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

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

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Abstract

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

10.1 Introduction

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

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

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

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

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

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

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

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

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

10.3 The Controversy on the Parallax of 1830 Groombridge

In 1842, Argelander announced that the star 1830 of the Groombridge Catalogue had a proper motion of $7''$.[7] This was seen as an indication of proximity. Christian Peters (1806–1880) tried to determine the parallax of this star carrying out a series of observations between 1842 and 1843, using the vertical circle of the Observatory of Pulkovo. These observations led to a value of $0''.226\pm0''.141$.[8] Also in 1842 Heinrich Schlüter started an independent observational programme at the Observatory of Königsberg, employing the same instrument (a Fraunhofer heliometer) and techniques used by Bessel to determine the parallax of 61 Cygni. His observations were later reduced by Moritz Wichmann (1821–1859).

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

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

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

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

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

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

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

10.4 An Astronomical Challenge to Portugal

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

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

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

10.5 The AOL in the Context of Portuguese Regeneration

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

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

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

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

10.6 Mobilising Astronomical *Know-How* to Lisbon

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

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

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

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

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

10.7 Organising the Observatory

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

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

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

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

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

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

10.8 A Monumental and Technical Assemblage to Measure the Universe

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

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

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

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

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

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

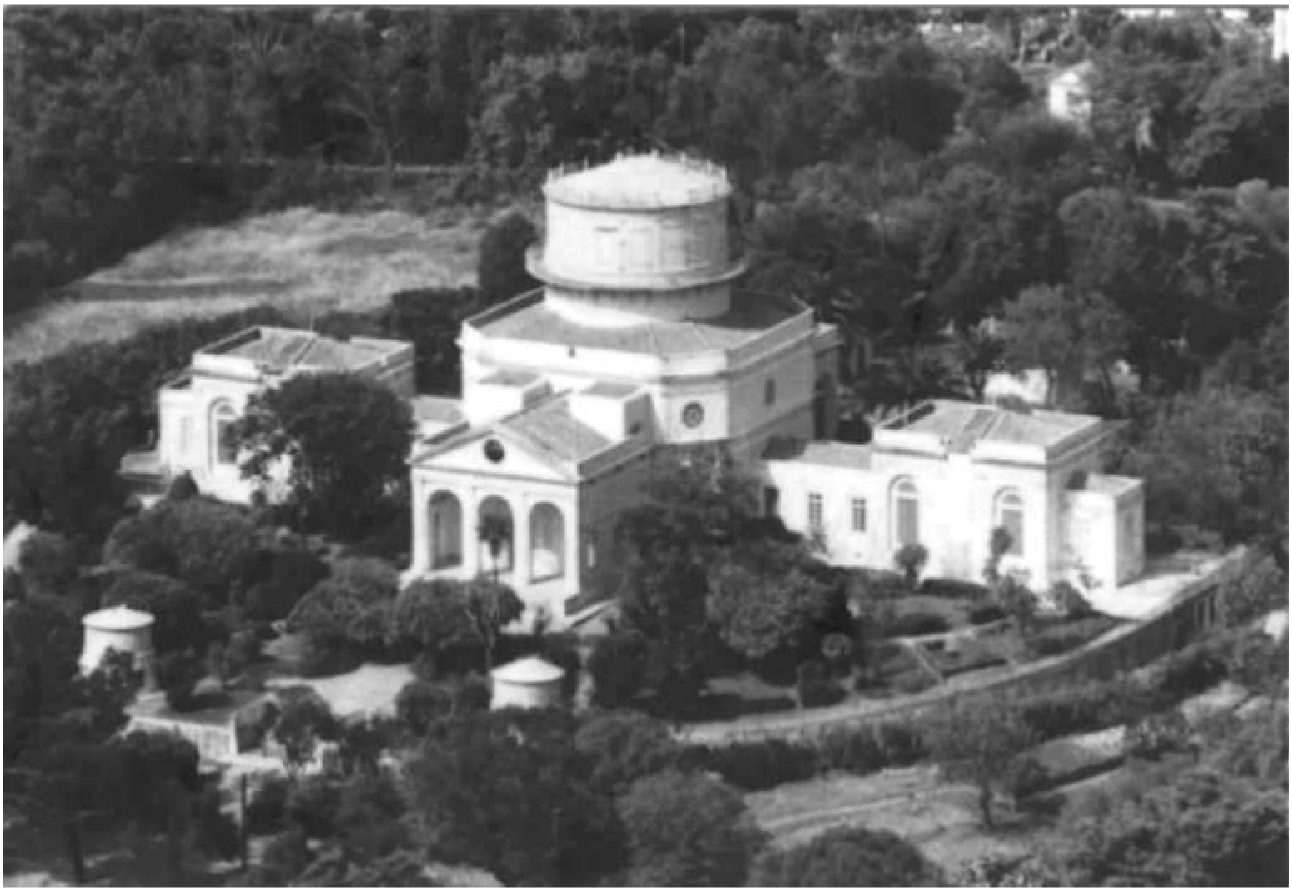

Figure 10.5: *Aerial view of the AOL (Archives of the AOL)*

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

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

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

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

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

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

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

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

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

10.9 Maximizing Tools and Techniques

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

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

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

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

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

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

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

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

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

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

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

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

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

10.11 Concluding Remarks

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

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

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

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

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10.13 Archives of the Astronomical Observatory of Lisbon

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