

Introduction - Re-Assembling the History of Meridian Circles

Introduction. Reconstituer l'histoire des cercles méridiens

Daniel Belteki and Julien Gressot



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Introduction

Re-Assembling the History of Meridian Circles

Daniel Belteki & Julien Gressot

Abstract — Meridian circles were tools of science, state and empire. Besides being used for astronomical observations, the by-products of observations made also had more utilitarian purposes applicable to commerce, transportation, industry and the expansion of empires. While meridian circles were created with the aim of producing spatial and temporal uniformity, observatories adopted different assemblages and configurations for their instruments. This issue brings together for the first time a variety of contributions to explore the material and social history of meridian circles. It deploys the concept assemblage to connect the different historical approaches together and to re-assemble the long history of the instrument.

Résumé — *Introduction. Reconstituer l'histoire des cercles méridiens — Les cercles méridiens sont des outils de science, d'État et d'empire. En plus d'être utilisés pour les observations astronomiques, les sous-produits des observations effectuées avaient aussi des objectifs plus utilitaires applicables au commerce, au transport, à l'industrie et à l'expansion des empires. Si les cercles méridiens ont été créés dans le but de produire une uniformité spatiale et temporelle, les observatoires ont adopté différents assemblages et configurations pour leurs instruments. Ce numéro rassemble pour la première fois une variété de contributions pour explorer l'histoire matérielle et sociale des cercles méridiens. Il déploie le concept d'assemblage pour relier les différentes approches historiques et réassembler la longue histoire de l'instrument.*

Mots-clés : sciences/techniques et sociétés, histoire matérielle, histoire conceptuelle et histoire des idées, sciences historiques, techniques et technologies, instruments et instrumentation, astronomie, époque contemporaine, précision, assemblage, cercle méridien

1. What Was a Meridian Circle?

Meridian circles are the forgotten pillars of nineteenth-century science and society. They were the main instruments used to determine accurate time for scientific research and public distribution. They were the instruments that created the fabric of temporal regimes within and across empires. The determination of time was intimately linked to the determination of geographical positions and the governance of imperial space. Therefore, controlling a meridian circle was essential for the temporal and spatial governance of an empire. The gradual adaptation of the Greenwich Meridian (defined by the Airy Transit Circle) as the Prime Meridian of the world demonstrates how imperial interests were intertwined with the uses of meridian circles (Withers, 2017).¹ With the advent of railway expansions and the emergence of telegraphy, meridian circles were the starting point for the distribution of time across nations. They also made it possible to synchronise time on a national scale at a period when the development of railway and telegraph networks required coordination of spaces. Thus, they were of great interest to the nation-states that were being built. For example, in 1852, the small Observatory of Bern distributed the time to the Swiss federal administration, a mission taken over by the Observatory of Neuchâtel in 1860 (Messerli, 1995). Yet, meridian circles have gradually disappeared from everyday use by the second half of the 20th century. This special issue aims to re-examine the histories of these instruments to demonstrate their historical contributions to science and society.

What was a meridian circle? A meridian circle allowed for observing and registering the time it took for a celestial body to pass across fixed horizontal wires seen in the field of view of the telescope. The instrument combined the functions of mural circle and a transit (or meridian) instrument. The former instrument determined the altitude (or height) of an astronomical body, while the latter determined the exact time when it crossed a fixed point in the sky. Combining these observations helped with keeping track of the accuracy of astronomical clocks. The same observations formed the basis of astronomical tables (predicting the motions of planets, stars, and

¹ Meridian circles and transit circles denoted the same type of instruments. The term meridian circle appeared more frequently in languages of continental Europe, while the term transit circle was more regularly used in anglophone countries.

astronomical bodies) and star catalogues. The measurements with the instrument also allowed an observer to determine their geographical location. Observations were made by either estimating the passage of a star across the wires while listening to a clock (the eye and ear or Bradley method) or by pushing a button to record the passage of an astronomical object on a chronograph (the chronographic or American method).² Determining the time required repeated observations to obtain the most accurate data possible. Strenuous calculations and statistical analysis followed the observations to compute the stars' exact positions while taking into account instrumental, environmental and human error, as well as other factors impacting the observations. Although other astronomical instruments (including the beats of astronomical clocks) were also used to determine the positions of stars, meridian circles allowed for such determinations with increased precision and by making the errors of the instruments visible and measurable.

2. A Brief History of Meridian Circles

The history of the meridian circle originated with Ole Roemer (1644-1710) (Nielsen, 1968; Ziggelaar, 1986). Taking advantage of his experiments at the Paris Observatory, where he worked between 1672 and 1681, he was the first to combine a telescope tube on a fixed horizontal support. This arrangement made it possible to know the horizontal coordinates of an object viewed through the telescope. In 1704 he created a new design by adding a vertical divided circle to his device to measure the vertical angle of a passing object. He called this new design a *rota meridiana* or meridian circle. The new design did not create any major interest either from manufacturers or astronomers during the 18th century. In fact, it was not before the following century that observatories were equipped with meridian circles in a nearly systematic way until the 19th century. The relatively slow uptake of the instrument among observatories has since been explained by a lack of cooperation between instrument makers and astronomers (Struve, 1845; Herbst, 1996). This cooperation was essential in order to test the quality and the practical design of a meridian circle before their arrival. In the absence of this

² A new design for impersonal micrometers allowed the observer to follow the passage of a star by moving a wire across the field of view. Since this tracking cannot be at an absolutely constant rate, the method known as the trained wire method also sought to automate the training of the wire with more or less satisfactory results.

key feature, it was not until the end of the 18th century that meridian circles gained more widespread presence. Major instrument makers of the age, such as Jesse Ramsden (1735-1800), Edward Troughton (1753-1835), Johann Georg Repsold (1770-1830), and Georg Reichenbach (1772-1826) began to experiment with the production of meridian circles. In 1779 Ramsden designed an altazimuthal circle for the Palermo Observatory, which marked the beginning of a movement to bring the design of meridian circles back to the forefront.³ By the end of the next century, the meridian circle became the essential tools of positional astronomy at observatories.

Like the designs of many other scientific instruments, the designs of meridian circles underwent changes over time. Improving the various parts of the instrument made it more and more useful for astronomers, gradually leading to being considered the most accurate scientific instrument of its time. Such developments included improvements made to the graduation of circles (Chapman, 1983; Bennett, 1987), micrometers (Brooks, 1991), optical lenses (Jackson, 2000; Jahn, 2008), the illumination system (Gressot & Jeanneret, 2022), better materials for the construction of telescope tubes, more stable pillars, and new developments within the theory of errors applied to calculations (Canales, 2001; Adler, 2003). The elite makers of meridian circles were mainly based in Europe during the nineteenth century. Instruments made by Repsold and Reichenbach were among the first meridian circles set up for regular use at observatories at Gottingen and Königsberg. They developed a distinct style for the instrument and championed keeping the sizes of the instruments relatively small. Ertel & Sohn were trained by Reichenbach and built upon their knowledge to continue the development of the instruments. Pistor & Martins furnished the Berlin Observatory with their own design of meridian circles. Wilhelm Eichens (1818-1884) and Marc Secretan (1804-1867) designed instruments for the Paris Observatory. Paul Gautier (1842-1909) had an international pool of clients and built instruments for observatories spanning from Brazil to Japan. Troughton & Simms emerged as the main instrument makers for observatories within the British empire. Their reputation was solidified by taking part in the decades-

³ While the telescope tubes of meridian circles do not swing/rotate horizontally, an altazimuthal circle allowed the telescope tube (or the entire instrument) to be rotated horizontally in 360 degrees.

long re-instrumentation of the Royal Observatory, Greenwich during the first half of the nineteenth century.

3. The Place of Meridian Circles within the History of Science

Although scientific instruments became objects of analysis for historians of science during the second half of the 20th century, meridian circles remained relatively underrepresented. Most often, they appear in general histories of observatories, telescopes, and graduated circles, as well as in inventories of astronomical instruments (King, 1979; Howse, 1986; Bennett, 1987). These histories were often written by curators exploring the histories of the collections of their institutions (Alberti, 2019). More detailed and isolated histories of the instrument were written by astronomers themselves. E. G. Martin (1949) offered a brief overview of the history of meridian circles in 1949, induced by his curiosity about the variations in the size of their apertures. Although it makes the intriguing claim that ‘there are too many transit circles in the world’, he explains this by the instrument being the foundational element of any observatory. His article finished with a useful (though relatively inaccurate) list of meridian circles. The next notable published work was R. H. Tucker’s (1969) examination of observing programs with meridian circles at various observatories. Although it was prefaced with a brief history, its survey of various meridian circles and their associated research programs around the world remains a valuable source of information. Erik Høg’s (1974) paper is similarly notable for the technical assessment of the automatisisation of meridian circles during the middle of the 20th century.

During the 1980s historical studies began placing more emphasis on the materiality of objects as a document and a source that can provide a better understanding of practices (Hicks, 2010; Bernasconi, 2016). Despite this, meridian circles remained relatively absent from such studies. A renewed interest in meridian circles only emerged during the end of the 20th century. The first detailed historical examination of meridian circles was carried out by Klaus-Dieter Herbst, which traced the history of meridian circles from 1700 to 1850 (Herbst, 1996). It placed as one of its questions why it took more than a century for meridian circles to replace its predecessors. Incorporating questions like those asked by proponents of the material turn, the detailed study focused on the dynamics between instrument makers and their

clients, as well as the availability of techniques and raw materials. Turning from overall histories to individual case studies, Gilbert Satterthwaite (2001) published an extensive overview of the history of the Airy Transit Circle. Claiming to be the last person to observe with that instrument, the work intertwined the tacit knowledge of an observer with historical technical reports about the instrument. Inventory operations have been carried out, particularly in France, to map meridian circles and to raise awareness of the importance of these artefacts. The work of Davoigneau & Le Guet Tully (2005) demonstrated the widespread presence of such instruments around France, their significant contributions to the history of the country and science, and prepared the grounds for more detailed historical analysis of individual instruments. The creation of this inventory was followed by the examination of individual histories of meridian circles. Poppi & al. (2008) provided an overview of German meridian circles at the Bologna Observatory. Granato (2008) examined the history of a Gautier meridian circle used in Brazil as part of the instrument's restoration. Bonifacio & al. (2009) examined the dissemination of new meridian circle designs by the instrument makers Troughton & Simms through the instrument at the Coimbra Astronomical Observatory. Following the focus on international exchange, Chinnici (2009) explored the connections between meridian circles at the Dunsink and Palermo. The meridian circle at Dunsink Observatory came under further investigation through an examination of the history of its object lens by Meurs (2010). These works provided the fundamental groundwork for another wave of studies that increasingly responded to the detailed exploration of interplay between science and society. Sanhueza-Cerda & Valderama (2020) explored the key role of international communications in establishing the scientific credibility and technical stability of meridian circles. Gressot & Jeanneret (2022) showcased the reliance on the meridian circle at the Neuchatel Observatory in the development of the history of the institution and the region. Berard & al. (2020) applied digital tools to create a digital version of the Toulouse-Jolimont meridian circle and to remodel it within its surrounding environment. Belteki (2020a; 2020b) examined the negotiations over the purchase of the objects glass for the Airy Transit Circle, and explored the story of a model made of the same instrument.

Surveying the elite instrument makers of meridian circles reveals their concentration within European empires. Their close connection to

maintaining the material culture of observatories shows how instruments like meridian circles were inseparable from imperial observatories. As Schaffer (2012) has highlighted, the manufacturing and the major alterations of instruments remained within the hands of these central instrument makers, even if they were installed at colonial observatories. This special issue provides further insights into how the dynamics between eminent instrument makers and major observatories operated. Meanwhile, as Sen (2016) also remarked, the minor alterations and the routine maintenance of scientific instruments remained in the hands of local artisans. Their stories have largely been neglected from historical accounts of meridian circles, and it is a potential avenue to explore for future researchers. Such accounts would help with reversing the centralised and Eurocentric history of scientific instruments. Although this special issue does not engage with such questions, its further focus on the eminent instrument makers reveals the gaps within the historical scholarship that decentralised approaches can fill.

Meridian circles supplied fundamental data about the position of astronomical objects, which helped in the construction of tables predicting their future positions. Such information was incorporated into nautical almanacs to aid navigation. This close connection reveals the ties of observatories to naval departments and institutions (e.g. US Naval Observatory, Royal Observatory at Greenwich etc.). Through the example of navigation we see that meridian circles connected the sky with the earth. The same observations helped with determining the exact geographical position of the meridian circles themselves. Given the precision attained with these instruments, they were the essential starting points of surveying and cartographic ventures. Projects such as the Ordnance Survey and the French triangulation maps used the positions of meridian circles as key reference points for their work. To ensure the accuracy of the positions of observatories, the advent of telegraphy allowed for the remeasurement of their longitudes. This prompted several observatories to carry out observations while being connected via a telegraphic network. Keeping our focus on the ground, with the increased precision of meridian circles during the 20th century, auxiliary instruments like seismographs also played an important role to account for the effects produced by seismographic activity that could jeopardise the precision of scientific instruments. Even though the instruments were gazing at the sky, they remained grounded on Earth. Among the public applications of meridian

circles, the most often emphasised has been the production of time. Yet, the role of the instrument is rarely highlighted in histories of time distribution. The previously mentioned repeated measurement of the motion of astronomical bodies served as the basis for determining time, which was later disseminated across regions. Accurate time was important for the maintenance of commerce, trade, and transport at increasing speeds. This same regular re-determination (or keeping) of time also allowed for the more reliable testing of the quality of chronometers. As a result, sites like the Royal Observatory, Greenwich carried out regular trials for evaluating the performance of the devices. Thereby, meridian circles were positioned at the center of the key tenets of public life.

4. Themes Explored in this Special Issue

A key overarching theme emerging from the historiography related to meridian circles is the “boundaries” of the instrument. In a literal sense, what were the material boundaries of the instrument? Was it confined to its internal parts or did its auxiliary parts (e.g. meridian marks, chronographs etc.) also form part of the instrument? This inclusion and exclusion raises questions about the historical expertise applied. For instance, if we include the building as part of the instrument, one has to rely on architectural expertise (Tirado & Tirado, 2019). In a more conceptual sense, if meridian circles produced time and space for regions and empires, then did these temporal and geographic zones also act as part of its boundary? To tackle this question, we asked contributors to this special issue to deploy the term *assemblage* (DeLanda, 2019; Buchanan, 2021). Although as Buchanan (2015) highlighted, different scholars tend to deploy the term differently, which can lead to different approaches, in the case of meridian circles it is a useful conceptual tool to highlight 1) the significance of the multiple parts of the instrument, 2) that the state of each component actively affected the observation, and thereby, 3) the products of a meridian circle were assembled by its parts.

A key advantage of using the term *assemblage* is the emphasis placed on interactions between the different parts of the assemblage. When limiting the scope of the analysis to the material components of the instruments, the approach demonstrates that the components are in a constant state of flux (Baker, 2012), they undergo constant repair and maintenance (Schaffer, 2011; Margocsy, 2017; Werrett, 2019), and are regularly adjusted or

modified for the needs of their users. When focusing on the interactions between material components of an instrument, the hierarchies of significance among the material components also seemingly disappear. This is especially heightened in the cases of precision instruments (like meridian circles), where the effect of each material component can have a measurable effect on the observation. Studies focusing on a singular component of an instrument provide new information on how a type of component can affect the observation (Chapman, 1983; Brooks, 1991). Thereby, using the term assemblage not only positions a component among multiple others, but also liberates its significance as a potential object (or subject) of analysis. This approach makes it also possible to see that the data produced by the meridian circle is at the centre of different networks (instrumental, actor, spatial), which must be investigated in order to understand how precision is forged, what it means and when it is reached or exceeded.

This focus on the active shaping of the instrument allows for enlisting as part of the assemblage seemingly unexpected entities. Coupled with the different ways in which contributors deploy the term assemblage showcases the various ways in which historians attempt to reassemble the material and historical context within which meridian circles operated (Latour, 2005). For example, Issenmann explores how the layout of the urban environment formed part of this larger assemblage. Belteki highlights how the air surrounding the instrument was monitored and brought into the assemblage of the instrument. Gressot & Jeanneret describe the various components of the instrument distributed around an observatory that made up the larger assemblage to produce, keep and distribute time which is built in close relationship with the instrument maker. Bell considers how meridian circles across North America created an assemblage for astronomical work. The deployment of the term assemblage in this way becomes a powerful tool to analyse the physical boundaries of the instrument.

This special issue also brings together a variety of expertise from curators, historians, and astronomers. What emerges from these accounts is that meridian circles have a variety of meanings to different individuals. For Wolfschmidt, the history of the instruments embodies the dynamics between the instrument makers and the astronomers. In Leppik's paper, the meridian circle becomes the central point around which the life of an astronomer can be explored. Meanwhile, in the articles of Schmidt & Dick and Jeanson &

Davoigneau meridian circles become symbols for the histories of astronomical institutions. Exploring the idea of symbolic instruments further, Aubin argues that meridian circles were not only symbols for observatories. Instead, meridian circles were deployed as rhetorical and cultural symbols at different locations and at different historical periods. In the papers by Lomb and by Soulu, meridian circles did not only define the history of an institution, but also that of larger geographical regions. The variety of these different starting points demonstrate that if meridian circles were the foundations for producing time and space for society, then exploring their histories possesses the ability to re-assemble the histories of the regions and entities that were defined by those temporal and spatial regimes.

It is also important to emphasise the gaps in this special issue and the ways in which we consider those gaps to be the necessary next steps for examining the histories of meridian circles. Although our initial aim was to tell a global history of the instruments, the final selection of articles remained Western in its focus. By combining the information presented in this issue with more recent research about the dynamics between empires and their colonies, it would be possible in the future to further explore the role of meridian circles in imperial ambitions and practices. The special issue also remains relatively silent about interactions between observatories. Astronomers discussed between each other how to coordinate their research, the latest astronomical publications, and the quality of the latest instruments. As the historical scholarship also highlighted, a similar discussion between astronomers and instruments makers were essential for the eventual uptake of meridian circles. Thereby, future research should examine such interactions between the individuals that surrounded meridian circles. In relation to the human component, there is no examination of the gendered nature of work with meridian circles. Were women trained to use these instruments, or were they trained on other types of astronomical instruments? Finally, there is little discussion in these papers about the role of funding institutions and scientific societies in relation to the history of meridian circles. How did funding bodies see meridian circles to contribute to their aims? And what was the role of scientific societies in the emergence of meridian circles as an essential astronomical instrument? To answer any of these questions, one must better understand the collective history of meridian circles. It was the aim of the editors of this special issue to bring together through these papers such a

collective history of the astronomical instrument. As a result, we consider the gaps and questions mentioned above as our future steps for exploration.

5. Meridian Circles Today

Before concluding this introduction, it is worth returning to the question of what happened to meridian circles during the 20th century and where they are now. During the 19th century timekeeping devices gradually attained better and better precision. This put increased pressure on the precision attained with meridian circles too. In addition, the size and shape of the instrument imposes mechanical constraints, making the determination of errors more complicated as the level of precision sought increases. Despite the attempts to develop accessories and auxiliary instruments to improve the precisions attained (e.g. the impersonal micrometer), meridian circles were unable to keep up with the precision demanded by the scientific community. In addition, new types of astronomical instrument, like the Photographic Zenith Tube (PZT) and the Danjon astrolabe were devised, which attained higher precision than meridian circles did. These new instruments improved the precision by a factor of ten, up to a thousandth of a second. By 1947 the International Astronomical Union considered the PZT to be the future of practical astronomy (Gressot, 2023). Although meridian circles were gradually abandoned, it was the paradigmatic shift followed by the introduction of atomic time, which made the astronomical time determination obsolete. Therefore, meridian circles today are more likely to be used for astronomical observations (e.g. for mapping the sky) rather than for time determinations.

Observations carried out with meridian circles were fundamental starting points for astronomical work during the 19th century and during the first half of the 20th century. They were the icons and symbols of astronomical work and observatory sciences for more than a century. Therefore, these instruments should play an essential role in how we exhibit, remember, and tell the history of science and astronomy during that time period. However, the large size of meridian circles and their loss of relevance to timekeeping methods have posed challenges to contemporary interpretations of the instrument. For example, the Airy Transit Circle at the Royal Observatory, Greenwich is housed in a small room that does not offer a good view of the instrument. Similarly, one of the meridian circles at the Paris Observatory

is preserved in a shelter.⁴ In the International Watchmaking Museum of La Chaux-de-Fonds, the second meridian circle of the Neuchâtel Observatory has been restored with the intention of presenting a beautiful object rather than the instrument as it was. At the Brussels Observatory, two Repsold meridian circles are still kept in the workshop in precarious conditions, raising the question of their durability as an artefact. Therefore, attempts at exhibiting them at their original sites often provide museum curators with practical challenges. In addition, given the close connection of the instrument with the original observing position, removing the instruments offer additional interpretational challenges. At the same time, the survival of unused meridian circles in stores and observatories was also ensured by their close connection institutions funded by governments, states, and empires. Thereby, exhibiting the history of meridian circles will always remain intertwined with the histories of such entities.

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⁴ Though it is worth remembering that instruments were also placed in spacious rooms, as in the case of the Strasbourg Observatory.

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