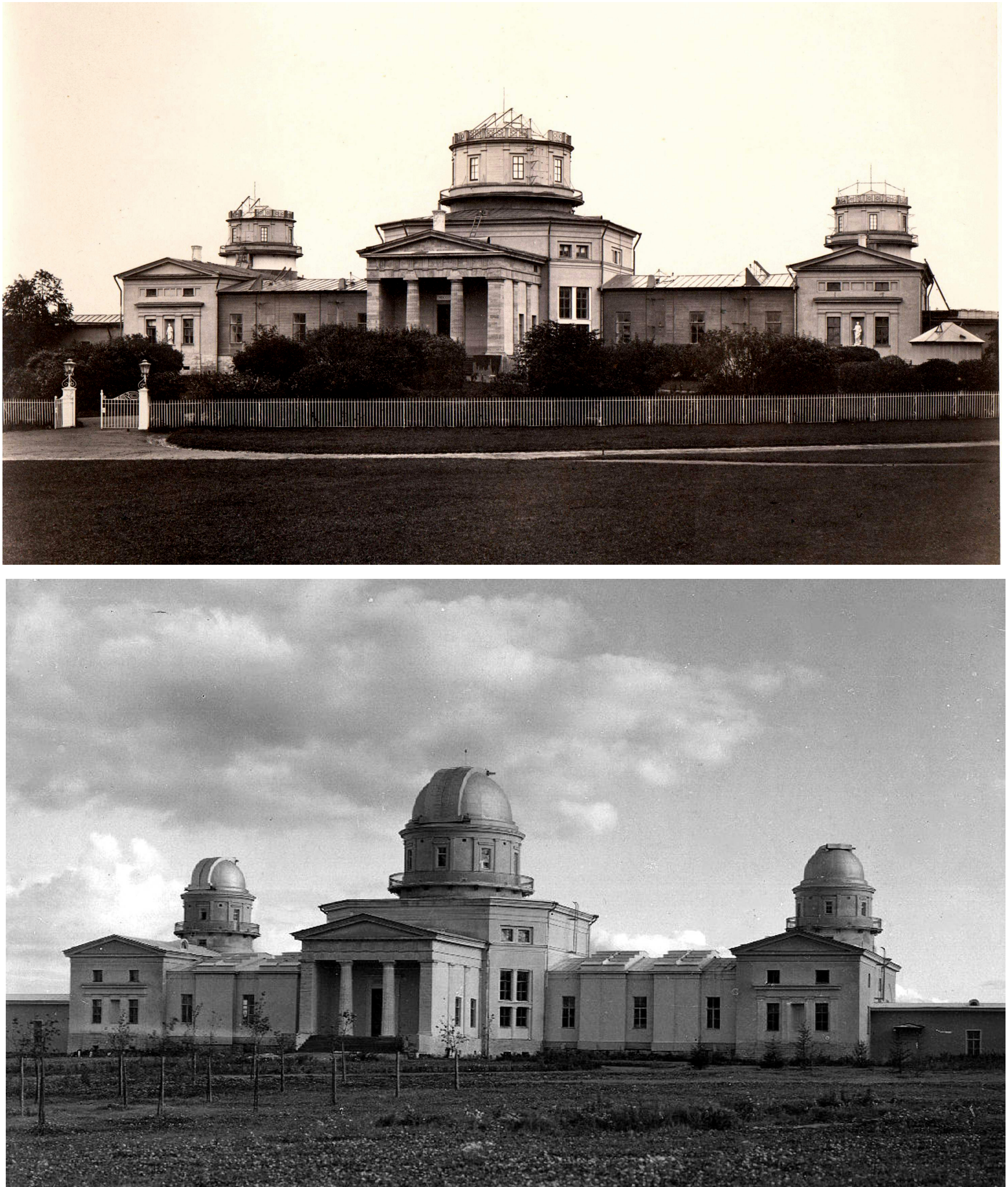

Figure 6.1: *Above: The Nicholas Central Astronomical Observatory (Pulkovo Observatory) (the view before WWII)*
Below: The restored Pulkovo Observatory (the view after WWII) (Pulkovo Observatory, St. Petersburg)

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

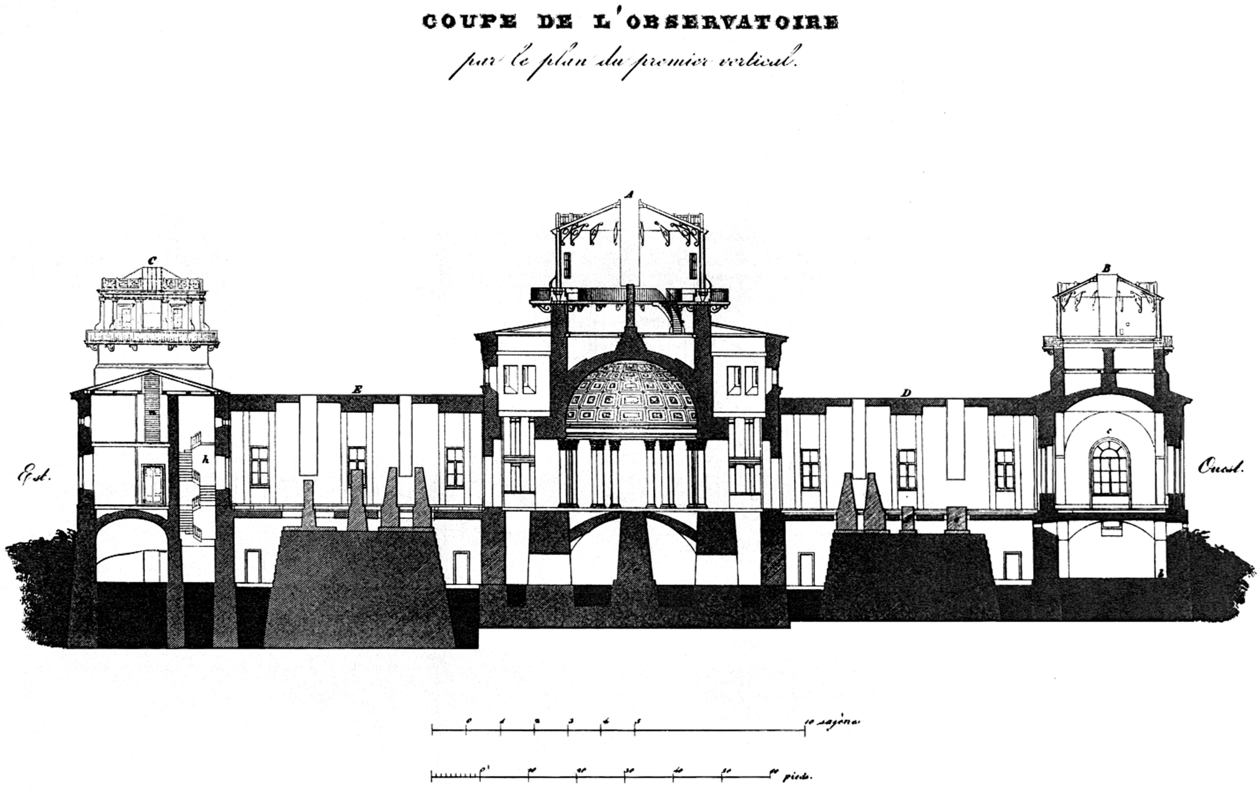

Figure 6.4: *The sectional view of the Nicholas Central Astronomical Observatory (Pulkovo Observatory) in the First Vertical Plane (Pulkovo Observatory, St. Petersburg)*

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 3^{rd} to the 9^{th} 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".

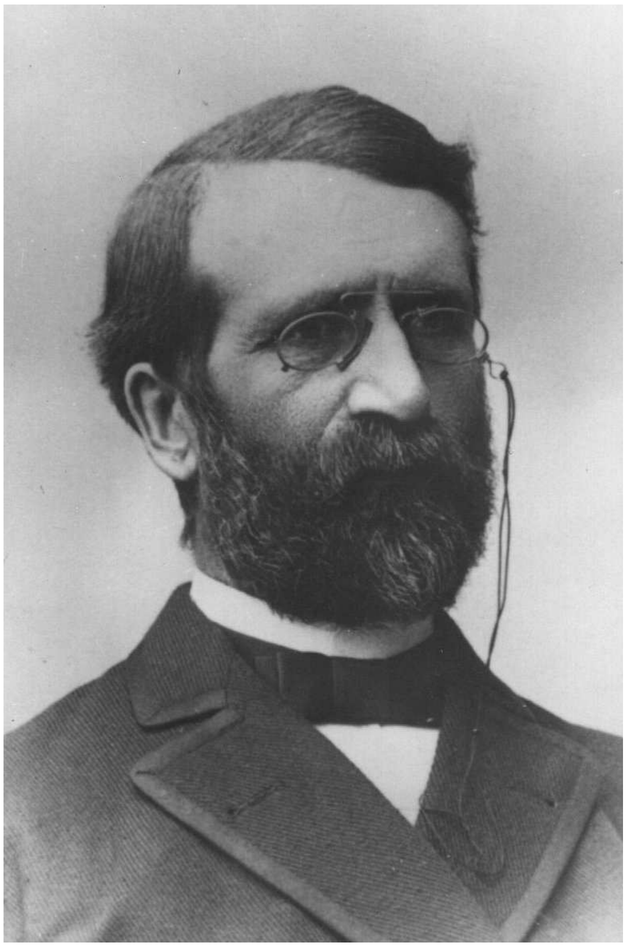

Figure 6.7: *Per Gustaf Rosén (1838–1914) (Pulkovo Observatory, St. Petersburg)*

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.

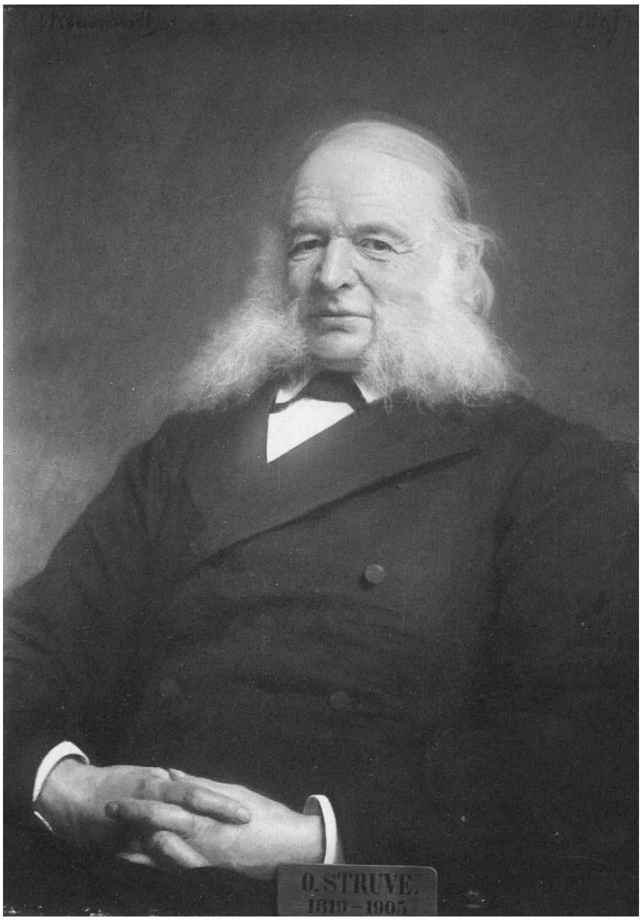

Figure 6.9: *Otto Wilhelm (Otton Vasil'yevich) Struve (1819–1905), director 1862 to 1889 (Courtesy of Pulkovo Observatory, St. Petersburg)*

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

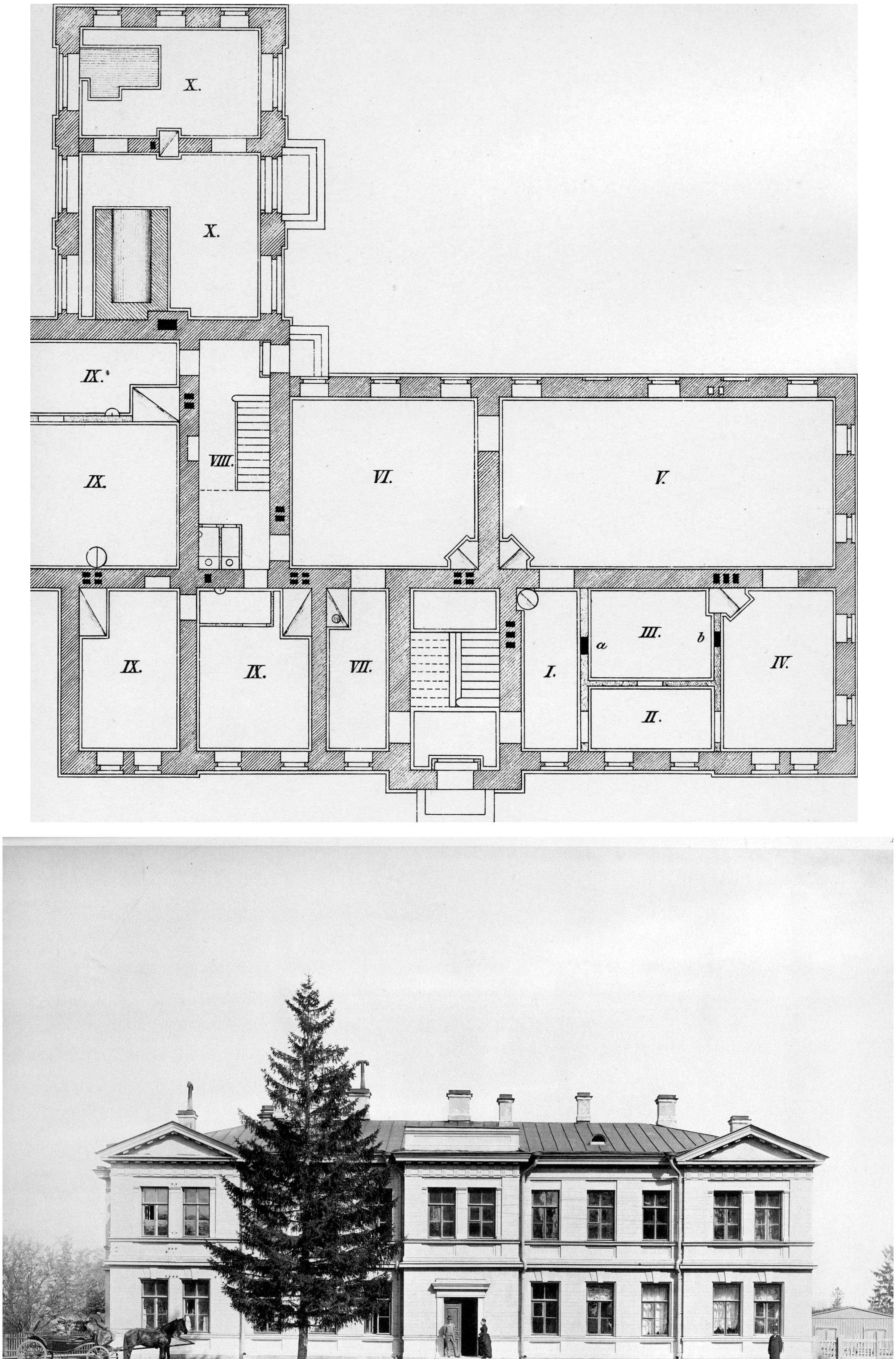

Figure 6.10: *Above: The Plan of the Ground Floor of the Astrophysical Laboratory Below: The Astrophysical Laboratory, architect Alexander F. Vidov (1886) (Pulkovo Observatory, St. Petersburg)*

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"*.

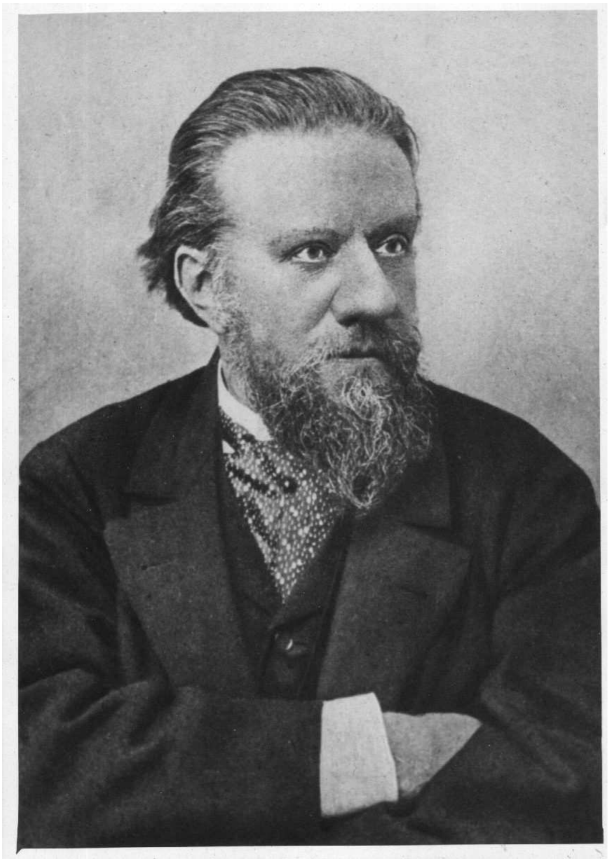

Figure 6.11: *Right: Hugo Gyldén (1841–1896) (Courtesy of Pulkovo Observatory, St. Petersburg)*

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

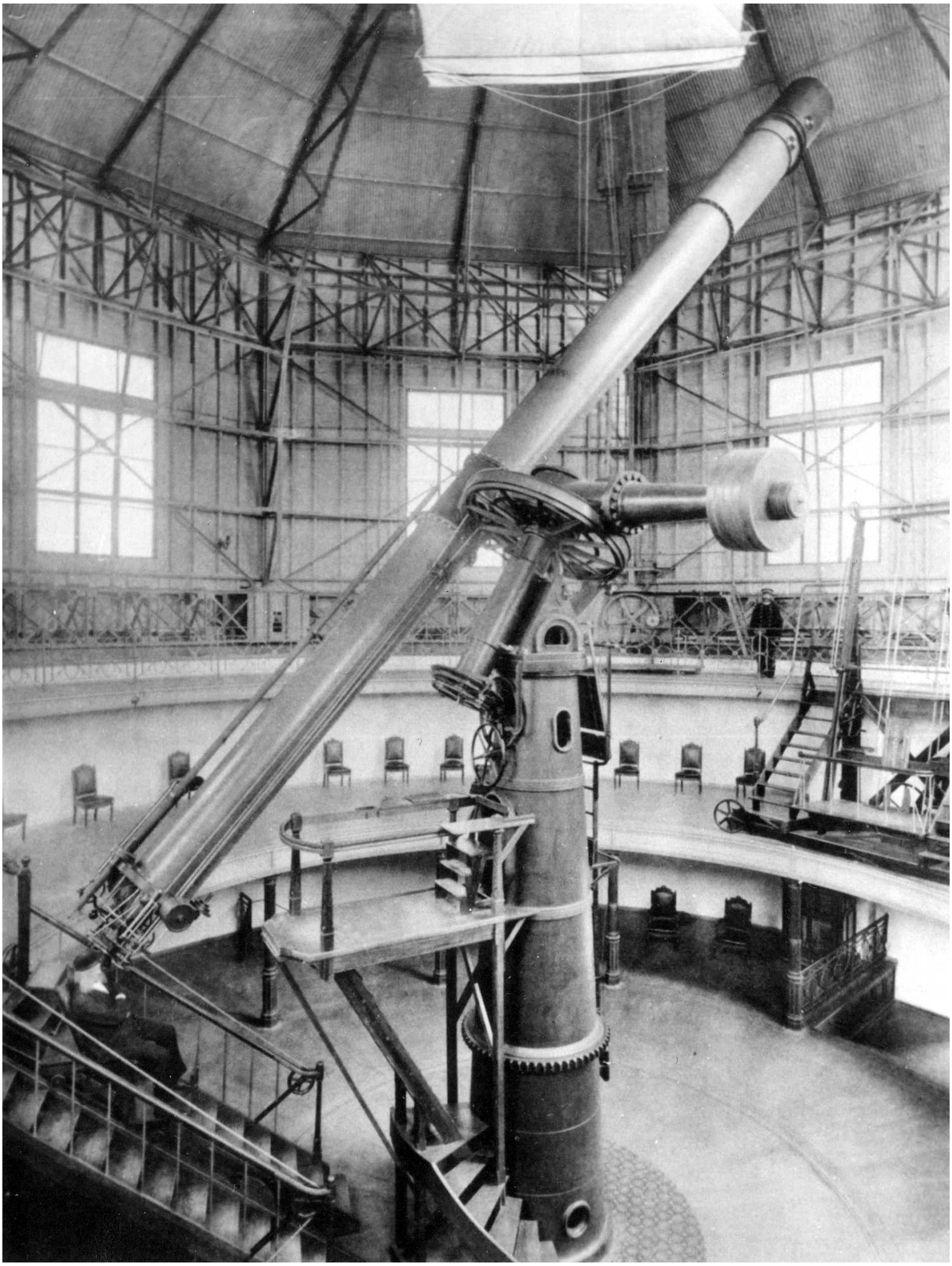

Figure 6.14: *The 30-inch refractor (76 cm), the optics by Alvan Clark & Sons of Cambridgeport, Massachusetts, the mounting and the tube by A. Repsold & Söhne (1883) (Pulkovo Observatory, St. Petersburg)*

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.

---

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?"

6.1 Bibliography

Абалакин, Виктор К.: *О. В. Струве – Дж. В. Скиапарелли. Переписка 1859–1904.* Санкт-Петерсбург: Наука 2005.

Dick, Wolfgang R.: Wilhelm Struve and the *Europäische Gradmessung.* In: *Geodeet* **30** (1994), Nr. 6 (Tartu).

McCutcheon, Robert A.: Sunset on Pulkovo. In: *Air & Space, Smithsonian Magazine*, Dec. 1994–Jan. 1995.

Passarge, Michael: Das Zentralobservatorium Pulkovo der Russischen Akademie der Wissenschaften. In: *Der Sternenbote* **42** (1999), Nr. 6 (Wien: Astronomisches Büro).

Porträtgallerie der Astronomischen Gesellschaft. Stockholm 1904.

Porträtgallerie der Astronomischen Gesellschaft. Budapest 1931.

Struve, Friedrich Georg Wilhelm: *Description de l'Observatoire Astronomique Central de Poulkova.* St.-Pétersbourg 1845.

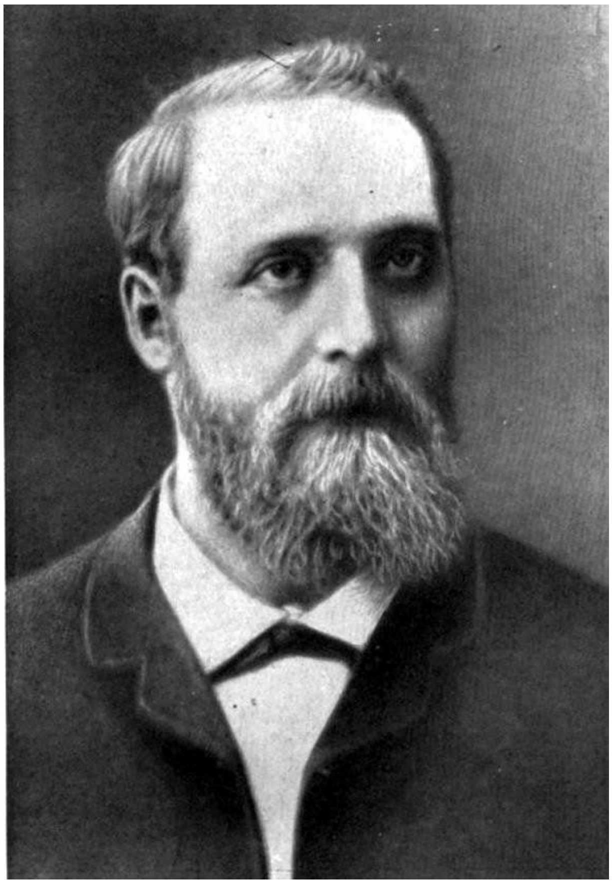

Figure 6.17: *Left: Theodore A. (Fyodor Alexandrovich) Bredikhin (1831–1904), director 1890 to 1895, Right: Aristarchos A. (Aristarkh Apollonovich) Belopolsky (1854–1934) (Pulkovo Observatory, St. Petersburg)*

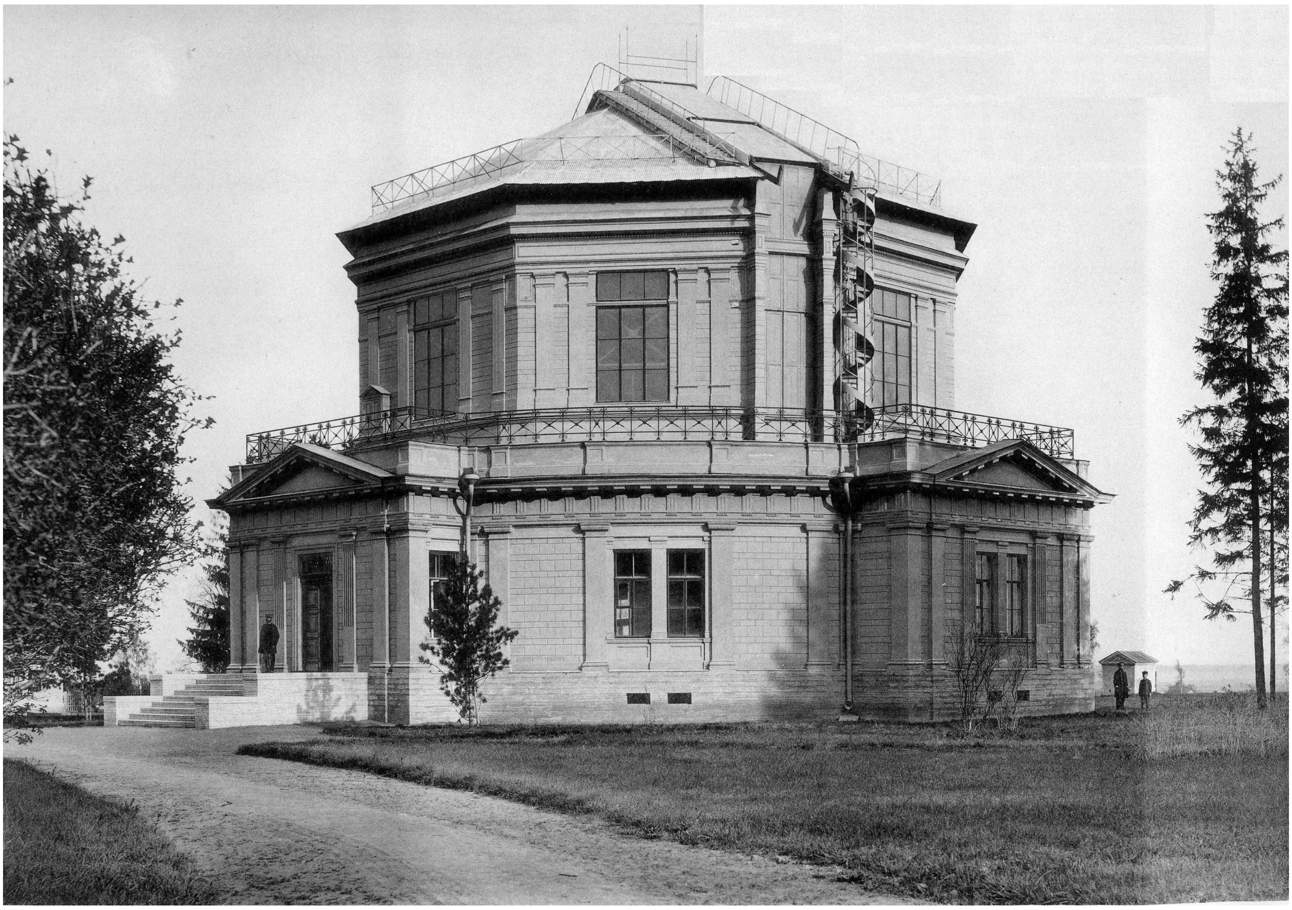

Figure 6.18: *The dome of the 30-inch refractor (Pulkovo Observatory, St. Petersburg)*