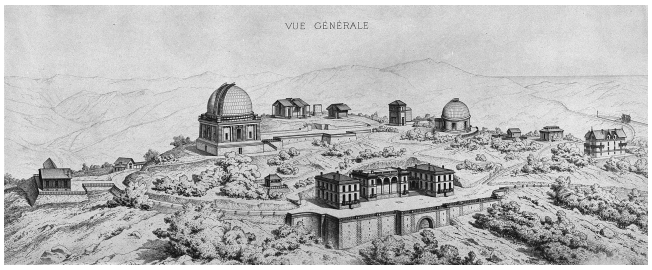

Figure 5.21: *Nice Observatory on Mont Gros (1888) with the large dome by Gustave Eiffel (Garnier, Charles: Monographie de l'Observatoire de Nice, 1892).*

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