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 19$^{\text{th}}$ 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 19$^{\text{th}}$ 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

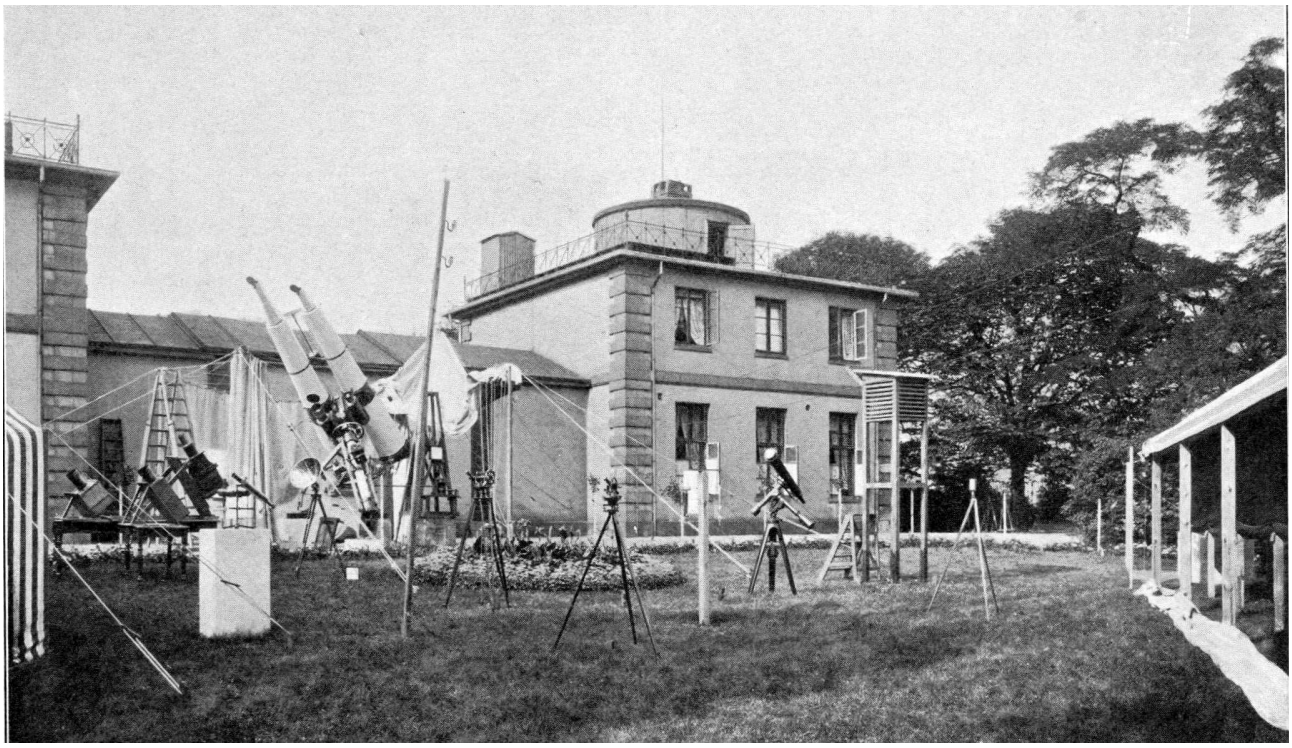

Figure 31.2: *Telescopes, prepared for the solar eclipse expedition in 1905, in front of the old observatory near Millerntor (Hamburg Observatory)*

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.

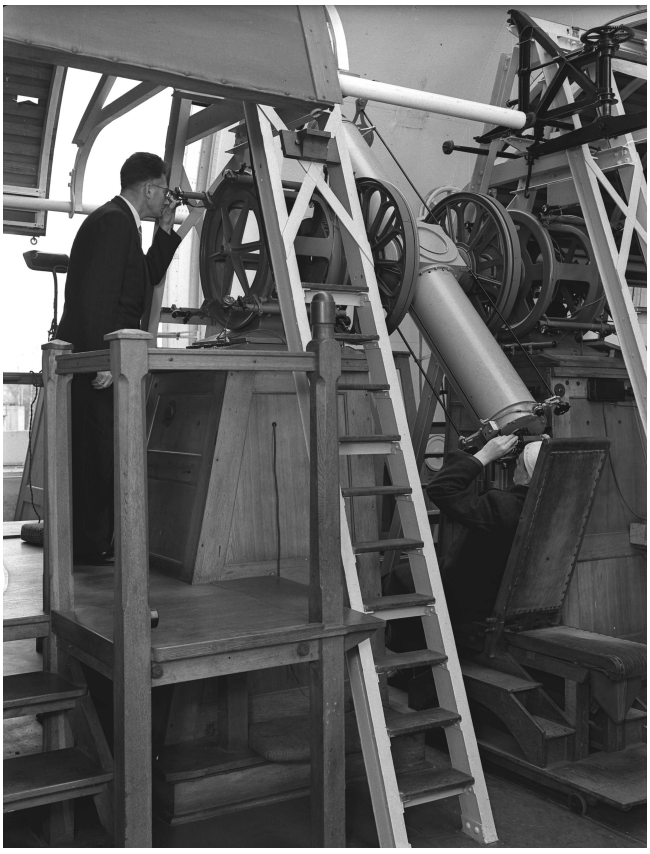

Figure 31.3: *19 cm Meridian circle, Steinheil, Munich, A. & G. Repsold, Hamburg, 1912 (Hamburg Observatory)*

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 20$^{\text{th}}$ century, and finally the instrument is nearly in its original condition.

At the begining of the 20$^{\text{th}}$ 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^{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.

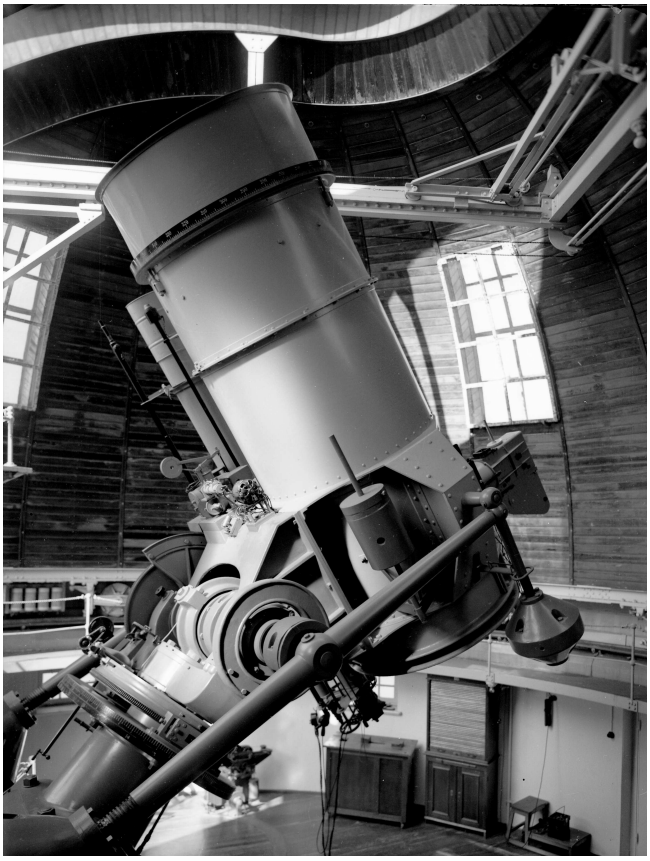

Figure 31.6: *1 m reflector, Carl Zeiss, Jena 1911 (Hamburg Observatory)*

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-

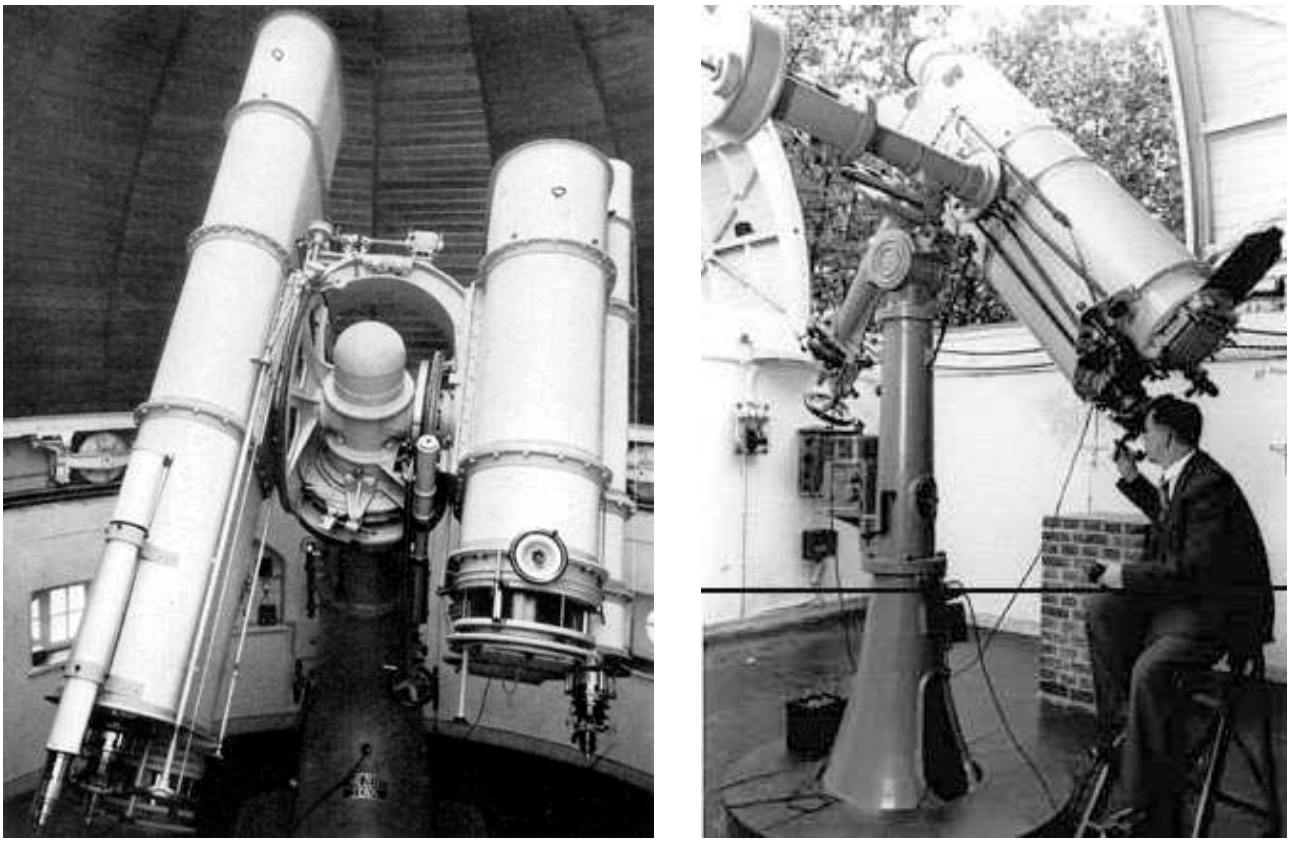

Figure 31.5: *34 cm Lippert astrograph in its original configuration, Carl Zeiss, Jena, 1911; AG Astrograph, Carl Zeiss Jena, 1924 (Hamburg Observatory)*

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.

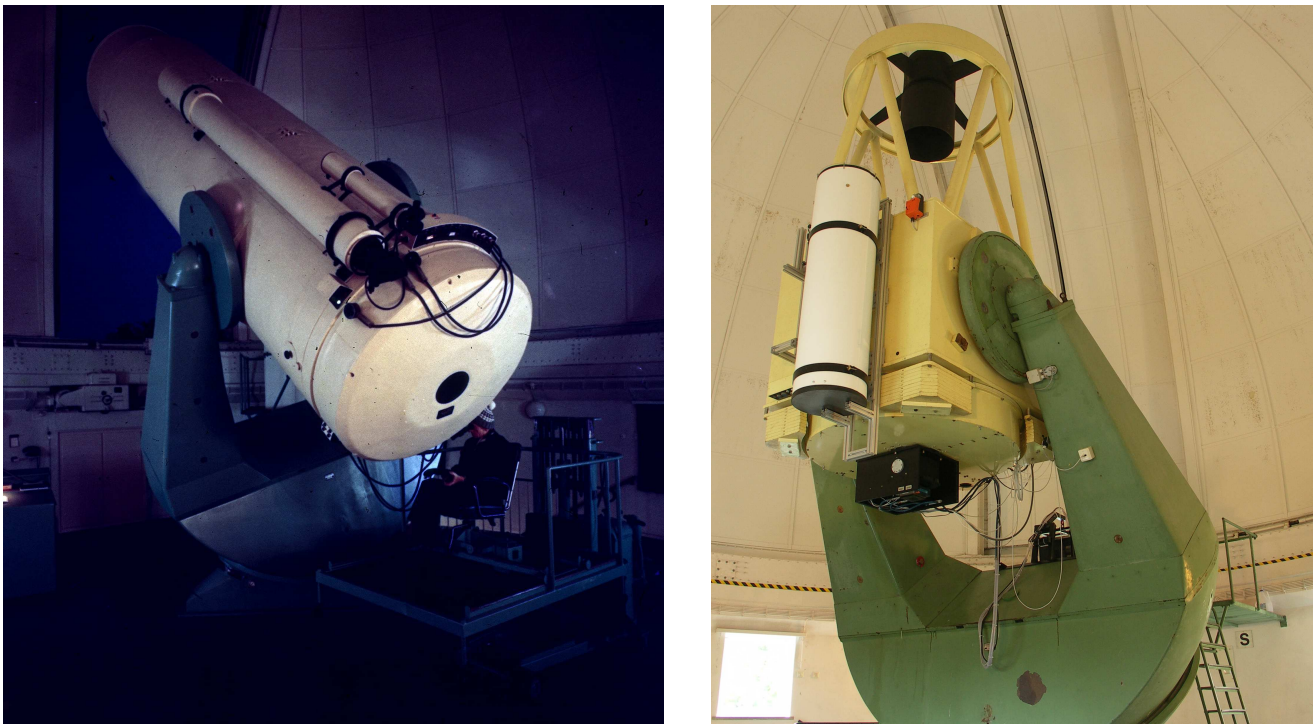

Figure 31.7: *Large 80 cm Hamburg Schmidt telescope, Zeiss, Jena, Heidenreich & Harbeck, Hamburg, 1954; 1.20 m Oskar-Lühning telescope, Grubb, Parsons & Company, 1975 (Left: Hamburg Observatory, Right: Photo: Matthias Hünsch)*

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 19th century to modern astrophysics of the 20th 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.

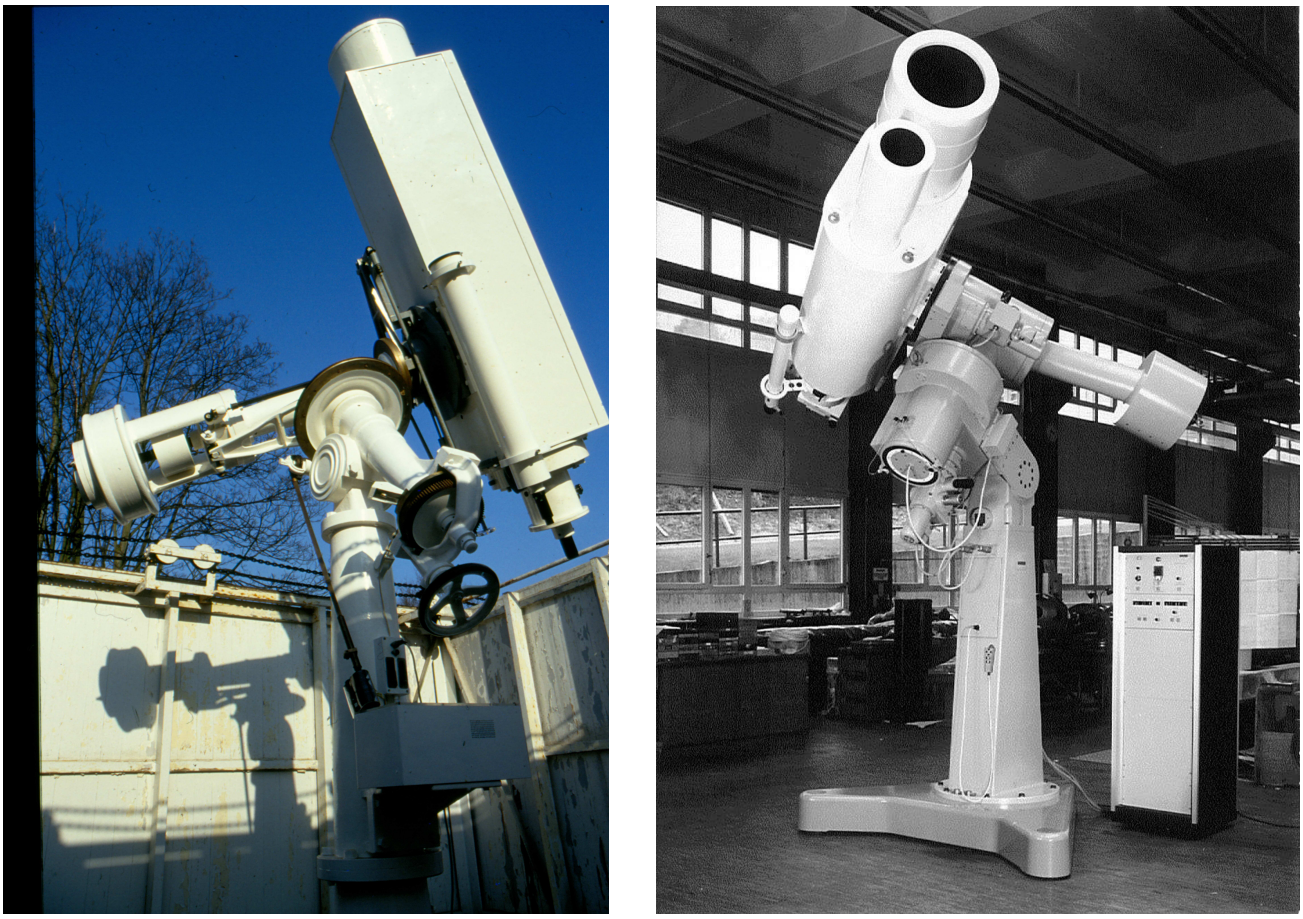

Figure 31.9: *40 cm Salvador reflector (1967) and 23 cm zone astrograph, Zeiss, Oberkochen (1973) (Hamburg Observatory)*

---

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.