Observatories, instruments and practices in motion: an astronomical journey in the nineteenth-century

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Abstract

This paper addresses the establishment and development of the Astronomical Observatory of Lisbon (AOL). It focuses on some aspects of a journey made by its first astronomer and director, Frederico Augusto Oom (1830–1890) who, between 1858 and 1863, visited several observatories and instrument workshops in Europe, and spent long periods studying and practising at the Observatory of Pulkovo in Russia. This case is used to illustrate how a specific site of knowledge can be approached as an open and dynamic embodiment, the constitution and development of which interconnects several actors and spaces through a wide array of practices and interactions. For that purpose, the AOL is contextualized in a broad space of circulation of observatory plans, management styles, instruments and practices that ultimately connected the networks and circuits of nineteenth-century European astronomy with the geography of the Portuguese overseas empire.

1. Introduction: "saudade" and an astronomical mission

On 24 August 1858 Frederico Augusto Oom (1830–1890), a young Sub-Lieutenant of the Portuguese War Navy, left Lisbon heading for the Observatory of Pulkovo near St. Petersburg (Fig. 1), as an envoy for the Portuguese government. In a sort of a travel journal, Oom sought to pen down the mixed feelings he experienced as he saw the Portuguese capital vanishing behind the ship that carried him away. On the one hand, Oom got immersed in a blend of "saudade" (nostalgia) and insecurity: he had been sent away from his loved ones to a remote place, in a mission expected to last several years, which he was not sure of being capable of accomplishing with success. On the other hand, he was enthused by the prospects of attaining a respectable social status, securing a good income, and then a family. He could not keep dark thoughts at bay though. In a fatalistic tone, Oom added in his notes that there was always a

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good solution to put an end to one man's troubles, whatever those troubles were: a revolver plus a "sphere of Pb" (a sphere of lead).[1]

Fig. 1 – The Observatory of Pulkovo in the nineteenth-century.
(F. G. Wilhelm Struve, *Description de l'observatoire astronomique central de Poulkova*, 1845)

The anguish of the envoy contrasted with the enthusiasm of the Portuguese dignitaries who had sent him to Russia. The year before, Pedro V, the King of Portugal,[2] had given his patronage to the foundation of a new observatory in the Portuguese capital.[3] This undertaking counted on the enthusiastic support of Wilhelm Struve (1793–1864), the director of the Observatory of Pulkovo.[4] Struve was widely recognised as a skilful astronomer, and Pulkovo hailed as the most sophisticated observatory in the world. Pulkovo hosted out extensive programmes of stellar observations that resulted in new stellar catalogues and in refined values for the fundamental constants of astronomy.[5] However, Struve and his great observatory were not able to provide a convincing response to one of the most vexing problems of practical astronomy: the measurement of stellar distances by the method of trigonometric parallax, that is, by measuring the apparent annual shift in the position of a star due to the orbital motion of the Earth. It is well known that, in the late 1830s, Wilhelm Struve, Friedrich Bessel (1784–1846)

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[1] Frederico Augusto Oom, untitled and undated manuscript, Archive of the Astronomical Observatory of Lisbon – MUHNAC (henceforth Archive of the AOL), A576.

[2] On the life and reign of Pedro V see Maria Filomena Mónica, *Pedro V* (Lisboa: Temas e Debates, 2007).

[3] There was already an observatory in Lisbon, the Royal Observatory of the Navy, but it was actually a makeshift arrangement of a poor set of instruments installed at the Navy Arsenal. On this observatory, see António Estácio dos Reis, *Observatório Real da Marinha* (CTT- Correios de Portugal, 2009).

[4] On the early history of the Observatory of Pulkovo, and on the lives and works of its first directors W. Struve and Otto W. Struve, see: Alan Batten, *Resolute and undertaking characters: the lives of Wilhelm and Otto Struve* (Dordrecht: D. Reidel Publishing Company, 1987), and "The Struves of Pulkovo – a family of astronomers", *The Journal of the Royal Astronomical Society of Canada* 71, 1977: 345-372; Adam J. Szander, "F. G. W. Struve (1793-1864): astronomer at the Pulkovo Observatory", *Annals of Science* 28, 1972: 327-346.

[5] Kevin Krisciunas, "Pulkovo and the National Observatory movement: an Historical overview", in: J. H. Liske, V. K. Abalakin (eds.), *Inertial Coordinate System on the Sky* (IAU, 1990), pp. 29-38.

and Thomas Henderson (1798–1844) presented the first consistent results for the measurement of stellar parallax.[6] What is usually overlooked is that these results were nonetheless surrounded by doubt, and that the aforementioned astronomers were themselves convinced that the methods involved in such measurements were still in need of further discussion and improvement.[7]

A controversy on stellar parallax measurements with the French astronomer Hervé Faye (1814–1902) had led Wilhelm Struve to recognise Lisbon as an optimal place to foster stellar astronomy.[8] Several stars deemed suitable for parallax measurements crossed the zenith of the Portuguese capital, or passed close to it. They could thus be observed with minimal effects from atmospheric refraction. Moreover, the dark summer nights of Lisbon would favour the observation of nebulae, whose nature was under debate. And generally, the mild Portuguese climate should provide plenty of occasions of good visibility.[9]

Struve was thus convinced that the stellar realms could be efficiently scrutinized in Portugal. He wanted Pulkovo to secure the international leadership in stellar astronomy (or, in coeval parlance, "sidereal astronomy"). If there was a possibility of setting up a new observatory afar, able to further this yet incipient field beyond what was feasible in Pulkovo, then it should better have a close relation with the Russian observatory. Consequently, Struve made himself available to advise the Portuguese authorities on all technical and organisational matters concerning the future Astronomical Observatory of Lisbon (henceforth AOL).

The Portuguese authorities were receptive to Struve's advice. The first decades of the nineteenth century had been rather turbulent in Portugal, with the Napoleonic invasions and the move of the Portuguese court to Brazil, then the civil war between liberals and absolutists, and, after the official implementation of a liberal monarchy in 1834, the frequent conflicts between the conservative and progressive sects of the new regime.[10] In 1851, a coup d'état known as Regeneração gave way to a period of political and social pacification, marked by a focus on the modernisation of the country through major programmes of infrastructural

[6] J. D. Fernie, "The historical search for stellar parallax", *Journal of the Royal Astronomical Society of Canada* 69, 1975: 153-161, 222-239; 70, 1976: 40. For a broader historical contextualization see Michael Hoskin, *Stellar Astronomy. Historical studies* (Bucks: Science History Publications, 1982).

[7] Pedro M. P. Raposo, "The quest for stellar parallax in the nineteenth century, the 'astronomical capital of the world' and the foundation of the Observatory of Lisbon", in: Luís Saraiva (ed.), History of Astronomy in Portugal. Institutions, Theories, Practices (Porto: Sociedade Portuguesa de Astronomia, 2014), pp. 241-264.

[8] *Ibidem*.

[9] W. Struve to Lobo de Moira, 30 June 1857, translation (French to Portuguese), in "Acta da Sessão de 28 de Novembro de 1857", Archive of the AOL, FO17.

[10] Maria de Fátima Bonifácio, *Uma história de violência politica. Portugal de 1834 a 1851* (Lisboa: Tribuna da História, 2009); *O século XIX português* (Lisboa: Imprensa de Ciências Sociais, 2002).

enhancement (roads, telegraphs, railways, etc.).[11] These programmes were motivated not only by the wish to bolster the economy, but also by a strong concern with the external image of the country. King Pedro V was particularly sensitive to these aspirations. Prior to his coronation, he went on two European journeys in order to appreciate the realisations of material progress abroad.[12] A visit to the Observatory of Brussels in 1854, in the context of these travels, convinced him that the absence of a proper observatory in Lisbon was a motive for national shame.[13]

It was thus extremely convenient that Wilhelm Struve was interested in Lisbon. Pedro V eventually entrusted Filipe Folque (1800–1874),[14] his former tutor in mathematics, the head of the Portuguese geodetic surveys, and a member of the King's entourage in his European travels, with the foundation of a new observatory. This assignment included taking care of the liaisons with Struve and other foreign astronomers. As the main scientific advisor of the undertaking, Struve recommended that at least one apprentice was sent to Pulkovo in order to learn and practise the techniques of precise astronomical measurement. The envoy was also expected to visit and study the facilities, instruments and administration of other observatories, and to call at instrument workshops. Frederico Augusto Oom, a former student of Filipe Folque at the Polytechnic School of Lisbon (where the latter held the chair of Astronomy and Geodesy) was the chosen one. His mission, which was to last for five years, was expected to render a skilful observer, and above all an advanced observatory. In fact, more than a training and fact-finding mission, it would be an observatory-making journey.

The first two years of Oom´s mission are relatively well documented; the remainder of it, not so much. Nevertheless, the available sources suffice to provide an insight on the encounters, interactions and activities entailed in the mission, and on how it developed in tandem with the inception of the AOL. Oom´s journey can thus be used to look into the interplay between mobility, displacement and circulation in the making of a specific site of knowledge, in this case an observatory.

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[11] António José Telo, "O modelo político e económico da Regeneração e do Fontismo (1851-1890)", in: João Medina (ed.), *História de Portugal – dos tempos pré-históricos aos nossos dias,* Vol. XI (Amadora: Ediclube, 2004), pp. 115-156; José Miguel Sardica, *A Regeneração sob o Signo do Consenso – A Política e os Partidos entre 1851 e 1861* (Lisboa: Imprensa de Ciências Sociais, 2001); Maria Filomena Mónica, *Fontes Pereira de Melo* (Lisboa: Aletheia, 2009).

[12] Filipa Lowndes Vicente, *Viagens e Exposições – D. Pedro V na Europa do Século XIX* (Lisboa: Gótica, 2003).

[13] Pedro V/Academia das Ciências de Lisboa, *Escritos de El-Rei D. Pedro V coligidos e publicados pela Academia das Sciências de Lisboa*, Vol. I (Coimbra: Imprensa da Universidade, 1922), pp. 196-197.

[14] On Filipe Folque see: Luís Miguel Carolino, "Measuring the Heavens to Rule the Territory: Filipe Folque, the Teaching of Astronomy at the Lisbon Polytechnic School and the Modernization of the State Apparatus in Nineteenth Century Portugal", *Science & Education* 21, 2012: 109-133; Rui Branco, *O mapa de Portugal. Estado, Território e Poder no Portugal de Oitocentos* (Lisboa: Livros Horizonte, 2003); Maria Clara Pereira da Costa, *Filipe Folque (1800-1874) – o homem e a obra. O diário da sua viagem à Europa integrado no séquito de D. Pedro V, alguns ofícios e cartas particulares* (Lisboa, 1986).

The history of observatories has been given a great impulse by an approach based on the concepts of "observatory sciences" and "observatory techniques". This approach seeks to capture not only how observatories functioned in the context of wider political, socio-economic and epistemic contexts, but also how the latter were themselves shaped by observatory practices.[15] Yet, observatories are still approached, to a significant extent, as reified and circumscribed entities, serving essentially as stage, scenario and point of passage for the development of such practices. This is possibly a reflection of a less-accomplished aspect of the so-called "spatial turn" in the history of science. The spatial turn was certainly important in that it led historians to turn their attention to the local specificities of knowledge practices and to the geographical nuances of knowledge production, dissemination and appropriation.[16] However, specific spaces of knowledge have often been approached in a somewhat static and descriptive way, in the sense that the focus is placed on their arrangement and configuration in a certain historical moment, and on what happened inside, through and around them. But how did such spaces themselves evolve? What kinds of knowledge practices were involved in their design, construction and reconfiguration? How does the formation of a specific site of knowledge relate to other sites, and what kind of exchanges and mediations take place between them? What happens to practices, skills, instruments and research programmes in these processes?

This paper aims to address these questions by following Frederico Augusto Oom in his astronomical journey through mid-nineteenth century Europe. By doing so, I intend to show that a specific site of knowledge may be regarded as a dynamical embodiment the configuration of which changes with time, and the development of which entails a wide array of interactions involving several other spaces and locations.

It has been remarked that embodiments are multivalent; they can entail and represent a wide range of meanings, skills, and processes, as they can also trigger challenges and invitations.[17] They involve people and objects alike, human and non-human entities. To understand how scientific practices develop through a multitude of embodiments, we must follow and study people as well as instruments, books, samples, letters, buildings and many

[15] David Aubin, Charlotte Bigg and H. Otto Sibum (eds.), *The Heavens on Earth - Observatories and Astronomy in Nineteenth Century Science and Culture* (Durham, North Carolina: Duke University Press, 2010).

[16] See, for instance: Charles W. J. Withers, "Place and 'spatial turn' in geography and history", *Journal of the History of Ideas* 70, 2009: 637–658; Diarmid A. Finnegan (2008) "The spatial turn: geographical approaches in the history of science", *Journal of the History of Biology* 41, 2008: 369–388; David Livingstone, *Putting science in its place: geographies of scientific knowledge* (Chicago: University Press, 2003); Stephen J. Harris, "Long-distance corporations, big sciences, and the geography of knowledge", *Configurations* 6, 1998: 269–304; Steven Shapin, "The house of experiment in Seventeenth-Century England, *Isis* 79, 1988: 373-404.

[17] Lissa Roberts, "The Circulation of Knowledge in Early Modern Europe: Embodiment, Mobility, Learning and Knowing", *History of Technology* 31, 2012: 47-68.

other entities. However, following people is probably the best way of capturing the interplay between all of these entities, as well as to analyse how this interplay is framed by specific agendas and research programmes, and to scrutinize the different meanings and representations they involve.

This is the approach I seek to develop here. I will begin by pointing out the constitutive character of travels in the making of observatories, and by emphasizing their importance in the establishment of the Observatory of Pulkovo. Then I proceed to illustrate how the AOL, as an evolving project, was set in motion between Lisbon and St Petersburg through Oom's travels. For that purpose, I shall focus on some specific episodes of Oom's visits to instrument workshops and meetings with instrument makers, on activities he performed as a trainee astronomer in Pulkovo, on his participation in an eclipse expedition, and on encounters he had with other astronomers in different observatories. Finally, I address the AOL in place: the actual Astronomical Observatory of Lisbon, as it became embodied on the slope of a hill facing the River Tagus; the transformations it underwent; and how such transformations relate to Oom's journey.

2. The "Astronomical capital of the world", its roots and circuits

The Observatory of Pulkovo was inaugurated with pomp and circumstance in 1839. It was lavishly funded by Tsar Nicolas I, who, after entrusting Wilhelm Struve with its foundation, gave him "carte blanche" to spend as much as necessary in order to obtain the best available instruments. The observatory's building was designed as a cruciform complex, consisting essentially of a central block with wings radiating to the south, east and the west (Fig. 2).[18] The east and west wings also had extensions to the north, each topped by a revolving dome. A similar but bigger dome topped the central body and housed a 15-inch refractor by Merz & Mahler, the largest instrument of its kind in the world until the 1870s. The other fixed instruments included an Ertel vertical circle and a transit instrument by the same maker (both installed in the west wing); a Repsold transit instrument in the prime vertical (installed in the south wing); a transit circle also by Repsold (in the east wing); and a heliometer by Merz & Mahler (in the small dome in the east wing). Comet seekers, portable instruments for astronomical and geodetic observations, small telescopes, clocks, chronometers and auxiliary

[18] For a full description of the Observatory of Pulkovo in its original form see F. G. Wilhelm Struve, *Description de l'observatoire astronomique central de Poulkova* (St. Pétersbourg: Imprimerie de l'Académie Impériale des Sciences, 1845).

devices such as a level examiner, thermometers and barometers completed a collection that showcased the state-of-the art of astronomical instrumentation. This sumptuous collection of instruments was complemented with a vast and equally magnificent library. Completeness was valued as much as the practical needs of scientific work. For instance, in a description of the heliometer, Struve acknowledged that, six years after the inauguration of the observatory, the instrument remained unused. Priority was given to other instruments, but the heliometer was an improved version of the instrument employed by Bessel in stellar parallax measurements. Thus, Struve asserted, it had to be included in Pulkovo´s equipment.[19]

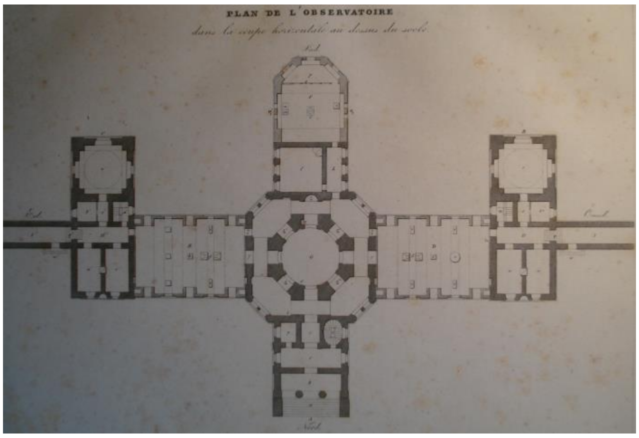


Fig. 2 – Plan of the Observatory of Pulkovo.
(F. G. Wilhelm Struve, *Description de l'observatoire astronomique central de Poulkova*, 1845)

The Observatory of Pulkovo was embedded in the culture of theatricality that pervaded Tsarist Russia.[20] It constituted a spectacle of big science, affirming the commitment of the Russian empire to scientific endeavour[21] in contrast with its external image of a fearsome and backward 'gendarme of Europe'.[22] The observatory soon started to attract prominent members of the international astronomical community. By the time Frederico Augusto Oom left Lisbon bound to Pulkovo in August 1858, the Central Observatory of Russia (as it was also known) had already been visited by Heinrich Christian Schumacher (1780–1850) of the Altona Observatory, the Astronomer Royal George B. Airy (1801–1892) of Greenwich, and G. P. Bond (1825–1865) of the Harvard College Observatory in Massachusetts, U.S.A, among

[19] *Ibidem*, p. 203.

[20] Simon Werrett, "The Astronomical Capital of the World: Pulkovo Observatory in the Russia of Tsar Nicholas I", in David Aubin, Charlotte Bigg and H. Otto Sibum (eds.), *The heavens on Earth…*, pp. 33-57.

[21] Mari Williams, "Astronomical Observatories as Practical Space: The Case of Pulkowa", in Frank A. J. L. James (ed.), *The Development of the Laboratory - Essays on the Place of Experiment in Industrial Civilization* (Hampshire and London: The MacMillan Press, 1989), pp. 118-135.

[22] W. Bruce Lincoln, *Nicholas I: Emperor and Autocrat of All the Russias* (Northern Illinois University Press, 1989), pp. 239-252.

others. Physical distance did not deter these astronomers from experiencing *in loco* what they perceived as the very embodiment of technical prowess in astronomy. The Central Observatory of Russia would keep on attracting prominent and less known visitors from all provenances. It was eventually dubbed the 'Astronomical Capital of the World'.[23]

But Pulkovo was by no means the only observatory to attract visitors. Throughout the nineteenth-century astronomers and practitioners in other fields got increasingly involved in international tours of places relevant to their specialities –observatories, museums, universities, laboratories, instrument workshops, and others. The traditional Grand Tour of noble education was thus assimilated into a new kind of learning and networking journey.[24]

The Central Observatory of Russia itself was, to a great extent, a product of the same processes of mobility. In 1834, when he found himself endowed with "carte blanche" from the Tsar, Wilhelm Struve knew where to find the advice and support he needed to set up the utmost observatory on Earth. Throughout his 25-year career as a professor of astronomy at the University of Dorpat (nowadays Tartu, Estonia), Struve had always been a keen traveller and a persistent networker, seeking to maintain close relations with the leading European astronomers and instrument makers of the day, especially those of the German lands.

His first assignment towards the establishment of the Central Observatory of Russia was precisely an observatory and instrument-workshop tour,[25] during which he discussed the plans for Pulkovo with prominent astronomers and craftsmen, such as: the already mentioned Friedrich Bessel, who was acclaimed as a master of precise astronomical measurement; Johan Encke (1791–1865), a renown observer based in Berlin; Bernhard August von Lindenau (1780–1854), formerly the editor of one of the first journals committed to astronomy and related sciences, known as *Monatliche Correspondenz*;[26] Heinrich Olbers (1758–1840), a medical doctor by training who became an authority in comets; Heinrich Christian Schumacher (1780–1850), editor of the important periodical *Astronomische Nachrichten*. Struve also maintained close contacts with other prominent mathematicians and astronomers such as Friedrich Gauss (1777–

[23] In his autobiography the astronomer Simon Newcomb (1835–1909) wrote: "I believe it was Dr. B. A. Gould who called the Pulkovo Observatory the astronomical capital of the world": Simon Newcomb, *The Reminiscences of an Astronomer* (Teddington: The Echo Library, 2007[1903], p. 149).

[24] For an overview of the role of travels in the making of knowledge, and some examples of tours such as those approached here but in fields other than astronomy, see: Ana Simões, Ana Carneiro, Maria Paula Diogo (eds.), *Travels of Learning. A Geography of Science in Europe* (Dordrecht: Kluwer Academic Publishers, 2003); Marie-Noëlle Bourguet, Christian Licoppe, Otto Sibum (eds.), *Instruments, travel and science: itineraries of precision from the seventeenth to the twentieth century* (London, New York: Routledge, 2002).

[25] F. G. Wilhelm Struve, *Description...*, p. 32.

[26] The full name of the journal was *Monatliche Correspondenz zur Beförderung der Erd- und Himmels-Kunde.* It preceded the *Astronomische Nachrichten* (mentioned below in the main text), which came to be one of the leading journals of astronomy in continental Europe, and which is still published nowadays.

1855) and Friedrich Argelander (1799–1875), whose advice he sought very frequently; and with instrument makers such as Carl von Steinheil (1801–1870) of Munich, the Ertel family (also of Munich), and the Repsold family of Hamburg.

Authorised by the Tsar to spend with no limits, relying on this network, and counting on the hard labour of Russian serfs, Struve would not have to wait for more than five years to see the Observatory of Pulkovo ready to be inaugurated. But there was more than spectacle about the observatory; through these contacts and exchanges, it was well grounded on the culture of precision that emerged in the German states over the first decades of the nineteenth century, whose main tenets were the commitment to rigorous measurement, the development of sophisticated instrumentation, and a thorough study and control of observational and experimental errors. This culture spurred the advancement of mathematical and physical sciences whilst providing the basis for modern administration and rationalised industrial production.[27]

Struve was careful in crafting the statutes of the Observatory of Pulkovo so that the Tsar agreed to commit it, primarily, to the advancement of astronomy. This allowed Struve to shape Pulkovo as the first national observatory dedicated to fundamental research.[28] In practice, it meant that Pulkovo would mainly seek to foster stellar astronomy on the grounds of precise measurement, namely by re-determining the fundamental constants of astronomy, and by measuring, as accurately as possible, stellar positions, the angular separation between components of double and multiple stars, and annual parallaxes.[29]

This required, among other things, that Pulkovo possessed first-class buildings and observation facilities, suitable for advanced scientific work. Struve's travels and contacts, together with his long experience as an astronomer at the Observatory of the University of Dorpat, allowed him to assemble a comprehensive synthesis of the foremost astronomical paraphernalia of the time. For example, the basic architectural shape of the Observatory of Pulkovo replicated a pattern that had become a common profile of astronomical observatories in the first half of the nineteenth-century, and which provided for a convenient distribution of

[27] Myles Jackson, *Spectrum of belief: Joseph von Fraunhofer and the craft of precision optics* (Cambridge - Massachusetts and London: MIT Press, 2000); Norton M. Wise (ed.), *The values of precision* (Princeton University Press, 1995); Katherine M. Olesko, *Physics as a Calling: Discipline and Practice in the Konigsberg Seminar for Physics* (Ithaca and London: Cornell University Press, 1991).

[28] Steven J. Dick, "Pulkovo and the National Observatory movement: an Historical overview", in J. H. Liske and V. K. Abalakin (eds.), *Inertial Coordinate System on the Sky* (IAU, 1990), pp. 29-38.

[29] F. G. Wilhelm Struve, *Études d'astronomie stellaire sur la Voie Lactée et sur la distance des étoiles fixes* (St-Petersburg: Imprimerie de L'Académie Impériale des Sciences, 1847).

workspace and instruments by the ground level and the upper floors.[30] Struve probably derived it from the observatories of Abo and Helsinki, where Friedrich Argelander had worked before moving to Bonn. Each of these observatories already incorporated other features adopted in Pulkovo, such as solid foundations for the piers supporting the instruments, and a large refractor. And Pulkovo´s much-envied 15-inch refractor (for several years, the largest in the world) was essentially a developed version of a famous 9-inch refractor made by Fraunhofer, which Struve had installed in Dorpat back in the 1820s. The revolving domes of the Observatory of Pulkovo also had the same design as the domes of the Dorpat Observatory. And the settings of its transit circle were based on those of the Berlin Observatory.

Pulkovo bore no striking resemblance to any of the abovementioned counterparts, but they all provided valuable elements and insights on issues such as the way to install the observational apparatus in order to achieve maximum precision, the architectural combination of residential and observing spaces, and the spatial organisation of the observatory as a workplace. Pulkovo was more about perfecting what already existed than about groundbreaking innovation.

It must be noted, though, that it was not a finished and closed showcase. In the *Description de l'observatoire astronomique central de Poulkova*, a detailed and lavishly illustrated, two-volume portrait signed by Struve himself,[31] and which the Russian authorities distributed to sovereigns and savants all over the world, the director of Pulkovo already pointed out several improvements that could be introduced in further versions of the apparatus presented in the book. Struve was not giving away his technical insights lightly: he was presenting Pulkovo as the template observatory to which all future astronomical endeavours should refer.

The AOL provided a convenient opportunity to produce a condensed and perfected version of Pulkovo, suited to excel in parallax measurements and other investigations in stellar astronomy. In order to make it state-of-the-art, it was imperative to travel again the circuits on which Pulkovo was grounded. Struve remained a keen traveller and would give a helping hand, using visits and journeys undertaken for other purposes to discuss some issues related to the Portuguese undertaking. However, if Oom was bound to become the first director of the AOL, then he should be able to do it on his own. And since it was, to a great extent, a matter of

[30] For an overview of the architecture of observatories see: Peter Müller, *Sternwarten in Bildern: Architektur Und Geschichte Der Sternwarten Von Den Anfangen Bis CA. 1950* (Berlin, Heidelber: Springer-Verlag, 1992); Marian Card Donnelly, *A short history of observatories* (Eugene: University of Oregon Books, 1973).

[31] See reference in note 18.

securing a sophisticated apparatus, it was very appropriate then that Oom began by visiting an instrument workshop.

3. An observatory in motion

3.1 At the workshop

Astronomers often called at instrument workshops or wrote to traders presenting ideas and requests the feasibility of which the craftsmen assessed on the grounds of their manufacturing experience. Preliminary tests and assessments were undertaken and discussed throughout the production process, especially when innovative designs or substantial modifications to previously existing instruments were involved.

This interaction between astronomers and craftsmen was framed by a tension between a gift economy and a commodity economy,[32] which pervaded the highly competitive business of advanced instrument making. Obviously, neither instrument makers were oblivious to profit, nor were astronomers amenable to give away all of their technical musings and insights for the financial benefit of others. Nevertheless, there could be substantial gains to both parts if their interests were efficiently negotiated, and if the outcome was sound: instrument makers augmented their repertoire, experience and prestige in the market, whereas astronomers got state-of-the-art instruments. Of course this was not always the case: instruments often proved faulty when put to work, and relations between users and suppliers could sometimes get sour.[33] But Wilhelm Struve had already established enduring relations with craftsmen such as the brothers Adolph Repsold (1806–1871) and Georg Repsold (1804–1867), who ran the firm founded by their father Johann Georg Repsold (1770-1830) some decades before.[34] By the time Oom went abroad, Wilhelm´s health was in decline, but his son Otto Struve (1819–1905), who also acted as an advisor to the Portuguese authorities, would maintain these liaisons as active and productive.

[32] Davis Baird, "Scientific instruments between making, epistemology, and the conflict between gift and commodity economies", *Society for Philosophy and Technology* 2, Summer-Spring 1997, http://scholar.lib.vt.edu/ejournals/SPT/v2n3n4/baird.html (accessed 8 July 2014).

[33] Simon Schaffer, "Easily Cracked: Scientific Instruments in States of Disrepair", *Isis* 102, 2011: 706-717; "The Bombay Case: Astronomers, Instrument Makers and the East India Company", *Journal for the History of Astronomy* 43, 2012: 151-180.

[34] In the period under focus here, the firm was named A. & G. Repsold. For an overview of its history see "Repsold, Johann Georg", Complete Dictionary of Scientific Biography, 2008, www.*encyclopedia.com* (accessed July 8, 2014).

The headquarters of the Repsold firm in Hamburg was the first official stop of Oom's mission, in September 1858.[35] The Repsolds had been commissioned the construction of the main instruments of the AOL.[36] These had been suggested by Wilhelm Struve and consisted of a transit circle, a transit instrument in the prime-vertical (the great circle at right angles with the celestial meridian), and a large equatorial refractor.

Oom was welcomed by Georg Repsold, who, after giving him a general tour of the premises, took the Portuguese envoy to see some components of the Lisbon meridian circle that had already been constructed. The transit circle had become the main observational instrument for cataloguing the heavens, that is, to measure accurately the coordinates of celestial objects.[37] In the Lisbon project, the transit circle had solely an ancillary role. It would be used to establish reference points for the stellar parallax investigations, and to determine local time. It was, nonetheless, carefully designed as an improved version of the transit circle of Pulkovo.[38]

As the future head of the AOL, Oom needed to master the anatomy and the inner workings of all of its major instruments. For the time being, as an apprentice, he would not have much input. But he was expected to oversee the manufacturing process, to check if everything went according to the plans ascertained between the Struves, the Portuguese authorities and the craftsmen, and to report on everything to Folque via mail. Oom was not only an astronomer in the making; he was also the eyes and ears of Folque and the other Portuguese dignitaries entrusted with the foundation of the AOL, amidst the international networks and circuits in which the new observatory was evolving.

Wilhelm Struve placed his greatest expectations on the prime-vertical instrument. He had used the Pulkovo´s prime-vertical (Fig. 3) to refine the values of the constants of aberration and nutation,[39] and believed that precise measurements of several stars in the prime vertical of Lisbon with a revamped instrument would give a decisive impulse to stellar parallax

[35] F. A. Oom to Filipe Folque, 17/29 September 1858, Archives of the AOL, FO18. Note that, at the time, Russia had not adopted the Gregorian calendar yet. Thus, the date for some letters cited in the remainder of the article is given in the old style/new style form, as in this case.

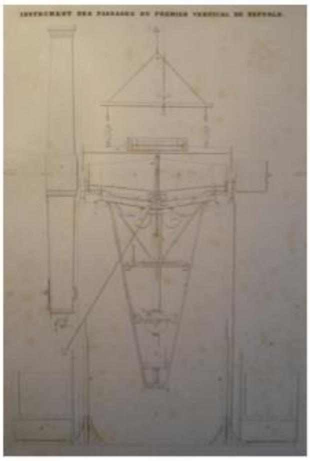
[36] The mechanical structures only; the optical elements (namely the objective lenses) would be supplied by the Merz and Steinheill firms.

[37] J. A. Bennett, *The divided circle: a history of instruments for astronomy, navigation and surveying*, (Phaideon, Christie's, 1987), pp. 174-177.

[38] The transit circle supplied to Lisbon was based on a similar instrument that the Repsolds had made for the Madrid Observatory in 1854, and in which they had had already introduced some improvements. One of the changes introduced had to do with the dimension of the circles (see fig. 12), which were smaller in the Madrid and Lisbon versions. It was assumed that the effects of flexure (bending by the effect of gravity) and temperature variations would be less significant for smaller circles (A. & G. Repsold to Folque, 26 April 1857, Archive of the AOL, C251).

[39] F. G. Wilhelm Struve, "Notice sur l'Instrument des passages de Repsold, établi à l'Observatoire de Poulkova dans le premier vertical, et sur les résultats que cet instrument a donné pour l'évaluation de la constante de l'aberration", *Astronomische Nachrichten* 20, 1843: cols. 257-262.

investigations. The new instrument (Fig. 4) was to be built only after the transit circle was completed, but the Repsolds had already assembled a tri-dimensional model, at the scale of 1/12, which they also presented to Oom. Models were especially useful in these preliminary stages, as they provided a basis to discuss and negotiate further modifications and improvements before actual production. The model that Oom saw at the Repsold warehouse already incorporated some changes indicated by Struve. They were essentially aimed at reducing the influence of mechanical errors in the observation, and at turning the instrument into a more versatile piece, adjustable to great circles other than the prime vertical. This last feature would increase the number of measurable stars.[40]




Figs 3 and 4 – Schematic drawing of the prime-vertical instrument of the Observatory of Pulkovo, and a redesigned version of the same instrument at the Observatory of Lisbon.
(F. G. Wilhelm Struve, *Description de l'observatoire astronomique central de Poulkova,* 1845, and Astronomical Observatory of Lisbon – MUNHAC, Museu Nacional de História Natural e da Ciência)

The model was then sent to Bonn Observatory, where Struve would call to discuss it with Argelander. Struve knew well that valuable insights and ideas came out of these conversations. In fact, the interaction between astronomers was as important as the exchange between astronomers and craftsmen, as far as the production of advanced instrumentation was concerned. Furthermore, Struve wanted to make sure that the revamped instrument, and the Lisbon project in general, garnered the support of his peers.

Struve was possibly disappointed to know that Argelander was not convinced by the prospects of measuring stellar parallax in the prime vertical. Argelander endorsed the construction of the instrument nonetheless, because it was, above all, an experiment in instrument design and observing techniques. After all, what did well-established astronomers

[40] Otto Struve to Filipe Folque, 2 July 1857, 23 January 1858, Archive of the AOL, FO17.

such as Struve and Argelander have to lose? The AOL would be located far away in the very western tip of Europe, and the Portuguese crown was putting the money in. If it succeeded, the merits would be theirs too; if it did not, the Portuguese would carry that burden. All they had to do was to steer it from afar and to assist Oom in his mission.

3.2 Placing the observatory from a distance

Despite this drive to explore new avenues, the experience accumulated in Pulkovo and other observatories was never to be overlooked. This applied not only to the building and the instruments, but also to the choice of the site where the AOL should be built. The Portuguese authorities initially considered some locations in Lisbon, conveniently close to the city's core, hence to the local centres of political and scholarly life. Struve had remarked on the importance of this proximity, but he equally underlined that the AOL should, at the same time, be distant enough to safeguard astronomers from the temptations of the capital. And above all, it had to provide stable ground for the main instruments, besides offering good visibility. None of the first suggested sites fulfilled these requirements.

King Pedro V eventually proposed that the observatory be built in Tapada da Ajuda, a royal estate used as a game park. Tapada was located in the outskirts of Lisbon, but within reach. And it faced the River Tagus, thus the observatory would feature as a landmark to those arriving in Lisbon or leaving the city by the river. Pedro V wanted it to be placed on the highest area of the park, but Peter Andreas Hansen (1825–1876) of the Gotha Observatory informed the Portuguese authorities that observations at the old building of this observatory, located on the top of a hill, had always been hampered by exposure to the wind.[41] The same could happen in Lisbon, he noted, if the AOL was placed atop Tapada. It was then decided that the AOL would be built further down, but another problem emerged: the soil was made of columnar basalt, a type of rock that tended to expand and contract with temperature variations.

The Portuguese authorities would not make a final decision without a seal of foreign authority. Since F. A. Oom was in transit, he would consult his expert interlocutors on this issue too. For that purpose, Tapada had somehow to go abroad with him. So it went, in the form of geological maps and a report commissioned from a professor of geology at the Polytechnic School of Lisbon.[42] This material was forwarded to F. A. Oom, who presented it to the

[41] "Acta da Sessão de 23 de Janeiro de 1858", Archive of the AOL, FO17.

[42] Francisco António Pereira da Costa, untitled and undated report, Archive of the AOL, C250.

Repsolds upon his first visit. They were used to assessing the stability of instruments; their opinion on this matter should be valued too. They approved the construction of the AOL further down in Tapada da Ajuda, but, careful as to the limits of their jurisdiction, recommended Oom to discuss the matter further with the astronomer Christian Peters. So did Oom, who, before reaching St. Petersburg, called at the Altona Observatory, where Peters, formerly an astronomer at Pulkovo, had moved. Peters warmly welcomed Oom. He keenly examined the charts and the report presented by the Portuguese envoy, and in the end gave his approval to the suggested site.[43] The Struves would have the final word, but they held the same opinion. It was thus decided that the AOL would be built on the slope of Tapada da Ajuda, roughly halfway from the top of the park.

Peters became an important advisor for the Lisbon project. He made himself available to oversee the acquisition of clocks and electro-chronographic devices from the Krille firm (later Knoblich), based in Altona. The Altona Observatory was to function as a checkpoint for these devices, which would be examined and tested there before their dispatch to Lisbon. As Oom was about to verify *in situ*, the Pulkovo astronomers were not particularly fond of electro-chronographic devices, preferring the old eye-and-ear method to the so-called American method.[44] However, several observatories in Europe had already adopted the latter, and the Portuguese authorities decided to adopt it too. It was then necessary to resort to other sources of expertise and advice on this particular matter. Nevertheless, Pulkovo continued to provide the main template for the AOL. Oom had to proceed to St. Petersburg.

3.3 Initiation at the 'Astronomical Capital'

Oom arrived in Pulkovo on 4 October 1858. Since Wilhelm Struve had fallen ill, Otto would supervise his apprenticeship. As an apprentice, Oom did not have immediate access to the main observing rooms. He would begin by working with a modest transit instrument supplied by the Ertel firm, which was placed in an external and small observation tower, usually reserved for apprentices and military officers practising to perform surveying work.

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[43] F. A. Oom, untitled and undated manuscript, Archive of the AOL, A576; F. A. Oom to Folque, 17/29 September 1858, Archive of the AOL, FO18.

[44] The ear-and-eye method consisted of estimating the fraction of a second corresponding to the transit of a star or other celestial object by a reticule wire. In the American method, an electric chronograph was used to record both the signals from the clock, and the signals produced by the observer by means of a telegraphic switch. See Ian Bartky, *Selling the True Time* (Stanford: Stanford University Press, 2000), esp. pp. 32-44.

Oom found the Ertel instrument in a serious state of disrepair, serving essentially as a nest for invading flies. His task was to make it fit to determine time accurately, through observations of stellar transits. There was a long way to go. It was necessary to disassemble the instrument and to put it together again, to determine the angular distance of its reticule threads, to align it with the meridian, to adjust the illumination of the field of view, to check the piers of the instrument, and to clean the divided circles (besides, of course, removing the flies).[45] This was the gist of practical meridian work, which any serious professional astronomer should master before engaging in higher scientific pursuits. If Oom was bound to direct a great observatory, connected to the "astronomical capital of the world", he ought to be equally at ease with a small transit instrument in a narrow observation tower, and with a great equatorial or prime vertical-instrument inside a fancy astronomical building. After all, Wilhelm Struve himself had performed similar operations early in his career, at the Observatory of the Dorpat University.[46] In Pulkovo, astronomers were supposed to be dexterous practitioners, not only learned gentlemen.

Moving around narrow spaces, fixing things by making the best use of what was at hand, upholding the scientific acumen with a clear objective in mind, and enduring adversity, none of this should be strange to a naval officer like Oom, who had experienced long periods embarked on the near-obsolete vessels of the Portuguese War Navy. Such a background surely helped to alleviate the hardships of becoming an astronomer in a place like Pulkovo, where, as Oom later wrote to Folque, in wintertime, temperatures could drop to the point of the telescope tube damaging the skin of the astronomer if he touched it carelessly.[47]

Fortunately for Oom, not all work involved such a level of physical strain and risk. A substantial part of his apprenticeship consisted of theoretical studies and computing work. Oom had been instructed in Portugal to study practically every topic of coeval astronomy, side-by-side with learning the craft of precise observation. He was particularly expected to learn the method of least squares. This is a statistical tool of paramount importance to deal with random errors of observation,[48] which, by then, was still absent from the teaching and practice of astronomy in Lisbon. Oom learnt it in earnest, applying the method to observations carried out in Pulkovo with the transit circle, and to sets of data concerning comparison stars used in the

[45] F. A. Oom to Filipe Folque, 2 February/22 January 1859, Archive of the AOL, FO18.

[46] Alan H. Batten, *Resolute and undertaking characters*, p. 18.

[47] F. A. Oom to Filipe Folque, 22 January/2 February 1859, Archive of the AOL, FO18.

[48] Zeno G. Swijtink, "The Objectification of Observation: Measurement and Statistical Methods in the Nineteenth Century", in: Lorenz Kruger, Lorraine Daston, Michael Heidelberger (eds.), *The Probabilistic Revolution. Volume I: Ideas in History* (Cambridge, Massachusetts and London: MIT Press, 1987), pp. 261-285, esp. p. 262.

observation of planets and asteroids. The German way of doing astronomy required the practitioner to be not only a proficient observer and a bit of a craftsman, but also an applied mathematician and proficient at computing.

Pulkovo was a small community of Baltic-German astronomers living an almost monastic life at the Central Observatory of Russia. As several visitors noted,[49] families were constituted there and grew through the arrangement of marriages within the community, and its members lived their lives practically confined to the observatory, which had is own logistics and rituals. During the first decades of Pulkovo´s activity, Wilhelm Struve was revered as an almighty patriarch. His son Otto, who succeeded him as director, maintained the ascendant of the Struve clan over the observatory. The Slavophil sects of the Academy of Sciences of St Petersburg were not pleased with this situation, but the German–Baltic bias and the influence of the Struves would prevail for five decades.

Unfortunately, the available sources do not tell us much about the way Oom lived and moved around the spaces of the Pulkovo Observatory, nor how he interacted with this community. His relationship with Otto seems to have been distant and cold. Although Otto continued his father's work as an advisor to the Lisbon project, he was far from showing Wilhelm's enthusiasm. Neither did Oom seem to have established any especial relations with other foreign apprentices working in Pulkovo. Among them was Giovanni Schiaparelli (1835–1910), later of Mars-canals fame.[50] Oom's warmest personal relations in Pulkovo were seemingly established with the astronomer Theodor Winnecke (1835–1897), who became the first director of the Strasburg Observatory.[51]

In any case, Oom was too busy with his assignments, which also included the study of German language. German was not only the colloquial language in Pulkovo´s daily life, but also the idiom in which some of the most relevant works in the astronomy and geodesy of the day were written. It was mandatory that Oom mastered it as well. He was at the Central Observatory of Russia, but also in a house of German science. As Oom had the chance to learn, Struve and his collaborators were sanguine in this regard. For instance, the repeating circle was much favoured by French astronomers for geodetic operations, but for the Struves, using this instrument was anathema. The theodolite and the reiteration method, emblematic of the culture

[49] See, for instance, Simon Newcomb, *The Reminiscences of an Astronomer* (Teddington: The Echo Library, 2007 [1903]), p. 150.

[50] K. Maria D. Lane, "Geographers of Mars. Cartographic Inscription and Exploration Narrative in Late Victorian Representations of the Red Planet", *Isis* 96, 2005: 477-506.

[51] Andre Heck, "Strasbourg Astronomical Observatory and its Multinational History", in: Andre Heck (ed.), *The Multinational History of Strasbourg Astronomical Observatory* (Dordrecht: Springer, 2005), pp. 1-61.

of precise measurement that developed from the early nineteenth century onwards in the German lands, were always to be preferred. The Struves even went to the point of lambasting the Ertel firm for engaging in the manufacture of repeating circles, as Oom told Folque in one of his dispatches.[52] Wilhelm Struve had also implemented at Pulkovo the principle that a major instrument should have a sole dedicated observer, so that their combined errors remained, as much as possible, constant. This approach, favoured by German astronomers, contrasted starkly with George B. Airy's management of Greenwich, where a number of hired observers performed mechanized observing tasks with the same instrument, according to a well-defined rota, as in a factory.[53]

During the first stage of his apprenticeship, Oom must have spent most of his time between his study and the small observation tower where he worked with the Ertel transit instrument. The opportunity to participate in a Russian expedition bound to Bilbao (Spain) to observe the solar eclipse of 18 July 1860 certainly emerged as an appealing prospect. Oom promptly requested to partake of it. It was not only an opportunity to testify a relatively rare and impressive phenomenon (weather permitting, of course), but also a chance to break temporarily from the routines of his apprenticeship, and to come closer to his native Portugal. But there was work to do all the way to Spain.

3.4 Between the observatory, the workshop and the field: an eclipse tour

In June 1860, on his way to Bilbao, Oom visited the Repsold firm again. The transit circle ordered for Lisbon had already been completed. Oom was instructed from Portugal to analyse it in detail, and then compare it minutely with the Pulkovo instrument upon his return to Russia.[54] This was intended to put him in good stead to install the instrument properly, to take advantage of the improvements it incorporated, and to deal with any technical troubles that might arise when it was put to work. And of course, to make sure that the Repsolds had built the instrument according to the ascertained plans.

Oom also examined an equatorial mount commissioned by the Gotha Observatory, which followed a design suggested by Peter Hansen.[55] Throughout the nineteenth-century,

[52] F. A. Oom to Filipe Folque, 22 January/2 February 1859, Archive of the AOL, FO18.

[53] Simon Schaffer, "Astronomers mark time. Discipline and the Personal Equation", *Science in Context* 2, 1988: 115-145; Robert W. Smith, "A national observatory transformed: Greenwich in the nineteenth-century", *Journal for the History of Astronomy* xxiii, 1991: 5-20.

[54] F. A. Oom to Filipe Folque, 31 July 1860, Archive of the AOL, FO18.

[55] A. & G. Repsold to Filipe Folque, 16 January 1862, Archive of the AOL, C251.

there was a wide effort to turn the equatorial refractor into a proper measuring device, able to compete with meridian instruments in the measurement of celestial coordinates.[56] Equatorials were normally used for micrometric measurements only. A micrometer with fixed and mobile threads would be coupled to the telescope focus, and then used to reckon small angular distances, such as the separation between the two components of a double star, or the distance between a certain star and another star of reference, so that possible changes in position due to annual parallax could be detected. It was chiefly for this last function that Wilhelm Struve had included the equatorial in his plans for Lisbon. Struve also wanted the instrument to be used in the observation of nebulae but he was equally keen to shape it into a measuring device in the sense described above. This required that its mount was very stable, so that the coordinates of the observed objects could be read accurately in the graduated circles attached to the mount's axes. Hansen's design sought precisely to fulfil this requirement. Struve then suggested it be included in the Lisbon equatorial, thus Oom was instructed to study the Gotha prototype and to report on it to Folque.[57]

During his travel to Spain, Oom also visited the observatories of Berlin, Bonn and Greenwich. In Berlin, Oom was welcomed by Johann Encke, who showed him the centralized system of time signals used in that observatory. The system consisted of a master clock electrically connected to slave clocks distributed around in the various observing rooms. Folque considered introducing a similar arrangement in Lisbon; since Pulkovo had nothing similar, Oom returned with a detailed description of the system.

The visit to the Bonn Observatory was also productive. Oom later wrote to Folque[58] about the long conversation he entertained there with Argelander. The astronomer and his visitor thoroughly discussed technical matters such as the design of the transit instrument in the prime vertical, and the best way to set up the piers on which the instruments would rest, in order to avoid the effects of humidity and temperature, and thus provide for higher precision. As already mentioned, Argelander was wary about the viability of performing stellar parallax investigations in the prime vertical, but he reaffirmed his support to the Lisbon undertaking before Oom.

Perhaps because the AOL was already well grounded on the Observatory of Pulkovo and its German networks, the ensuing visit to the Royal Observatory, Greenwich, was

[56] James A. Bennett, *Church, State and Astronomy in Ireland – 200 years of Armagh Observatory* (Belfast: Armagh Observatory/The Institute of Irish Studies-The Queen's University of Belfast, 1990), p. 23.

[57] F. A. Oom to F. Folque, 31 July 1860, Archive of the AOL, FO18.

[58] *Ibidem*.

seemingly more circumstantial. Prior to joining the British and Russian parties aboard the HMS *Himalaya* towards Bilbao, Oom went to Greenwich, where he was received by Airy. He did not report any particular conversation with the Astronomer Royal; nor did he convey any detailed analysis of the instruments, which he said, nonetheless, to have observed carefully, tersely describing them as "monstrous".[59]

This does not mean that Greenwich did not have an influence on the AOL. Folque had visited the British observatory in 1854, in the context of Pedro V´s European tours. This visit was pivotal in motivating him to steer the foundation of a new observatory in Lisbon, as suggested by the enthusiastic recollections he left in his travel journal.[60] A few years after these journeys, a time-ball was installed at the Lisbon port, very likely as an emulation of the Greenwich time-ball.[61] Airy had also advised Folque and other Portuguese dignitaries on matters such as the acquisition of clocks.[62] And the study of electro-chronographic devices at Greenwich was certainly informative.

His eclipse tour had already been worthwhile, but there was still the phenomenon itself to observe. Throughout the remainder of the nineteenth-century, eclipse expeditions would become major social events, causing the paths of science, empire and tourism to converge.[63] For astronomers, professional and amateur alike, they kept on providing occasions to recreate the observatory (at least partially) in the specific circumstances of fieldwork. Similar to what was happening in observatories, laboratories and other sites of knowledge production, fieldwork in astronomy was increasingly subjected to the principle of the division of work, as Oom had the opportunity to experience.[64] He was assigned a very specific task in the context of the Russian expedition: to observe and draw the appearance of the solar corona during the totality of the eclipse, from a station he would set up himself close to a village called Urbaneja, in the outskirts of Bilbao. Although photographic techniques were already applied to the observation of eclipses, the efficacy of photography to capture phenomena such as the solar corona was still a matter of debate. For that reason, drawing remained a valuable procedure.[65]

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[59] *Ibidem*.

[60] Maria Clara Pereira da Costa, *Filipe Folque (1800-1874) – o homem e a obra*, pp. 26-27.

[61] António Estácio dos Reis, *Observatório Real da Marinha*, p. 153.

[62] Correspondence between G. B. Airy and the Count of Lavradio, January-February 1853; Correspondence between G. B. Airy and the Count of Lavradio, Dent and Frodsham, January-March 1855, Cambridge Central Library: RGO 6/145 – Letters from Observatories; George B. Airy to Filipe Folque, 25 August 1858, Filipe Folque to George B. Airy, 13 September 1858, translations (English to Portuguese) in "Acta da Sessão de 15 de Setembro de 1858", Archive of the AOL, FO17.

[63] Alex Soojung-Kim Pang, *Empire and the Sun: Victorian Eclipse expeditions* (Stanford: Stanford University Press, 2002).

[64] The other members of the Russian party were Otto Struve, Theodor Winnecke, and Giovanni Schiaparelli.

[65] Alex Soojung-Kim Pang, *Empire and the Sun*, p. 87.

Oom did very well. Airy, who commanded the British expedition, would later remark that Oom's drawing[66] and those made by two engineers, Bonami and Weedou, constituted the only set of matching representations of the corona obtained from the occasion of this eclipse, whereas the many other depictions analysed by the Astronomer Royal were generally discrepant.[67] This made a good line in Oom's curriculum, but above all the eclipse tour gave him further insights into what it meant to set up an expedition, to extend and recreate the observatory afield, to adapt the apparatus to the conditions of fieldwork, and to organize labour in such circumstances.

3.5 Back to Pulkovo: hard practice and soft espionage

After the preparatory stage with the Ertel instrument, Oom was increasingly given access to other spaces and instruments at Pulkovo, and entrusted with more delicate observations. These included measurements with a circular micrometer; observations of the comets I 1861 and Rümker; observations of occultations; and heliometric observations of the minor planets Troi and Victoria.[68] Oom also partook investigations of the personal equation, that is, of the effect of personal errors in observation, a matter of paramount importance in the nineteenth-century quest for objectivity and precision.[69] Side-by-side with these activities and his ongoing theoretical studies, Oom also studied the Pulkovo instruments in detail, especially those that would also be represented in the apparatus of the AOL. These not only included the transit circle, the prime vertical and the great equatorial, but also accessory devices such as the level trier and the barometer.

Level triers were used to calibrate spirit levels, which served, among other functions, to assess the horizontality and verticality of the axes of meridian instruments. The position of an air bubble as seen against a scale marked on the level's tube could be translated into an angular

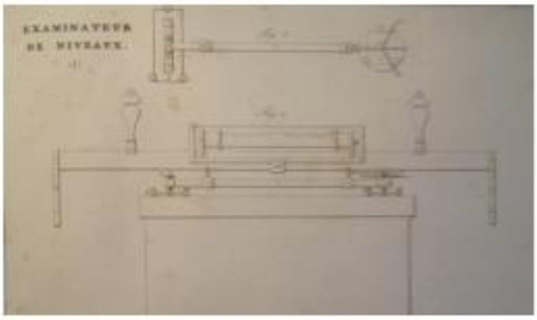
[66] The original watercolour made by F. A. on the basis of his drawing is kept at the Archive of the AOL under the shelf mark F595.

[67] *The Atheneum* no. 1769, p. 376, quoted by José Silvestre Ribeiro, *O Real Observatorio Astronomico de Lisboa. Noticia historica e descriptiva* (Lisboa: Typographia da Academia Real das Sciencias, 1871), p. 21.

[68] Frederico Oom, manuscript notes, Archive of the AOL, A634.

[69] On the investigations partook by Oom see Otto W. Struve, "On the Measures made on Artificial Double Stars, and on the Observations of the Eclipse of 1851", *Monthly Notices of the Royal Astronomical Society* 20, 1860: 341. For a broader contextualisation see: Cristoph Hoffmann, "Constant differences: Friedrich Willhelm Bessel, the concept of the observer in early nineteenth century practical astronomy and the history of personal equation", *British Journal for the History of Science* 40 (2007): 333-365; Jimena Canales, "Exit the frog, enter the human: Physiology and experimental psychology in nineteenth-century astronomy", *British Journal for the History of Science* 34, 2001: 173-197; Lorraine Daston, Peter Galison, "The Image of Objectivity", *Representations* 40, 1992: 81-128; Simon Schaffer, "Astronomers mark time. Discipline and the Personal Equation", *Science in Context* 2, 1988: 115-145.

value, if the level was properly calibrated.[70] Oom used the Pulkovo level trier (Fig. 5) to practise the techniques involved in this operation, and to ascertain a suitable design for a level trier for the AOL (Fig. 6). The device was commissioned to Brauer, the mechanic of Pulkovo.



Figs. 5 and 6 – Schematic drawing of the level-trier of the Observatory of Pulkovo, and photograph of another version of the same device at the Observatory of Lisbon.
(F. G. Wilhelm Struve, *Description de l'observatoire astronomique central de Poulkova,* 1845, and Astronomical Observatory of Lisbon – MUHNAC, Museu Nacional de História Natural e da Ciência)

Brauer was amenable to construct the level trier and to discuss its design with Oom, but displayed a completely different attitude when required to supply a barometer similar to Pulkovo's, which, like the level-trier, he had built himself. In the face of Brauer's reluctances, Folque instructed Oom to make accurate drawings of the barometer and to forward them discreetly to Lisbon. If Brauer was trying to safeguard his barometer model, he did not succeed. Oom made the drawings, the latter reached Lisbon, and the Instituto Industrial de Lisboa (an industrial school in the Portuguese capital) used them to assemble a very similar device. When negotiation did not work, resorting to this kind of soft espionage could be a viable solution.

Towards the end of his five-year stay in Pulkovo, Oom was finally assigned the prime-vertical instrument. Following Otto Struve's instructions, Oom used the instrument to observe the zenith distances of 99 stars, which he would then compare with the same distances as determined with meridian instruments. This was not a stellar parallax programme proper, but constituted important preparatory work for the observations to be made with the prime-vertical of Lisbon.

In August 1863, Oom finally left Pulkovo, endowed with good references from Otto Struve, who already in 1862 had described him as an accomplished observer.[71] Oom was also

[70] Once placed on the trier, the spirit level was subjected to slight changes in inclination, so that the bubble moved along the scale. Readings were made throughout the process in another scale, associated with the level-trier. The angular value of each division could then be determined through calculation. See William Chauvenet, *A Manual of Spherical and Practical Astronomy, Vol. II: Theory and Use of Astronomical Instruments, Methods of Least Squares,* 5th Edition (New York: Dover Publications, 1960[1891]), pp. 75-76.

[71] Excerpts from *Rapport annuel présenté le 14 Juin 1863 au comité de surveillance de l'Observatoire Central Nicolas par le Directeur du dit Observatoire,* transcription in folder A634, Archive of the AOL.

awarded with the 2nd order of St Stanislas, a distinction conferred by the Tsar on foreign men of science, which had previously been awarded to prominent astronomers such as Airy, Leverrier, Bessel, Schumacher and Encke.[72] Some of the works carried out by Oom in Pulkovo were published in the bulletin of the Academy of Sciences of St Petersburg; others appeared in the annals of the Pulkovo Observatory, compiled later by Otto Struve.[73] On his way to Lisbon, he passed again by Bonn, where he attended the foundation meeting of the Astronomische Gesellschaft.

The Portuguese apprentice had become a fully-fledged and respectable astronomer. And he did not return alone to Portugal. Before leaving Russia, Oom married a lady called Alexandrina Müller, whom he had met in his occasional instances of socialization outside the observatory. The anguish expressed in his earlier travelling notes had proved unfounded – at least so far.

4. The AOL in place

4.1 Reshaping the observatory

The construction of the AOL had started in 1861. A few years before, the Struves had sent some architectural drafts to Lisbon. These drafts presented a reduced and truncated version of the Russian observatory, consisting of a building with a central body topped by the dome for the great equatorial, and two observational wings extending to the south and the east (Fig. 7).[74] The Commission was generally amenable to accept all advice that came from Pulkovo, but was not particularly happy with this unimpressive structure. The Struves had simply assumed that functionality should stay above æsthetical value, and that expenses should be kept to a minimum. They certainly knew that the Portuguese authorities could not avail themselves of such liberalities as the "carte blanche" given by Nicolas I. And the instruments would already be expensive enough.

72 Alan Batten, *Resolute and undertaking characters*, p. 97.

73 Frederico Augusto Oom, "Vergleichung des Armag-Catalog von Robinson mit der Aboer von Argelander', *Bulletin de l'Academie Impériale des Sciences de St.-Pétersburg* III, 1862: 415-428; 'Observations faites a l'instrument des passages établi dans le premier vertical', in Otto Struve (ed.), *Observations de Pulkova*, vol. III (St.-Pétersburg: Imprimerie de l'Academie Impériale des Sciences, 1870), pp. 227-237; 'Observations', *Ibidem*, pp. 139-199.

74 FO12, Archive of the AOL.

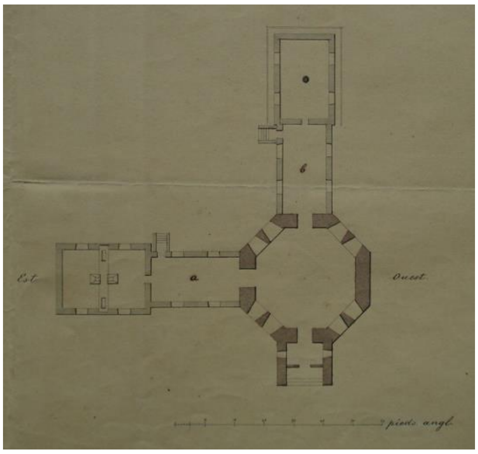


Fig. 7 – Draft of a proposed plan for the building of the Observatory of Lisbon.
(Archive of the Observatory of Lisbon - MUNHAC)

However, the Portuguese authorities understood that if Portugal was to have a sophisticated observatory, then it should be something remarkable, a facility fit not only to observe, but also to be observed, and with reverence. A French architect working in Portugal, Jean Colson, was hired to turn the drafts sent from Pulkovo into the plans of the elegant building, very much akin to Pulkovo's (albeit smaller), which can still be seen and visited today in Tapada da Ajuda (Fig. 8).[75] Many changes were introduced in order to augment its monumental effect: a third wing was added to the west; the observing room of the prime-vertical was moved from the south to the north side, so that an aesthetically unpleasant parasol for daytime observations could be discarded; the entrance, adorned with a neo-classical portico, as in Pulkovo, was relocated to the southern-side, facing the river Tejo.

Fig. 8 – Building of the Observatory of Lisbon.
(Observatory of Lisbon – MUNHAC)

[75] Pedro Abreu, "The Astronomical Observatory of Lisbon: elements for the history of its architecture", in: José Afonso, Nuno Santos, André Moitinho and Rui Agostinho (eds.), *Past meets present in Astronomy and Astrophysics. Proceedings of the 15th Portuguese National Meeting* (World Scientific, 2006), pp. 101-104.

The modest building suggested from Pulkovo was thus transformed into a proper scientific monument. But there was no serfdom in Portugal (at least in the sense it existed in Russia until 1861), and the desire of a humble constitutional king was by no means the same as the caprice of the Emperor of All the Russias. It would take a long time to put up the AOL. To make things worse, Pedro V died prematurely in November 1861. The AOL thus lost its patron when it was little more than a construction site with some foundation works.

This is most likely what Oom found in Tapada when he came back to Lisbon two years later. He had been trained to lead an observatory that was yet to be materialised. He decided then to complete his training as a hydrographic engineer, which, at least, would allow him to progress in his military career. Being the most skilful and learned astronomer in his country, for the time being, was irrelevant for that purpose.

The construction works of the AOL seem to have been resumed in earnest only in 1864. Folque entrusted Oom with supervising the assemblage of its apparatus, namely the construction of the observation rooms, the installation of the instruments, and the completion of the central tower, where the great equatorial was to be set up. Over the next decade or so, hydrographic engineer Oom would act as a sort of astronomical engineer, interacting closely with construction workers, some military officers deployed to protect the observatory's site, and a few scientific collaborators, in order to make sure that all the structures and facilities fulfilled the requirements of precise observation. He would now put in practice much of what he had learnt throughout his journey. The assemblage of the AOL involved procedures such as aligning the observation rooms according to the compass points and disposing its shutters accordingly; firming the piers of the instruments, and assembling the latter; setting up a system of electro-chronographic devices to coordinate time and observation signals all over the observatory's spaces; and designing and assembling the dome of the great equatorial.[76] The delay in the construction of the AOL was possibly advantageous; in Oom's absence, the observatory would, most likely, have been fashioned more as a palace than as a proper observation structure.[77]

[76] Filipe Folque, *Direcção Geral dos Trabalhos Geodésicos, Topographicos, Hydrographicos e Geologicos do Reino - Relatório dos Trabalhos Executados nesta direcção durante o anno de 1871* (Lisboa: Imprensa Nacional, 1872), pp. 8-9; *Direcção Geral dos Trabalhos Geodésicos, Topographicos, Hydrographicos e Geologicos do Reino - Relatório dos Trabalhos Executados nesta direcção durante o anno de 1870* (Lisboa: Imprensa Nacional, 1873), pp. 5-6; Frederico Augusto Oom, "Jornal dos trabalhos executados no ROAL, 1867-1869", Archive of the AOL, FO557.

[77] In fact, during the nineteenth century, several architects involved in the design of observatories sought to remain faithful to the basic structure of Greek temples, usually with results that were not particularly satisfactory. One striking example is the so-called Playfair Building of the Royal Observatory, Edinburgh, at Calton Hill. See Marian Card Donnelly, *A short history of observatories*, pp. 87-94.

In 1867 Oom returned to Hamburg to oversee the dispatch of the instruments he had seen coming into existence, in various stages, during his previous tours. However, as Oom started to unseal the crates back in Lisbon, a Pandora´s box also began to open. The apparatus, in general, looked fine; that was not the problem. The problem was – who was going to work these instruments? Oom could not do it all by himself. Besides, if the AOL was to adopt the principle of one observer–one instrument applied in Pulkovo, thus he would need at least two skilful observers, and ideally three, so that he could concentrate on the observatory's management.

He was certainly pleased to have a recent and promising graduate of the Lisbon Polytechnic School, Henrique de Barros Gomes (1843–1898), coming as a volunteer to partake in the assemblage of the prime-vertical instrument, which was set up between 1867 and 1868. Under Oom´s supervision, Barros Gomes carried out a detailed study of the instrument and the respective observational methods.[78] This was not simply a matter of transmitting what Oom had learnt abroad; it was the full formation of a specialized observer able to work with an enhanced instrument, whose design and construction Oom had followed closely, but that he had never operated himself.

But when Oom was already convinced that he had found a man able to measure stellar parallax in the prime vertical of Lisbon, alas, Barros Gomes left the observatory to embrace a career in politics and administration. And how could the young Gomes, fortunate to be a member of the small highly educated Portuguese elite, be censored? Regardless of his abilities and potential, there was no career for him at the AOL. In fact, there was not even a career as yet for Oom because the AOL did not exist officially as such. During these years, it was a branch of the Portuguese geodetic surveys – a stratagem that Folque, the head of the surveys, had implemented in order to keep the (slowly) emerging observatory under his control.

This situation would change only when the AOL had its own statutory decree. But getting it approved would prove a difficult matter. Oom had thoroughly discussed the organization of the AOL with Otto Struve, Peters and Argelander.[79] There was a consensus among these savants that the AOL should be officially committed to the advancement of stellar astronomy. Priority was thus to be given to the measurement of stellar parallax, the observation of double and multiple stars, and the investigation of nebulae. After all, it was for this purpose

[78] Henrique de Barros Gomes, *A Astronomia moderna e a questão das parallaxes siderаes* (Lisboa: Typographia da Academia Real das Sciencias, 1872).

[79] Frederico Augusto Oom, *Considerações acerca da organização do Real Observatorio Astronómico de Lisboa* (Lisboa: Imprensa Nacional, 1875).

that Wilhelm Struve (who died in 1864) had conceived it in the first place. This programme was to be carried out by a staff of five astronomers, with the assistance of a secretary, two guards, a mechanic, and a carpenter. The principal astronomer, or director, would have the final world in every decision made at the observatory. Each one of the other astronomers would be assigned observations with a specific instrument, and other well-defined tasks. All astronomers were expected to dedicate their lives exclusively to the observatory, eschewing any other jobs or appointments. In other words, the AOL was to be organized according to the principles that governed the Observatory of Pulkovo.

However, these ideas found stark resistance when put forward in Portugal. A statutory proposal originally accorded between Oom and the Academy of Sciences of Lisbon, in which the abovementioned tenets were presented in the form a legal bid,[80] was substantially revised by a parliamentary commission led by António José Teixeira (1830–1900), a professor of mathematics at the University of Coimbra (by then the only University in Portugal). In the new proposal, the AOL appeared as a generalist observatory, not committed to any branch of astronomy in particular. The principle of exclusive dedication to the observatory had disappeared. And the criteria for the admission of astronomers had been alleviated, so that professors from the University and other higher-education institutions were granted access to the scientific posts of the observatory, regardless of their abilities in practical astronomy. Furthermore, the director ceased to be the almighty figure in the administration of the observatory. According to the new proposal, decisions were to be made collectively by a directing board, as in the University. The distribution of power in the observatory was a particularly sensitive issue. As a critic put it in a newspaper article, an almighty director could be acceptable in Tsarist Russia, but it was repugnant in liberal Portugal.[81]

The parliamentary commission had essentially reformulated the bid according to the prevailing culture in Portuguese scholarly institutions. A culture of bookish dons, who often accumulated several political and administrative appointments and sinecures with their teaching duties, and who were supposed to be respected, above-all, for their diplomas and official titles. Practical skill, let alone familiarity with craftsmanship, was irrelevant in this context – if not downgrading at all. The chances of finding skilful astronomers among these ranks were unequivocally low, and even if there were any, they were not likely to deliver themselves to a life

[80] *Diário da Câmara dos Senhores Deputados*, 23 March 1875.

[81] *Diário Popular*, 14 February 1876. The article is unsigned but the author was, most likely, Mariano Cirilo de Carvalho (1836–1905), a politician, journalist and lecturer of Mathematics at the Lisbon Polytechnic School.

of relative isolation at the observatory, with plenty of better career prospects around. Barros Gomes´s case had already provided a clear token.

Nevertheless, Oom fought with all means at his disposal against the new bid. Folque died in 1874. The affair concerning the organization of the AOL lasted between 1875 and 1878. Oom was now fully invested as the harbinger of the "sidereal" AOL. And he succeeded in the end. The programme in stellar astronomy and organizational principles he stood for prevailed in the Statutory Decree of the Royal Astronomical Observatory, which was finally approved in May 1878.[82] However, Oom soon found out that, if the scholarly elite of his country was not a reliable source of prospective astronomers, there was nowhere else to find them.

4.2 Refiguring the apparatus

Oom was lucky, at least, to count on one reliable collaborator, his fellow naval officer and hydrographic engineer César Augusto de Campos Rodrigues (1836–1919) (Figs 9 and 10). When he joined Oom in Tapada da Ajuda in 1869, Campos Rodrigues was already recognised in a local circle of mathematicians and military engineers as a virtuoso with a keen interest in scientific instruments, and an ability to operate, fix and improve them. Campos Rodrigues was also a solitary bachelor, akin to retreat and isolation. He could not have a better place to work in Portugal than the AOL, and Oom could not have found a better sidekick.

Over the years, Oom and Campos Rodrigues would enrich the apparatus of the AOL with several accessories and contrivances.[83] Campos Rodrigues was able to develop what Oom had brought from abroad, in many respects. For instance, he eventually engaged in an investigation of the level-trier constructed by Brauer, which rendered an efficient application of the method of least squares to the calculations involved in the calibration of levels.[84]

[82] *Lei organica do Real Observatorio Astronomico de Lisboa - Carta de Lei de 6 de Maio de 1878* (Lisboa: Imprensa Nacional, 1903).

[83] Pedro M. P. Raposo, "Down-to-Earth solutions for celestial purposes: remarks on the life and works of the astronomer/instrument maker Campos Rodrigues (1836–1919)", in Bart Grob, Hans Hooijmaijers (eds.), *Who Needs Scientific Instruments: Conference on Scientific Instruments and Their Users*, 20-22 October 2005 (Leiden: Museum Boerhaave, 2006), pp. 203-206.

[84] Frederico Oom, *Exames de um nível no Observatório da Tapada* (Lisboa: Imprensa Nacional, 1926).

Figs. 9 and 10 – Frederico Augusto Oom (1830–1890) and Campos Rodrigues (1836–1919). (Observatory of Lisbon - MUNHAC)

Mechanical and woodworking workshops were eventually installed in one of the two residential buildings that came to complement the main building of the observatory.[85] Observing chairs, photographic apparatus, collimation accessories, slide-rules, reticules, clockwork elements and many other pieces would be built or at least modelled and tested between these workshops, the astronomers' offices, and the observing rooms.

Evidently, the AOL was not self-sufficient. It was vital to keep up international liaisons. Devices such as chronographs were conceived and modelled at the AOL, but ordered from foreign firms, such as Hipp of Nêuchatel (later Peyer & Favarger Co.). The completion of the observatory's premises also required foreign assistance. Oom designed the dome of the great refractor himself, on the basis of the domes he had observed in Pulkovo and other observatories. However, he could not find a factory able to build it in Portugal. The construction of the dome was eventually commissioned from a German firm of naval construction, which sent some of its workers to Portugal for the specific purpose of assembling it in place. The Repsolds intervened as intermediaries, a role they also played in other transactions involving different suppliers of instruments and accessory devices.

It was equally important to interact with local craftsmen. For instance, the mechanics of the Industrial Institute of Lisbon, where, as already mentioned, a barometer similar to Pulkovo's was constructed, on the basis of Oom's "secret" drawings. The Institute supplied the observatory with other accessory devices, such as an electric switchboard through which all electric and chronographic connections within the observatory were centralized and controlled,[86]

[85] Contrary to Pulkovo, where the main building of the observatory also contained the astronomers' lodgings, in Lisbon there were two independent buildings for that purpose, located symmetrically (on the east and west sides) to the main building.

[86] For a description of this device, and others conceived and used in the AOL, see Real Observatório Astronómico de Lisboa,

similarly to what Oom had seen in Berlin, and probably in Greenwich. Another local supplier was Maximiliano Herrmann (1832–1913), a prominent, Lisbon-based electrician, inventor and businessman, with whom the AOL maintained an enduring relation. Thus the AOL constituted a local network of technical expertise through which the functionality and efficiency of the observatory's apparatus could be maintained and even reinforced.

One crucial problem remained: to constitute a stable and competent staff, able to turn the grand stellar project into reality. This, Oom never managed to accomplish. The AOL remained understaffed for most of its first decades of activity. Oom's only full-time collaborators were Campos Rodrigues and another naval officer and hydrographic engineer called Augusto Alves do Rio (1845–1905). But even the latter, albeit a dedicated and competent observer, eventually left the observatory to enjoy the riches of a familial heritage. There was always a better prospect than spending one's life confined to an observatory.

Not for Oom and Campos Rodrigues though. If the grand stellar programme designed by Wilhelm Struve now seemed like a mirage, their shared ability to shape and refigure the observatory apparatus could at least be mobilised towards something useful. Consequently, the grand programme in stellar astronomy was upheld as a foundational badge, but in practice it was left aside in favour of timekeeping. In 1885 the AOL started to transmit the official time via telegraph to a time-ball installed in the port of Lisbon (in replacement of the older time-ball mentioned above). The time signals of the AOL were also disseminated to telegraph and railways stations. The signals were sent from the main clock of the observatory, which was rated according to regular observations of star transits. Everything was done with great care. The AOL's time signals, whose errors were published quarterly in the official journal of the Portuguese Government, became the public emblem of its commitment to precision.[87]

The observations of stellar transits to determine local time were performed not with the transit circle, as originally suggested by Wilhelm Struve, but rather with two small and portable transit instruments, set up in the east wing of the observatory (the transit circle, which in the drafts of the Struves was placed in the east wing, had been moved to the west wing). Each instrument (Fig. 11) consisted essentially of a modified theodolite, coupled to a round base. The instrument could be reversed over the base during the observations, in order to eliminate the collimation error. Oom had conceived this system himself, inspired by a similar functionality in the prime-vertical instrument of Pulkovo. Oom essentially combined this arrangement with

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Observations méridiennes de la planète Mars pendant l'opposition de 1892 (Lisboa: Imprensa Nacional, 1895).

[87] Pedro M. P. Raposo, *Time, Weather and Empires: the Campos Rodrigues Observatory in Lourenco* Marques (1905-1930). DOI: 10.1080/00033790.2014.917352

general features of theodolites and some structural aspects of the Ertel transit instrument with which he had begun his apprenticeship.

Fig. 11 – Portable transit instrument designed by Frederico Augusto Oom.
(Observatory of Lisbon - MUNHAC)

Oom negotiated the construction of the rekindled instruments with the Repsolds, who accepted to construct them according to Oom's requirements. The new model ended up included in the Repsold catalogue.[88] Initially just a rapporteur and go-between in these affairs, Oom had also become an instrument designer and negotiator on his own right.

At least in the AOL, the modified theodolites proved efficient and relatively easy to operate. They became the focal point of the AOL's observing activity. Timekeeping, which the statutory decree of the observatory mentioned solely as an ancillary function, was much less enthusing than stellar parallax research. But it was what the AOL was able to perform on a regular basis with the available personnel. And importantly, it gave the observatory a relevant place in the life of the nation. Portugal was under a major effort of infra-structural enhancement, of which the expanding telegraphic and railway networks constituted the foremost representatives. In this context, efficient timekeeping was much more urgent than speculative investigations in stellar astronomy. And one must not forget that the latter were to be fostered as an exploratory programme, with no guarantee of satisfying results. In fact, looking with hindsight, it is not likely that the apparatus and methods proposed by the Struves would bring

[88] For a description of the instruments see César A. de Campos Rodrigues, "Corrections aux Ascensions Droites de quelques étoiles du Berliner Jahrbuch observées à Lisbonne (Tapada)", *Astronomische Nachrichten* 159, 1902: cols. 329-360.

any significant advancement to stellar parallax measurements or to the study of nebulae, which only took off with the application of photography and spectroscopy.[89]

Thus the imposing AOL, an embodiment of a grand research project, was transformed into a rather traditional observatory focused on meridian work. This was, by no means, a rare situation amongst national observatories established before the rise of astrophysics.[90] And the AOL had been, at least, efficiently reworked. But that was seemingly not enough for Oom.

5. Conclusion

The darkest thoughts of the young naval officer and envoy of the Portuguese government apparently still lurked in the mind of the mature astronomer. On 24 July 1890, Frederico Augusto Oom put an end in his life, shooting himself in the head with a revolver. Oom allegedly refused to let himself be consumed by a terminal disease that was diminishing his intellectual abilities. Added to this, he probably never reconciled to the fact that the grand astronomical observatory for which he had left Portugal haunted by insecurity and "saudade", had become little more than a foundational emblem, a virtual image of scientific bravado floating over a rather mundane timekeeping facility.

Oom did not live to see his companion Campos Rodrigues and his son Frederico Thomaz Oom (1864–1930) confirming the name of the Astronomical Observatory of Lisbon as a workhorse of precise astronomical measurement before the eyes of the international scientific community, at the turn of the twentieth century. A land army engineer by training, Frederico Thomaz sought to vindicate his father, becoming an astronomer at the AOL himself, and assuming the role of manager and spokesman of the observatory, as an obsessively low-profile Campos Rodrigues took the official post of director whilst staying in the shadows, immersed in his devices and contraptions.

The renewed Oom–Rodrigues partnership managed to reinforce the staff of the AOL, and to put the transit circle (Fig. 12) to work. In 1904, Campos Rodrigues was awarded the Valz Prize of the Academy of Sciences of Paris for the contribution of the AOL to measure the solar parallax, a parameter of paramount importance in the determination of astronomical

[89] For an overview see John North, *The Fontana History of Astronomy and Cosmology* (London: Fontana Press, 1994), mainly chapters 16 to 20.

[90] Steven J. Dick, *Sky and Ocean Joined – The U.S. Naval Observatory 1830-2000* (Cambridge: University Press, 2003), p. 363.

distances.[91] Even if indirectly, the AOL gave a contribution to the development of stellar astronomy.

The commission of French academics that decided to distinguish Rodrigues noted that the Lisbon observatory had excelled in the measurement of stellar coordinates by meridian observations, working in a situation of material constraint.[92] In fact, the equipment of the AOL had never been substantially renewed, at least in the sense that no major instruments were ever acquired ever since the orders of the late 1850s. The apparatus of the observatory had, nevertheless, been substantially improved. The transit circle that Frederico Thomaz and Campos Rodrigues used to carry out their noteworthy observations was a much-improved version[93] of the instrument dispatched from Hamburg in the late 1860s.

Fig. 12 – Transit circle of the Observatory of Lisbon.
(Observatory of Lisbon - MUNHAC)

[91] The solar parallax is the angle subtended at the sun by the semi-diameter of the Earth. The Astronomical Unit (AU), that is, the average Earth-Sun distance, is derived from the solar parallax. The AU is a fundamental parameter in the measurement of astronomical distances, providing a yardstick to measure all other distances in the solar system. Besides, combining the known angular value of the annual displacement of a certain star – that its, its annual parallax - with the AU, the distance between that star and the Sun can be obtained (note, however, that, even for the closest stars, the values of annual parallax are very small, lying below one second of arc, thus the longstanding difficulty in measuring stellar parallax). On the contribution of the AOL for the accurate measurement of the solar parallax see Pedro M. P. Raposo, "The astronomer/instrument maker Campos Rodrigues and the contribution of the Observatory of Lisbon for the 1900-1901 solar parallax programme", in José Afonso, Nuno Santos, Rui Agostinho, André Moitinho (eds.) *2005: Past meets Present in Astronomy and Astrophysics – Proceedings of the 15th Portuguese National Meeting* (World Scientific Press, 2006), pp. 97-100.

[92] *Comptes Rendus hebdomadaires de l'Academie des Sciences des séances* CXXXIX, 1904: 1075.

[93] For a full description, see note 86.

Over the years, Campos Rodrigues had also carried out studies on personal equation,[94] and developed expedite processes of data reduction involving graphic tools and slide-rules,[95] side-by-side with his many other contrivances. These developments were embedded in the culture of precision in which Frederico Augusto Oom had been indoctrinated. This culture acquired a solid footing at the AOL through his interaction with Campos Rodrigues; Frederico Thomaz Oom would assure its continuity. This was also possible because Campos Rodrigues and Frederico Thomaz Oom were able to incarnate the *persona* of the astronomer as a multivalent and practical expert, which Frederico Augusto Oom had began to embody through his journey. Their common background as military engineers was certainly helpful in this respect.

The accomplishments of the turn to the twentieth century were an exceptionally successful instance of the AOL's effort to make use of an apparatus whose highlights, the great equatorial and prime-vertical instrument, remained practically unused for many years. They were only put to regular use, respectively, in 1910 and 1930 only, but for functions other than those originally indicated by Wilhelm Struve.[96]

At first sight, it is ironic that an observatory modelled on Pulkovo, and equipped with enhanced versions of some of its main instruments, ended up focusing energies and resources on observing spaces and instruments that were, in the case of the transit circle, ancillary, and in the case of the small transit instruments, simply absent from the foundation project. Although Wilhelm Struve had designed the AOL as a condensed and highly specialised version of Pulkovo, the Portuguese observatory was, for many decades, even more redundant than the lavishly equipped Central Observatory of Russia. However, we must not overlook the fact that, by suiting the transit circle and the small transits to precise observation, the astronomers of the AOL gave continuity to a chain of developments in instruments and techniques that were emblematic of the nineteenth-century drive for precision in astronomy and surveying. Given the specific circumstances in which the AOL developed, it was sensible to rely on this well-established chain, instead of engaging in more risky pursuits.

All of these instruments are reasonably preserved and still in place at the AOL. Together with the observatory's buildings, they remain as an embodiment of the grand

[94] Campos Rodrigues, "Personal Equation", *The Observatory* 25, 1902: 121-124.

[95] Frederico Oom, *Méthodes de Calcul Graphique en usage à l'Observatoire Royal de Lisbonne (Tapada)* (Lisboa: Imprensa Nacional, 1905).

[96] The prime-vertical instrument was employed in latitude measurements. The great equatorial was used, in a first stage, for a variety of observations by the astronomer Manuel Soares de Melo e Simas (1870–1934). It was later deployed to the regular observation of occultations of stars by the Moon.

programme of stellar astronomy conceived by Wilhelm Struve, as they also embody the aspirations of modernity and cultural sophistication of mid-nineteenth century Portugal. But above all, they embody the many instances of interaction, exchange and appropriation that took place not only during Frederico Augusto Oom's mission, but also thereafter, in the assemblage of the AOL, in the refiguring of its apparatus, and in the extension and development its networks and circuits.

Far from being a closed embodiment of a somewhat fanciful research project, the AOL functioned as an active and changeable space of technical innovation, grounded on the culture of precision. Not only the AOL assimilated and developed this culture, as it also contributed to disseminate and expand it. It did so in various ways: by providing technical advice and assistance to other institutions, and to other practitioners engaged in surveying works and similar operations; by providing training for hydrographic engineers, some of whom came to play a prominent role in Portuguese science, politics and imperial affairs;[97] and by readapting and exporting its timekeeping expertise to the overseas colonies of the former Portuguese empire.

In 1907 Frederico Thomaz Oom travelled to Hamburg, where his father had stopped several times, in order to examine the timekeeping system of the port of that city. This system was then combined with a reworked version of the AOL's timekeeping apparatus that was installed at the Campos Rodrigues Observatory, inaugurated in Lourenço Marques (nowadays Maputo), Mozambique, one year later. Oom went to Mozambique in person to install the system.[98] His advice was then required for a similar venture in Goa, and fifteen years later he travelled to Luanda, Angola, in order to plan the upgrade of the João Capelo Observatory, located in that city.[99] Thus the circuits of scientific and technical expertise in which the AOL was grounded were extended into the wider geography of the Portuguese overseas empire.

It is unfortunate that Wilhelm Struve's programme for Lisbon remained as a scientific reverie, whilst the dark musings of young Frederico Augusto Oom became a self-fulfilling prophecy. Still, the creative potential of the AOL as a dynamical and open embodiment was stronger than the destructive power of a "sphere of Pb". Oom's journey could thus be continued after his demise.

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[97] Pedro M. P. Raposo, "Surveyors of the Promised Land: hydrographical engineers and the techno-scientific resurgence of the Portuguese overseas empire", *HoST – Journal of History of Science and Technology* 7 (2013): 85-119.

[98] See reference in note 87.

[99] Frederico Oom, "Novo Observatório em Luanda', 30 September 1922, Archive of the AOL, DD601.

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