Stabilizing Local Knowledge: The Installation of a Meridian Circle at the National Astronomical Observatory of Chile (1908–1913)

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Abstract: This essay examines the problems associated with the installation of a precision instrument at the National Astronomical Observatory of Chile, starting before its construction and following the process through its installation to its later useful life. Between 1908 and 1913, the director of the observatory, Friedrich W. Ristenpart, corresponded with the German manufacturer, A. Repsold & Söhne in Hamburg, trying to identify the critical points pertinent to the installation of the instrument in Chile. These communications reveal how the installation of the instrument required the stabilization of local knowledge (location, adjustment, calibration, and staging) that would allow the data it obtained to be universally validated. This correspondence between user and manufacturer also reveals that the phenomenon of the mobility of instruments implies much more than simply transporting something from one place to another: there is no movement without some type of coordination between the extraction of an object from a certain place and context and its insertion into a new place and set of relationships.

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Acknowledgments. This essay was made possible by FONDECYT Grant 1170625, as well as a 2018 research stay at the Max Planck Institute for the History of Science in Berlin (supported by the Alexander von Humboldt Foundation). I would like to acknowledge the support given by Jürgen Renn and Ulrich Mücke for the development of the research in Germany and the anonymous referees for their comments, criticisms, and recommendations.

Isis, volume 113, number 4, December 2022.
 https://doi.org/10.1086/722407

From a distance, astronomical observatories all seem to be the same, as if foreign to the places in which they are built. If one examines their domes, their architecture, and the forms of their telescopes, one can discern a deliberate attempt to construct a uniform space. This phenomenon is not simply a matter of influences, styles, or fashions; it corresponds, above all else, to a model of objectivity that allows us to verify universally data that were obtained locally. Here, the use of space and the construction of the buildings are fundamental. Uniformity means that global networks, which are necessary for the construction of astronomical knowledge, can be articulated through the use of similar techniques and instruments. In this attempt at unification, astronomers have employed a variety of strategies to erase or silence specific localities—what Peter Galison has called the *local delocalization* of scientific work.[1] This tension produces a conflict between the universal plane, which gives objective meaning to science, and the local setting, where the instruments operate. The observatory, in this sense, offers historians of science an exceptional opportunity to examine the many dimensions of movement in both directions: from the *no place* to the situated and from the local to the delocalized.[2]

In this local/global framework, what is the place of the observatory as a place of science? David Aubin has shown how, in recent decades, historians of science have studied the ways in which scientific knowledge is locally constructed in a specific place and under specific circumstances. Insertion of, say, a new telescope in a local environment can have effects on the type of knowledge produced there and, thus, on the nature of the activities developed at the site. Aubin and Stéphane Le Gars have developed the idea that astronomical observatories construct a place of *de-placement*. The strategies utilized at observatories are distinct from those of the laboratory sciences: while laboratories aim to become *no-places* and to distance themselves as much as possible from local conditions, observatories cannot use this strategy because they need those conditions to be taken into account in the outside world. The transformation of the observatory into a standard data point in observation networks supposes a relative lack of place—or delocalized place, to use Galison's term—but, at the same time, the incorporation of the local into the global. In this way, the data from any given observatory can be correlated with data from other places. In the *laboratory/field* dyad, the place of production of astronomical knowledge is a heterotopic space: a place in a network, but at the same time a *de-placing*.[3]

Now, for periodic observations to be able to function within this network, it is necessary to neutralize the observations—in other words, to make the instruments that collect them function correctly in this intersection between the situated and *de-placement*, between the local and the global.

Omar W. Nasim argues that astronomical observatories have done everything possible to stabilize themselves, from the cultural and epistemic as well as the architectonic and material point of view. In this process, the observatory "is as stable as its principal instruments." For the neutralization of stabilization to function successfully, it must be framed within what Aubin calls the *regime of spatiality*, in which the instruments are, at a minimum, inserted on three levels: in the architecture of the building, through their placement within the observatory, and according

[1] Peter Galison, "Material Culture, Theoretical Culture, and Delocalization," in *Theatrum Scientiarum: Collection, Laboratory, Theater*, ed. Helmar Schramm, Ludger Schwarte, and Jean Lazardzig (Berlin: De Gruyter, 2005), pp. 490–506, on p. 490. Reference taken from Omar W. Nasim, "Observatorium," in *Handbuch für Wissenschaftsgeschichte*, ed. Marianne Sommer (Stuttgart: Metzler, 2017), pp. 180–192, on p. 181.

[2] Nasim, "Observatorium," p. 181.

[3] David Aubin, "L'observatoire: Régimes de spatialité et délocalisation du savoir, 1769–1917," in *Histoire des sciences et des savoirs de la Renaissance à nos jours*, ed. Dominique Pestre (Paris: Le Seuil, 2017), Vol. 2, pp. 54–71; and Stéphane Le Gars and Aubin, "The Elusive Placelessness of the Mont-Blanc Observatory (1893–1909): The Social Underpinnings of High-Altitude Observation," *Science in Context*, 2009, 22:509–531.

to the nature of the geographical and abstract space in which they are found.[4] This explains why these places of science must constantly adapt to the size, availability, and materiality of their objects for making observations and measurements. The more precision an instrument was capable of, the more necessary it became to focus on the other determinants of stability that guaranteed the accuracy of its observations.[5]

Observatories have therefore been designed as a stage on which instruments can function, and it is fundamental that the instruments be permanently, securely installed and carefully calibrated.[6] In short: the dynamics of the observatory are put at the service of the precision and exactitude of its instruments.

Precision took on the sense of an "action at a distance technology" by stabilizing the veracity of the information registered at observatories. This technology could not be reduced to the instrument in itself: it was a set of protocols that functioned through a network of observers who had to learn "to accommodate their experience and their way of writing and acting, . . . making . . . transparent the movements and displacements that occurred at the observatory." The existence of a precision instrument in a particular place did not guarantee its use within the transnational network of astronomy. If the data could not be protocolized, "it played a purely rhetorical function." Here, the handling of the instrument's mechanics had to adapt to a "community objectivity" that would guarantee "the homogeneity of the results." In this sense, the calibration and control of instruments become crucial, as they guarantee the circulation of the knowledge thus produced. The problems of establishing such precision thus become, at the same time, matters of agreement within a community and, therefore, of standardization. For this to occur, there needs to be agreement on the norms of comparison. Precision, as M. Norton Wise has argued, "is always the accomplishment of an extended network of people." Wise affirms that instruments "were typically designed as balances"—that is, that "they constituted a network . . . which gave substance to the belief that the laws of nature . . . acted to produce equilibrium."[7] Ensuring the precise functioning of instruments allowed transnational networks to reach this state of equilibrium.

While the ideal of precision crosses borders, we still know little about how cultural differences serve to validate standards of exactitude.[8] Wise argues that instruments, whether they be material or mathematical, function as a network of interrelated technologies.[9] What happens when we look at this network from countries that don't produce these instruments? How is precision activated at a distance? This essay explores this process in the case of the 1911 installation of a meridian circle built in Hamburg, Germany, at the National Astronomical Observatory of Chile. This installation was monitored by the observatory's director, Friedrich W. Ristenpart, who corresponded extensively with the manufacturer, A. Repsold & Söhne, before the meridian circle was built, at the time of its arrival in Chile, and during and after its installation. This correspondence between the user and the manufacturer reveals that the phenomenon of the mobility of instruments implies much more than simply transporting something from one place to another: there is no movement without some type of coordination between the extraction of an object

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[4] Nasim, "Observatorium" (cit. n. 1), p. 181; and Aubin, "L'observatoire."

[5] Nasim, "Observatorium," p. 181.

[6] *Ibid.*

[7] Nuria Valverde Pérez, *Actos de precisión: Instrumentos científicos, opinión pública y economía moral en la Ilustración española* (Madrid: CSIC, 2007), pp. 33, 34, 39 (here and throughout this essay, all translations into English are my own); and M. Norton Wise, *The Values of Precision* (Princeton, N.J.: Princeton Univ. Press, 1995), pp. 8, 9, 94.

[8] In fact, Wise himself argues that the workshop that gave rise to his seminal book "has not decided the question of how cultural differences should be located": Wise, *Values of Precision*, p. 11.

[9] *Ibid.*, p. 94.

from a certain place and context and its insertion into a new place and set of relationships. It is specifically this process of coordination that enables us, as historians, to bridge the gap between distant, heterogenous places. If precision instruments allow for the "the travel of data by imposing forms of equivalence and modes of comparison between them," those instruments must be managed so that they work properly in unusual, foreign, or strange places.[10] This essay describes a case where such management revolved around the problem of precision.[11]

THE MERIDIAN CIRCLE: THE PRECISION OF A TRANSIT INSTRUMENT

One fundamental problem with telescopes was that they had to make measurements that could be standardized while still maintaining sufficient mobility to follow the movement of the stars at night. From the seventeenth century on, a mural quadrant was combined with the telescope, known as a "transit instrument," allowing astronomers to track the apparent movement of stars in their right ascension. The transit instrument, mounted on a horizontal axis, allowed the vertical plane to be tracked with the help of a sidereal clock. Until the eighteenth century, astronomy required the combined use of clocks, telescopes, and mural quadrants to generate data, which was primarily organized into tables. Nevertheless, telescopes tended to distort the position of the meridian owing to their own weight and therefore had to be constantly realigned.[12]

German manufacturers, as part of the accelerated industrialization process of the early nineteenth century, developed a solution to the problem of the measurement and observation of the heavens, one that involved coordinating devices that needed to be constantly synchronized. To solve this problem, they added to the apparatus a declination circle that would also contain coordinates, thus achieving greater efficiency and avoiding confusion. A second essential change occurred in Germany at the dawn of that century: the invention of the equatorial mount with a divided-object glass micrometer that allowed the two halves of the lens to separate along a common diameter, moved by micrometric screws. This modification of the device was based on the use of reticules and cables that allowed telescopes to center on objects and the angles between them (as developed by the Englishman William Gascoigne in 1770).

One of the most important developers of astronomical measurement and observation instruments in Germany was Joseph Fraunhofer, who designed and built some of the best telescopes of the early nineteenth century, such as the Great Dorpat Refractor, also known as the Fraunhofer nine-inch, which was the largest telescope of its type in the world for many years. This device laid the groundwork for other German manufacturers, as it was equipped with the first "German equatorial mount," which would become standard for the great refractors of this epoch.[13] What was most relevant for the German production of precision objects, however, was Fraunhofer's belief that the artisanal practice of fashioning optical glasswork should be performed "from the knowledge deeply embedded in the craftsman's culture and hands." This meant that the

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[10] Marie-Noëlle Bourguet, Christian Licoppe, and H. Otto Sibum, *Instruments, Travel, and Science: Itineraries of Precision from the Seventeenth to the Twentieth Century* (London: Routledge, 2002), pp. 5, 8 (quotation).

[11] Regarding the history of scientific instruments and the problem of precision see Bernward Joerges and Terry Shinn, *Instrumentation between Science, State, and Industry* (Dordrecht: Kluwer, 2001); Helmar Schramm, Ludger Schwarte, and Jan Lazardzig, *Instruments in Art and Science: On the Architectonics of Cultural Boundaries in the Seventeenth Century* (Berlin: De Gruyter, 2008); Richard J. Spiegel, "John Flamsteed and the Turn of the Screw: Mechanical Uncertainty, the Skillful Astronomer, and the Burden of Seeing Correctly at the Royal Observatory, Greenwich," *British Journal for the History of Science*, 2015, 48:17–51; and Laura Cházaro, Miruna Achim, and Nuria Valverde, *Piedra, papel y tijera: Instrumentos en las ciencias en México* (Mexico City: UAM, Unidad Cuajimalpa, 2018).

[12] J. L. Heilbron, *The Oxford Companion to the History of Modern Science* (Oxford: Oxford Univ. Press, 2003), p. 411; and Jürgen W. Koch, *Der Hamburger Spritenzenmeister und Mechaniker Johann Georg Repsold (1770–1830), ein Beispiel für die Feinmechanik im norddeutschen Raum zu Beginn des 19. Jahrhunderts* (Hamburg: Books on Demand, 2001).

[13] Henry C. King, *The History of the Telescope* (Mineola, N.Y.: Dover, 1995), p. 180.

manufacturers of German instruments had more autonomy and, in contrast to instrument-makers in Great Britain, engaged in more cooperative, less hierarchical dialogue with the scientists who used their devices. At the same time, Fraunhofer became an exemplar of the benefits of the union of scientific research and technological innovation with industry. In this association, the strong backing of the government was fundamental, especially in Bavaria and Prussia.[14] Over the course of the nineteenth century, German manufacturers positioned themselves as the suppliers who could ensure the most precise measurements by producing the most powerful lenses, particularly the Munich workshops of Fraunhofer, carried on by Georg Merz after his death, Pistor & Martins in Berlin, and Repsold & Söhne in Hamburg. These manufacturers set the standard with their telescopes, which were acquired by the primary observatories of Europe and the United States.[15]

Of all the instruments available, the ones that were the most trustworthy and most in demand, thanks to their exactness, were transit instruments. Transit instruments were the first to use hollow cones for telescope tubes and a microscope to help the eye take readings with the pointer. The meridian circle, a telescope that can only move along the plane of the meridian, is one of the most important transit instruments.[16] This instrument possesses an axis mounted on a vertical circle that revolves with it and whose divisions are read with a micrometric microscope mounted solidly on one of the pillars securing the telescope. This allows astronomers to measure the right ascension and declination of a star simultaneously.[17] To make measurements, the astronomers noted which stars were at the meridian at each moment of the sidereal day, as measured by the clock. Finely graduated circles read with a micrometer allowed them to recognize centering errors and other pivoting problems easily. Precision chronometers ("regulators") were also used in the measurement of certain angles, "measuring the time that it takes for the stars to cross an illuminated wire (or rather, spiderweb) reticule in the focal plane of the transit telescope."[18]

The reliability of the meridian circle increased its use—and increased use in turn improved the reliability of the instrument and enhanced its scientific value. The tables of stellar movements prepared by Wilhelm Bessel and the installation of Johann Georg Repsold's meridian circle in Königsberg in 1841 gave the meridian circle "the status of an almost cult instrument." Measurements of stellar coordinates were being done nearly everywhere, making this exercise into an end in itself. Bessel's work, continued by F. W. A. Argelander (1799–1875), laid the basis for the *Bonner Durchmusterung*, published in 1859, which "has continued to be the standard reference work for identifying stars" to the present day.[19]

A meridian circle from the Repsold works in Hamburg played an integral role in the compilation of these astronomical records. Its measurement norms, especially with the design of its gravity pendulum, met the needs of astronomers who wanted to increase the accuracy of measurements of the declination of stars from centiseconds to milliseconds. The founder of this so-called dynasty was Johann Georg Repsold (1770–1830), who in 1799 had opened a mechanical

[14] Myles W. Jackson, *Spectrum of Belief: Joseph von Fraunhofer and the Craft of Precision Optics* (Cambridge, Mass.: MIT Press, 2000), pp. 8 (quotation), 9.

[15] Heilbron, *Oxford Companion to the History of Modern Science* (cit. n. 12); Ileana Chinnici, *Merz Telescopes: A Global Heritage Worth Preserving* (Cham: Springer, 2017); King, *History of the Telescope* (cit. n. 13); and Koch, *Der Hamburger Spritenzenmeisterund Mechaniker Johann Georg Repsold* (cit. n. 12).

[16] King, *History of the Telescope*, p. 104 (transit instruments); and *Meyers Enzyklopädisches Lexikon*, Vol. 11 (Leipzig: Verlag des Bibliographischen Instituts, 1885–1892), p. 492 (meridian circle).

[17] Robert Bud and Deborah Jean Warner, eds., *Instruments of Science: An Historical Encyclopedia* (New York: Garland, 1998), p. 628.

[18] John North, *Historia Fontana de la astronomía y la cosmología* (Mexico City: Fondo de Cultura Económica, 2005), p. 315.

[19] *Ibid.*, pp. 316, 315.

workshop in Hamburg that specialized in astronomical and geodetic instruments. Repsold began manufacturing precision instruments to make navigation safer, something of great interest in the city of Hamburg. At first Repsold equipped lighthouses, seawalls, and anchorages. In fact, the 1825 construction of a state astronomical observatory in Hamburg was undertaken in order to determine the city's coordinates precisely for ships leaving port. In this context, the fabrication of a meridian circle played a role in the determination of geographical coordinates. At the same time, Repsold productively worked as a manufacturer of surveying and measuring instruments, pendulum clocks, standard measures, and auxiliary astronomical instruments.[20] Right from the start, Repsold worked to meet the observational needs of Wilhelm Bessel (1784–1846), Friedrich Gauss (1777–1855), and Heinrich Christian Schumacher (1780–1850).[21] His connection with the users of these devices (a relationship that was very common among German workshops) ensured that his instruments—particularly the meridian circle—were rapidly acquired by observatories such as those in Hamburg, Zurich, and even Dorpat, now known as Tartu, in Estonia. Nevertheless, Repsold's relationship with Gauss was what introduced his work to scientific circles, as well as what inspired him to improve the device's micrometer. In 1836, after his death, his children and grandchildren worked with the Georg Merz workshop to improve the optical parts of the company's telescopes, particularly the meridian circle, and filled orders from around the world.[22] It is one of these very purchases that allows us to study how a meridian circle came to Chile and what material conditions defined its installation and functioning.

A MERIDIAN CIRCLE FOR THE NATIONAL ASTRONOMICAL OBSERVATORY OF CHILE

The National Astronomical Observatory of Chile was founded in Santiago de Chile in 1852 after the Chilean government purchased the instruments and installations left behind by the Astronomical Expedition to the Southern Hemisphere, led by James M. Gilliss (1811–1865).[23] From the start, the observatory was part of global astronomical networks. The institution's work not only situated measurement points in the Global South but allowed for coordination with

[20] Koch, *Der Hamburger Spritenzenmeister und Mechaniker Johann Georg Repsold* (cit. n. 12), pp. 310–314.

[21] Johann A. Repsold, *Zur Geschichte der astronomischen Messwerkzeuge von Purbach bis Reichenbach: 1450 bis 1830* (Leipzig: Wilhelm Engelmann, 1908), pp. 112–117.

[22] For further reading see Gudrun Wolfschmidt, "Telescopes Made in Berlin: From Carl Bamberg to Askania," in *From Earth-Bound to Satellite: Telescopes, Skills, and Networks*, ed. Alison D. Morrison-Low *et al.* (Leiden: Brill, 2012), pp. 177–194, esp. pp. 177–178.

[23] In 1849, the problem of the solar parallax brought Gilliss, an astronomer at the United States Naval Observatory, to Chile to make observations of Venus and Mars that would be compared with others made by his compatriots in the United States. This undertaking meant making observations from places close to their meridian but latitudinally separated, which required them to have points of observation in both hemispheres. From its origin, astronomy in Chile played the role of observing the skies of the Global South within the framework of these networks. See Philip C. Keenan, Sonia Pinto, and Héctor Alvarez, *El Observatorio Astronómico Nacional de Chile (1852–1965)* (Santiago de Chile: Univ. Chile, 1985), pp. 99–106; Wendell W. Huffman, "The United States Astronomical Expedition (1849–52) for the Solar Parallax," *Journal for the History of Astronomy*, 1991, 22:208–220; H. W. Duerbeck, "National and International Astronomical Activities in Chile, 1849–2002," in *Interplay of Periodic, Cyclic, and Stochastic Variability in Selected Areas of the H-R Diagram*, ed. Christian Sterken (San Francisco: San Francisco Astronomical Society of the Pacific, 2003), pp. 3–20; Steven J. Dick, *Sky and Ocean Joined: The U.S. Naval Observatory, 1830–2000* (Cambridge: Cambridge Univ. Press, 2003); Andreas Schrimpf, "An International Campaign of the Nineteenth Century to Determine the Solar Parallax: The U.S. Naval Expedition to the Southern Hemisphere, 1849–1852," *European Physical Journal H*, 2014, 39:225–244; Germán Hidalgo, "Revisiting J. M. Gillis's Astronomical Expedition to Chile in 1849–1852," *Journal of Astronomical History and Heritage*, 2017, *20*:161–176; Catalina Valdes, Amarí Peliowski, Rodrigo Booth, and Magdalena Montalbán, "Alcances naturalistas de una expedición astronómica: James Melville Gilliss y la institucionalización de la ciencia en Chile (1849–1852)," *Historia (Santiago)*, 2019, 52:547–580; and Carlos Sanhueza-Cerda and Lorena Valderrama, "Finding a Point of Observation in the Global South: The C. L. Gerling and J. M. Gilliss Correspondence (1847–1856)," *J. Hist. Astron.*, 2020, *51*:187–208.

other observatories in the North in the use of telescopes and in studies on the declinations of planets. During the nineteenth century, the National Astronomical Observatory of Chile tried to meet its obligations in global projects such as the Carte du Ciel and observations of the transits of inner planets, comets, and eclipses—but above all in completing charts of the Southern Hemisphere.[24] Owing to financial difficulties, the increasing importance of meteorology for the institution, and, especially, its inability to meet its assigned tasks in global observation projects, the Chilean observatory lost international relevance and its instruments and facilities deteriorated. By the end of the nineteenth century, the Chilean observatory was far from being a reference point, having only completed geodesic tasks for cartographic purposes and establishing the official time, as well as serving as a meteorological observatory.

At the beginning of the twentieth century, however, the Santiago observatory had a very different outlook. The institution sought to return to its glory days after a period of administrative and personnel difficulties. One important change was the arrival of a contingent of German astronomers, chief among them Friedrich W. Ristenpart (1868–1913), the new director who took up his post in 1908, and Walter Zurhellen (1880–1916) and Richard Prager (1883–1945), who served as the directors of the astrophotography and calculation departments, respectively. It is no surprise that a group of Germans would take charge: the founder of the institution was Karl Moesta, a Prussian, and from the start its technicians and instruments also shared this national origin.[25]

Ristenpart was without doubt the most important astronomer ever to join the observatory in Chile. He had studied classical precision astronomy in Jena and Strasbourg and had worked in Heidelberg and Kiel. From a young age, he sought to systematize the observations of stellar positions scattered in observatory catalogues. In 1908 he was Privatdozent at the University of Berlin and, on being contacted by the Chilean government to reorganize the observatory, he did not hesitate before accepting. He saw his task as foundational, declaring: "I was convinced that *nothing* should be conserved of the old observatory, not the buildings, not the lenses, not even the work system . . . it was essential . . . that the Santiago Observatory do work befitting its situation, being located in the southwestern extreme of a network that brings together all observatories."[26] Ristenpart was convinced that Chile would resume its role as a vital point for observations in the Global South.

Starting in 1909, Ristenpart set to work to design a plan for the new observatory, in anticipation of its move from the center of Santiago (Quinta Normal) to the south of the city (Lo Espejo),

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[24] The Carte du Ciel was a network that sought to capitalize on the new techniques and instruments for stellar photography developed by the Henry brothers. By 1887, twenty observatories had collectively committed to photographing the entire sky, in search of stars with predetermined magnitudes. One of these observatories was the National Astronomical Observatory of Chile, which was in charge of photographing the sky between the declinations of 17 and 23 degrees. The importance of Chile's participation in this project lay not just in the fact that it would receive photographic plates and a Gautier telescope from Paris, but also that the observatory had the chance to participate in the development of new, emerging scientific techniques modeled on international practices. On the Carte du Ciel see David Aubin, "The Fading Star of the Paris Observatory in the Nineteenth Century: Astronomers' Urban Culture and Observations," *Osiris*, 2003, N.S., *18*:79–100; and Charlotte Bigg, "Photography and the Labour History of Astronomy: The Carte du Ciel," *Acta Historica Astronomiae*, 2000, 9:90–106. Both references are taken from Nasim, "Observatorium" (cit. n. 1), p. 184. On Chile's role see Keenan *et al.*, *El Observatorio Astronómico Nacional de Chile*, p. 124.

[25] Keenan *et al.*, *El Observatorio Astronómico Nacional de Chile*, p. 129. On the German influence from the time of the observatory's founding see Carlos Sanhueza-Cerda, "Chile y Alemania 1871–1914: Un vínculo que se solidifica," in *Deutschland und Chile, 1850 bis zur Gegenwart: Ein Handbuch*, ed. Stefan Rinke (Stuttgart: Heinz, 2016), pp. 53–82.

[26] Friedrich Ristenpart, "Astrónomos alemanes en Chile," in *Los Alemanes en Chile* (Santiago de Chile: Universitaria, 1910), pp. 177–193, on p. 187. On the arrival of Ristenpart see Keenan *et al.*, *El Observatorio Astronómico Nacional de Chile*, p. 129.

which was predicated on a renewed focus on so-called positional astronomy or astrometry.[27] Implementation of this plan required an inventory of the observatory's existing instruments, with particular attention to their condition and their possible uses. This allowed the new director to identify needs and personnel shortcomings, as well as to justify further acquisitions. Ristenpart's objective was to reposition the National Astronomical Observatory through its participation in international projects, and so it had to be able to capture data on stars at least to the tenth visual magnitude. The observatory's move to Lo Espejo was in line with this plan to the extent that the new site would provide better visibility for observations.[28]

Of course, instruments had been fundamental throughout the observatory's history. In the 1910 annual report Ristenpart mentioned the order for a seven-inch meridian circle, placed with A. Repsold & Söhne in Hamburg, Germany (see Figure 1). For Ristenpart, acquiring a meridian circle from Hamburg fit with his larger desire to "create a German observatory on southern soil," as he mentioned in a letter to the company.[29] This interest can be seen not just in the new building and its instruments, but also in a reorganization that sought to separate astronomy from meteorology, as well as in the hiring of new, specialized personnel.[30]

The new meridian circle would enhance the observatory's powers. In effect, this instrument (as would be declared in an internal regulation approved years later) would serve the purposes of the Meridian Service, contributing to establishing the official time, determining latitudes and longitudes, and preparing catalogues of stars and planets.[31] Ristenpart himself trained his students at the University of Chile in the use of this new instrument. His astronomy textbook was even dedicated to the "theory of instruments." In his classes, Ristenpart sought to "educate . . . students so that they can later work independently with the first-class instruments that the government will provide to the new observatory."[32]

Ristenpart explained his reasons for this purchase to the German manufacturer. In a letter dated 30 November 1908, he noted his intention to verify the data contained in the catalogue of circumpolar stars between 65 and 90 degrees S that had been prepared by the U.S. expedition to Chile led by Gilliss.[33] This astrometric task required new instruments. As he argued, "the old Gautier meridian circle . . . could still be used for determining the hour, but not for the

[27] Astrometry is the branch of astronomy that involves precise measurements of the positions and movements of stars and other celestial bodies. See Jean Kovalevsky and P. Kenneth Seidelmann, *Fundamentals of Astrometry* (Cambridge: Cambridge Univ. Press, 2004).

[28] Keenan *et al.*, *El Observatorio Astronómico Nacional de Chile* (cit. n. 23), p. 130.

[29] Friedrich W. Ristenpart to A. Repsold & Söhne, 21 Feb. 1909, Staatsarchiv Hamburg, A II 28: ". . . auf sudländiche Boden eine Deutsche Sternwarte zu erreichen." The 1910 annual report can also be found Staatsarchiv Hamburg, A II 28.

[30] The new personnel included fourteen assistants or calculators, as well as three assistant photographers and staff for the meridian department. See Rodrigo Fornos, *Science Still Born: The Rise and Impact of the Panamerican Scientific Congresses, 1898–1916* (New York: iUniverse, 2003), p. 68.

[31] "The Santiago National Astronomical Observatory in 1909," in *Anales de la Universidad de Chile*, Vol. 127, p. 751 (enhanced powers). For the internal regulation see Archivo Nacional de Chile, Ministerio de Justicia e Instrucción Pública, Vol. 5459, 1929.

[32] "Poder educar a . . . mis alumnos para que pudiesen trabajar independientemente más tarde con los instrumentos de primera clase con que el Gobierno dotaría al nuevo Observatorio en Espejo." See Friedrich W. Ristenpart, *Clases de Astronomía profesadas en la Universidad de Chile por el director del Observatorio Astronómico Nacional Dr. Friedrich Wilhelm Ristenpart* (Santiago de Chile: Cervantes, 1912); this text compiled the notes of Ristenpart's assistants Rosauro Castro and Rómulo Grandón.

[33] Ristenpart to Repsold, 30 Nov. 1908, Staatsarchiv Hamburg, A II 28: ". . . mein Absicht ist den südlichen Circumpolar Sternkatalog von Gilles [Gilliss] neu zu beobachten (65–90°)." This is the first record we have of the correspondence between the manufacturer and the end user. On the Gilliss expedition see note 23, above.

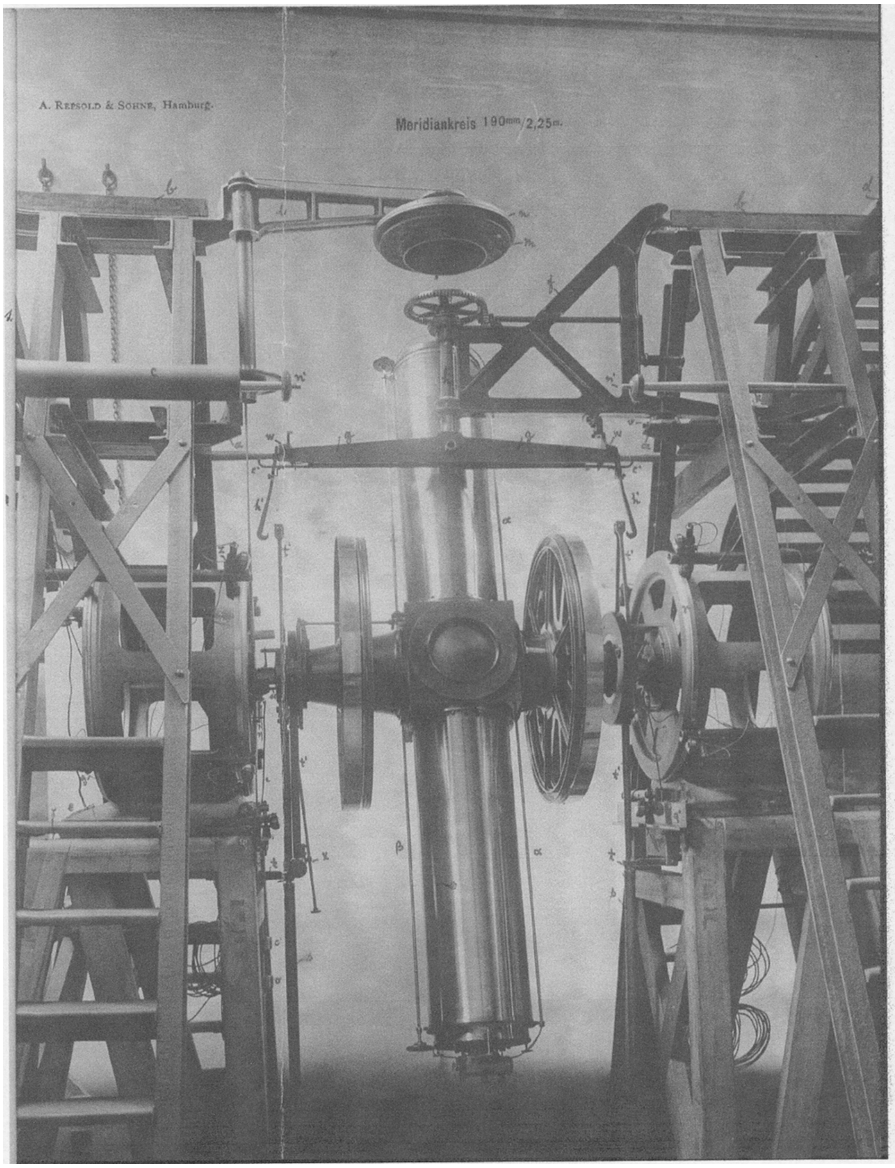

Figure 1. Repsold's meridian circle, circa 1910. Photo from the Staatsarchiv Hamburg, Germany.

'detail work' of the latest astronomy, especially in terms of observations made from the Southern Hemisphere."[34]

The mere purchase of a latest-generation device was not sufficient to make such "detail work" possible: its proper installation and use were also fundamental. How could it be ensured that this new instrument would produce reliable information? What steps would be necessary to

[34] *Ibid.*: "der alte Meridiankreis von Gautier, die Kriegsbeute der chilenen aus dem Krieg mit Peru wohl noch Zeitbestimmungen gut genug sei, aber nicht für die feinen Aufgaben, die speciell auf der Südhalbkugel von einer solchen Instrumente verlangt werden müssen."

calibrate it and maintain it in the Chilean context? Before and during the construction of the instrument—and following its arrival in Chile—Ristenpart sent letters to the manufacturer, trying to identify the critical points regarding installation. This correspondence played an important role, as it allowed adaptations to be made, both by the manufacturer before the instrument was shipped to Chile and by the observatory staff once it had arrived. As was argued at the beginning of this essay, achieving precision depends not only on the quality of the instrument itself but also on a set of maintenance and observational protocols. In this sense, the communications between the end user and the manufacturer were crucial.[35]

MANAGING A MERIDIAN CIRCLE: STABILIZING THE TECHNICAL PERSONNEL

Local observers, whether collaborators, assistants, or hired technicians, were crucial to the functioning of the new instrument. This posed a challenge, given the country's human capital at the time. The manufacture and installation of an instrument reveal the full spectrum of techniques that allow it to be used: its calibration, adaptation, repair, and later maintenance. Ristenpart was aware of the difficulties of having precision instruments in the absence of trained personnel: he recognized that the entire local team had to be educated, which led to his interest in writing treatises for his students at the University of Chile. His lament regarding his isolation, written a month after the meridian circle's arrival, reflected not only the fact that he had to do everything himself ("keine andere Ratserholung als bei Ihnen selbst") but also his awareness that the educational system (engineering schools, courses on optics and mathematics), workshops, and the availability of replacement parts were what would guarantee the proper use of his new instrument.[36]

Ristenpart mistrusted the local knowledge available to him. Even though there were German watchmakers residing in Chile at the end of the nineteenth century—for example, Louis Grosch (d. 1902), who maintained, adapted, and repaired telescopes, clocks, and chronometers—he never saw them as the sort of local resource that would enable him to achieve and maintain instrument precision.

Ristenpart's mistrust was made clear when he requested that the manufacturer simplify the instrument's parts. While one of the most important characteristics of the Repsold meridian circle was an "ocular head" (*Ocular-Kopf*) with an integrated micrometer that allowed for the automatic registration of the passage of stars and their declinations, Ristenpart requested that the manufacturer make it possible to use the "old method"—that is, to perform these registrations manually. He argued that it is "doubtful that my local employees will learn to handle the new micrometer."[37] Despite the major advance represented by the Repsold micrometer, the observatory's director stipulated to the manufacturer that it was necessary that the thread system could be manipulated with a screw and that these screws had to be readable.[38]

Precision depended not only on the characteristics of the instrument itself but also on its local stabilization; Ristenpart believed that this could be achieved only by bringing a specialized

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[35] Regarding the role of correspondence in the history of science see Dirk van Miert, ed., *Communicating Observations in Early Modern Letters (1500–1675): Epistolography and Epistemology in the Age of the Scientific Revolution* (London: Warburg Institute; Turin: Nino Aragno, 2013).

[36] Ristenpart to Repsold, 14 June 1911, Staatsarchiv Hamburg, A II 28.

[37] Ristenpart to Repsold, 30 Nov. 1908: ". . . aber nebenher die Möglichkeit nach der alten Methode zu registrieren, bestehen, da es mir zweifelhaft erscheint, dass alle meine hiesigen Mitarbeiter die handhabung des neuen Micrometer erlernen." On the characteristics of this instrument see Koch, *Der Hamburger Spritenzenmeister und Mechaniker Johann Georg Repsold* (cit. n. 12).

[38] The characteristics of this meridian circle are specified in the contract dated 6 Apr. 1909 and in the assembly instructions (*Erstellung*) that accompanied the instrument to Chile. See Staatsarchiv Hamburg, A II 28.

technician to the country. This is a topic that arose time and time again in his letters to Repsold. A letter from the director of astrophotography, Walter Zurhellen, to the manufacturer also stressed the role played by the technician—but with a different assessment: regarding the movement of the meridian circle's photographic plate, Zurhellen informed Repsold that a mechanic in Chile could manufacture parts for the micrometer and so they only needed a standard machine of the Potsdam-Bonner type.[39] In this case, local knowledge made it possible to acquire products at prices more accessible to the observatory's budget. But what happened when local experts were not up to the task of making modifications? The answer to this question becomes clear when we examine what happened when the instrument's mechanical parts had to be modified to enable it to make measurements in the Southern Hemisphere, as the manufacturers had aligned it in accordance with the direction in which the observer had always been located: the north.[40] Here, as in other situations, the presence of qualified mechanics was essential to ensuring the instrument's proper functioning. This problem had been foreseen before its arrival, but it became clearer when it came time for installation. How could the instrument be adapted in accordance with the manufacturer's instructions, when correspondence was slow and could be interrupted by the outbreak of war? This explains why the conversations between the observatory director and the manufacturer always came back to the possibility of bringing a German technician to Chile.[41] As training someone properly could take years, it would be easier to recruit qualified personnel from outside.

The problem of mechanical assistance was partially resolved before Ristenpart even had to ask, as the Chilean government hired a technician from Berlin, Richard Wüst (1880–1954). The arrival of Wüst (ca. 1909), who had experience working for the German optics manufacturer Zeiss, was good news for Ristenpart—and he said as much in a letter to the Hamburg manufacturer. Wüst cleaned the meridian circle's lens of the mold it had accumulated before arriving in Chile. He then put three bronze cylinders at the bases of the pillars, where mercury levels and counterweights would later be introduced to balance the instrument and ensure its proper functioning.[42]

The guidance of a technician made it clearer what was needed—in particular, what had to be purchased and what could be adapted so that the observatory instruments would function properly for the purposes of the measurement tasks at hand. This technical support also meant improved coordination with the manufacturer when it came to meeting the needs of the observatory and ordering replacement parts for the meridian circle as well as its other devices.[43]

In the year following Wüst's arrival, Ristenpart noted that the advice of the German technician had led him to change his mind about buying parts for the micrometer for the Gautier

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[39] Walter Zurhellen to Repsold, 18 Apr. 1910, Staatsarchiv Hamburg, A II 28: "Sie sehen, dass Sie viele Wünschen vom mir Horen würden, wenn wir einen neuen Apparat zu bestellen hätten. Das ist indes nicht unsere Absicht, da wir eben dem augenblicklichen nur noch einen von dem einfachen Potsdam-Bonner Typus brauchen, und unser Mechaniker diesen abgesehen vom Micrometer selbst herstellen kann."

[40] *Ibid.*: ". . . an der Seite, auf der sich der Beobachter fast immer befindet, . . .: Im Norden."

[41] Time and again, Ristenpart asked that Repsold help him hire someone, "preferably single," who would be offered a salary in accordance with the local cost of living, as "it is not expensive [here]," as well as lodging at the observatory. Among his conditions, Ristenpart requested that the assistant be competent (*tüchtig*) but above all that he have an irreproachable character (*tadellosem Charakter*) and be someone he could trust. Ristenpart to Repsold, 21 Feb. 1909, Staatsarchiv Hamburg, A II 28.

[42] Archivo Nacional de Chile, Ministerio de Justicia e Instrucción Pública, Vol. 3184, 1911.

[43] Ristenpart had Wüst's help in tackling the problem of the Gautier refractor: they not only had to build a new micrometer (which would modernize the instrument) but also repair the mechanism. Here the role of Wüst was crucial, as he could identify the problem with the apparatus that allowed its secondary controls to be improved and thus avoid deceleration. See Ristenpart to Repsold, 16 Mar. 1910, Staatsarchiv Hamburg, A II 28.

refractor's photographic plates, as Wüst had argued that they were "inessential or, rather, superfluous."[44] Wüst was fundamental in resituating the observatory in global projects by repairing the Gautier equatorial astrophotography telescope, used for the Chilean portion of the Carte du Ciel, and the Bamberg passage instrument used to observe the movement of the South Pole.[45]

CALIBRATING A MERIDIAN CIRCLE: STABILIZING THE AUXILIARY DEVICES

The auxiliary devices were just as important as the technical personnel for ensuring the functioning of the new meridian circle. In other words, beyond the acquisition of the primary instrument, a series of other artifacts needed to be manufactured to ensure its correct operation. The problem was that each auxiliary piece had to be imported to Chile and then calibrated by the observatory itself. How could their correct assembly and, therefore, precision be ensured?

One case is that of the observing chairs, which must be calibrated in conjunction with each instrument so that they can follow the movements of the telescope. Omar W. Nasim has recently shown how astronomers during the nineteenth century "concentrated on the function of the chair with respect to the observer's body in connection to the telescope and the motions of the heavens."[46] We can see that the manufacturer and the observatory director discussed this topic in their correspondence. On 21 August 1909 Ristenpart, taking advantage of his contractual ties to Repsold, ordered the construction of a chair for the observatory's old Eichens meridian circle. Some months later, on 26 January 1910, he thanked the manufacturer for the chair, which had reached Chile, but complained that its dimensions were not adequate for use with the instrument in question. It seems that the data sent from Chile were never taken into consideration. If the chair was not calibrated "for the exact mass of our meridian circle," the director wrote, it was impossible to make a zenith reading because the chair was "too high."[47] In June that same year, Ristenpart sent one more letter that dealt with the observing chair, making it clear that the problem with the chair was not so much its dimensions but the height at which the observer would look through the telescope's sight. For the manufacturer, this question revolved around the sight and not the chair, which he claimed was properly designed. This meant that the Chilean observatory had to reinstall the instrument to adapt it to the recently acquired chair.

How important are observing chairs, really? Was it simply a matter of reinstalling the telescope, as if it was the problem? We must not forget that each telescope must be anchored and adjusted to the movements of the observatory dome. This case represented a lesson to be learned before the new meridian circle reached the observatory. Ristenpart did not miss the opportunity to emphasize the importance of these auxiliary devices to the manufacturer, an aspect that is frequently overlooked in the process of manufacturing high-precision instruments. As Ristenpart noted, owing to the fact that astronomers observe stars, "and one star follows another rapidly, after a few short seconds," the difference in declination had to be followed in such a way that "the position of the head has to be moved from one star to the next."[48] Ristenpart suggested to the

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[44] Ristenpart to Repsold, 26 Jan. 1910, Staatsarchiv Hamburg, A II 28: ". . . habe ich zwei Stellen seines Briefes eingeklammert, weil mir der Mechaniker diese Teile als entbehrlich oder vielmehr überflüssig bezeichnete."

[45] Archivo Nacional de Chile, Ministerio de Justicia e Instrucción Pública, Vol. 5459, 1929.

[46] Omar W. Nasim, *The Astronomer's Chair: A Visual and Cultural History* (Cambridge, Mass.: MIT Press, 2021), p. 10.

[47] Ristenpart to Repsold, 26 Jan. 1910: "Man kann nämlich nicht im Zenit oder auch nur in 20° Abstand von demselben beobachten, weil der Stuhl zu hoch für das Ocular ist."

[48] Ristenpart to Repsold, 11 June 1910, Staatsarchiv Hamburg, A II 28: "Sie müssen bedenken, wir beobachten Zonensterne, bei denen ein Stern rasch, in wenigen Sekunden auf den andern folgt, die Verschiedenheitin declination ist nicht gross, aber immerhin so gross, dass die Kopfhaltung meist von einem zum nächsten Stern etwas geändert werden muss."

manufacturer that the new meridian circle, which was about to be sent to Chile, should include a chair with a crank that could easily be raised or lowered, thus allowing measurements to be made with the required precision. The next problem lay in how to power this movement. On this point, in a transfer of knowledge from the user to the manufacturer, Ristenpart requested that a chair be built for the meridian circle that used endless screws (*Stuhl mit einer Schraubenbewebung*) so that observations would not depend on the speed with which the observers turned the crank.[49]

INSTALLING A MERIDIAN CIRCLE: STABILIZING THE PLACE OF OBSERVATION

As we have already seen, precision goes beyond having an instrument with cutting-edge technical features: calibration depended on local knowledge, but also on the place where the telescope was going to be used. The purchase of the meridian circle formed part of the plan for the Chile observatory's new facilities. Previous locations, such as Santa Lucía Hill and the Quinta Normal complex, had played a role in shaping the observatory's collection of instruments. These sites, whether located in the city center (Santa Lucía) or near the new train station to the west (Quinta Normal), destabilized observation practices because of the levels of light pollution or the dust suspended in the air. New telescopes with a greater degree of precision required new observation sites. In 1909 the observatory director had told the manufacturer about the advantages of a move to a site further removed from the quickly growing city, as well as the "fortunate position of the new observatory."[50] The 1909 annual report highlighted the advantages of the new site, as it was "situated on high ground, with the surrounding lowlands completely clear." The location to the south of the city (Lo Espejo) made it possible to have an unobstructed view in every direction, as there were neither buildings in the way nor any human traffic, and "in no direction is the horizon narrowed by more than five degrees."[51]

This broad horizon allowed, for the first time, the design of facilities that could be based around the observation instruments. A review of the plans for the new facilities at Lo Espejo in the archives of Chile's Ministry of Public Works makes clear that the new instrument was to be used in conjunction with older ones (see Figure 2). Here we see how the equatorial Grubb telescope (which was larger than the new instrument and therefore needed to be inclined more) would be located at the center in a latitudinal arrangement. The meridian circles (including the one being ordered from Repsold) would be oriented in a north–south direction. South of the equatorial Grubb would be the equatorial Eichens and the equatorial astrophotography telescope. They could all be placed so as to allow for observations without interfering with each other. It was essential that no instrument impede the visibility of the horizon. Given that the building was being designed at the same time as the construction of the new instruments, everything could be adapted to the observatory's needs.

Essential to the functioning of the new meridian circle was the presence of a pillar for calibrating the line of the meridian: it would consist of a painted structure that could be observed through the instrument's lens. Ristenpart thought that it was very important that the site for

[49] *Ibid.*

[50] Ristenpart to Repsold, 21 Feb. 1909: "Ich werde in der glücklichen Lage sein, auf der neuen Sternwarte . . ."

[51] *Anales de la Universidad de Chile*, July–Dec. 1910, Vol. 127, p. 754: "Las ventajas de la situación del terreno consisten en estar situado en una altiplanicie con alrededores enteramente despejados, que se eleva suavemente desde Santiago para descender también suavemente hacia San Bernardo. . . . La situación en Lo Espejo . . . difícilmente podrá ser sobrepasada por otra respecto a la grandiosidad de sus alrededores. Hacia el este se acampa en ancha línea la alta cresta de la cordillera de Las Condes, exactamente al este se abre el Cajón del Maipo. . . , hacia el oeste . . . las cumbres de la cordillera de la costa; al norte algunas montañas solitarias, las más cercanas a 30 kilómetros, elevando una marcada cumbre precisamente en el meridiano. . . . En ninguna dirección es estrechado el horizonte por más de 5 grados."

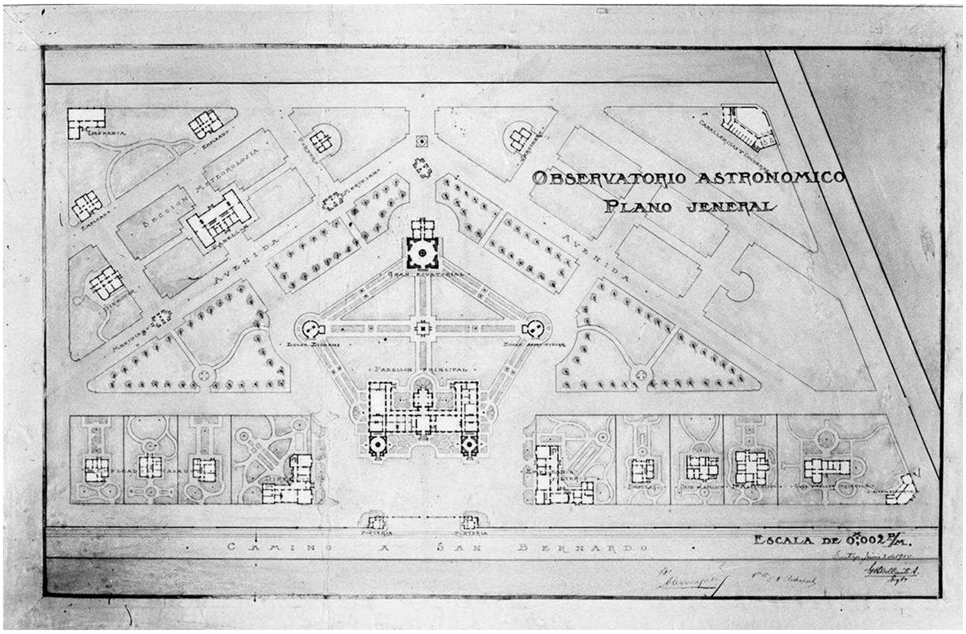

Figure 2. General plan of "Lo Espejo" Astronomical Observatory. Photo from the Legacy of the Ministry of Public Works of Chile, National Archive of Chile, 1911, Fondo "Obras Públicas."

the new meridian circle allow the pillar to be located "as far from the meridian circle as possible while still being onsite." To ensure that the new facilities would allow for the continuity of work with the meridian circle, on 9 June 1909 he requested that the Chilean Ministry of Justice and Public Instruction provide a lot sufficiently large enough that "in the future, no one may restrict the view with intermediate constructions."[52]

The fact that the buildings and telescopes were being built at the same time allowed for better coordination and more effective placement. Unlike at the observatory's previous sites (such as Santa Lucía Hill and Quinta Normal), the instruments could now complement each other. Ristenpart mentioned this to the manufacturer: the idea (as can be seen in Figure 2) was that both the old and the new meridian circle would be aligned so that they could function as a collimator. Ristenpart therefore opted to place them in a "semicylindrical structure in the upper part of the building."[53]

The coordinated placement of buildings and telescopes also influenced decisions on the dimensions of the housing and dome for the new meridian circle. Ristenpart didn't have many issues with the dimensions of the instrument itself because, as he mentioned to the manufacturer, "At the end of your letter, you asked about the dimensions of the room in which the meridian circle will be housed, but as the new observatory is still under construction, I'm lucky enough to be able to adapt

[52] Archivo Nacional de Chile, Ministerio de Justicia e Instrucción Pública, oficios, 1909: ". . . de manera que en el futuro nadie pueda quitarle la vista por construcciones intermedias."
[53] Ristenpart to Repsold, 21 Feb. 1909: ". . . ich denke an eine halbzylindrische Construction des Oberteiles. . . ." A collimator is a device allowing the direction of a telescope to be adjusted to obtain a beam of parallel rays of light, using a bulb. This operation allows for the precise orientation of optics within a telescope. See Fritz Hodam, *Technische Optik* (Berlin: VEB Verlag Technik, 1967).

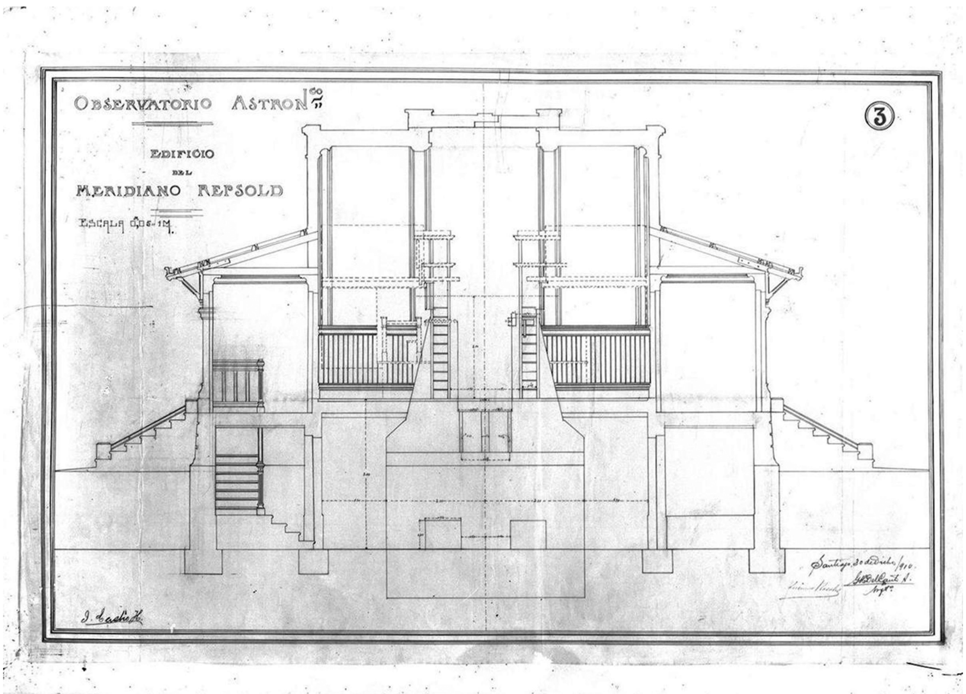

Figure 3. Repsold meridian circle construction plan. Photo from the Legacy of the Ministry of Public Works of Chile in the National Archive of Chile, 1911, Fondo "Obras Públicas."

the building to the dimensions of your instrument."[54] We can conclude from their correspondence that the two men discussed the design of the space that would house the meridian circle. In a letter dated 11 June 1910, Ristenpart commented that "finally I can begin on the design and construction of the meridian house in accordance with your outline, and I hope to finish it before the meridian circle arrives."[55] We can see from the plans for the meridian circle building at Lo Espejo that it was designed to allow for the ascending movement of the meridian circle, as well as that this dome was the only one that allowed for the entrance of light to be controlled (see Figures 3 and 4).

One very important aspect of the instrument's placement had to do with light within the dome. Ristenpart engaged in many lighting tests before the new instrument arrived, as he explained to Repsold: "I've tried many different windows in our observatory, but neither the tallest nor the most beautiful have given me enough light on the white surfaces (that is, on all of them at the same time)." The problem lay in that a series of windows oriented toward the zenith had to be built so that "enough light could enter in a staggered fashion." Ristenpart opted for a skylight because, as he mentioned to the manufacturer, "lighting with a skylight is the best for our instrument, which is why we have also built measurement rooms with skylights in our observatory."[56]

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[54] Ristenpart to Repsold, 21 Feb. 1909: "Am Schlüsse Ihres werten Briefes fragen Sie nach den Dimensionen des Meridiansaales. Da die Sternwarte neugebaut wird, bin ich glücklichen Lage umgekehrt den Meridianbau den Dimensionen Ihres Instrumentes anpassen zu können."

[55] Ristenpart to Repsold, 11 June 1910: "So werde ich denn endlich nach ihrer Skizze jetzt an der Entwurf und die Ausführung des meridianhauses gehen können, und hoffe fertig zu werden, ehe den Meridiankreis kommt."

[56] Ristenpart to Repsold, 18 Apr. 1910, Staatsarchiv Hamburg, A II 28: "Ich habe die verschiedene Fenster in unserer Sternwarte durchprobiert, aber selbst das höchste und schönste hat mir kein hinreichendes Licht auf die sämtlichen weissen Beleuchtungsflächen (d.h. auf alle gleichzeitig) gegeben. Das ist auch kein Wunder; die Fenster müssten sozusagen bis zum Zenith

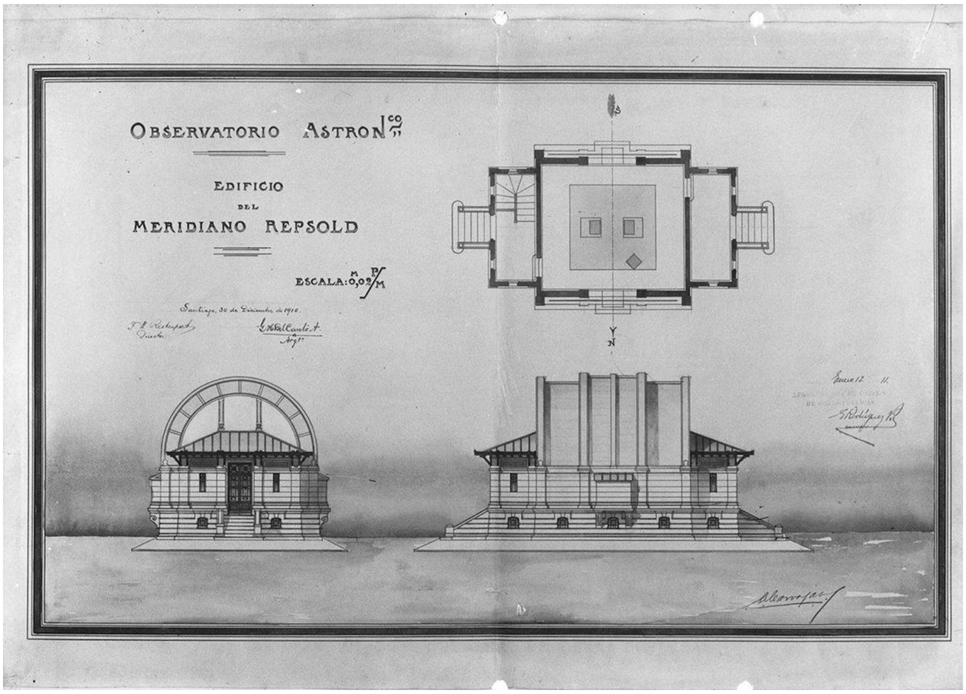

Figure 4. Repsold meridian circle construction plan. Photo from the Legacy of the Ministry of Public Works of Chile in the National Archive of Chile, 1911, Fondo "Obras Públicas."

The procedures used, the installation instructions included with the sale of the instrument, and international protocols (applied here for dome design, lighting, and coordination with other instruments) were not enough to guarantee the success of this endeavor. On 14 June 1911, one month after the instrument's arrival in Chile, Ristenpart was still unable to finish installation because he could not understand the mechanism through which the base would be affixed to the pillars that anchored the meridian circle to the ground. Was he doing something wrong? Ristenpart told Repsold that he couldn't find "the holes that permitted such an adjustment." His letter ended with a request: "Perhaps you could be so kind as to enlighten us on this point."[57]

Construction of the building housing the new instrument, designed by the architect Hermógenes del Canto, was closely supervised by Ristenpart. A 1912 progress report on the new observatory at Lo Espejo reveals the care with which the base pillars for the lens of the Repsold meridian circle were built. The architect reported how, as these bases "require great stability, they must be built with concrete and not with brick, as the latter is too elastic a material. . . . This work has been executed in accordance with the orders of the Director of the Astronomical Observatory, both in the use of materials as well as the dimensions, heights and sections of the supports. This same norm has been adopted in all the facilities for scientific work." Nevertheless, the director did not always have all the necessary construction knowledge: in the end, the building

gehen, um hinreichendes Licht über den Vorsprung Scalenbrücke herüberzusehen. Zu viel Licht bekommt man freilich auch so nicht, da der Himmel hier meist tiefblau, und das Oberlicht von mässiger Grösse ist. . . . Jedenfalls ist die Beleuchtung mit Oberlicht für unsern Apparat offenbar die beste; wir werden also auch in der neuen Sternwarte Messzimmer mit Oberlicht bauen."

[57] Ristenpart to Repsold, 14 June 1911: "Es sind aber keine Durchbohrungen zu sehen, die ein solches Festschrauben erlaubten. Vielleicht haben Sie die grosse Güte, uns über diesen Punkt recht ausführlich zu unterrichten."

Figure 5. Repsold's meridian circle today at the National Astronomical Observatory of Chile in Cerro Calán, Santiago, Chile. (Ximena Zúñiga. Copyright courtesy of the author.)

had to be made of brick, whose elastic characteristics recommended its use in an earthquake-prone country like Chile. At the same time, the block that established the meridian's direction was miscalculated by Ristenpart, as the Chilean construction workers discovered. Ristenpart then ordered them to "change the position of the sight" to make the instrument operative.[58] A year after its arrival, the meridian circle finally had a building that allowed it to function correctly.

CONCLUSIONS

The term "instrument" has a variety of meanings in natural philosophy: it can be understood as a model or analogy for nature, an extension of the senses, a measurement device, a way of creating

[58] Archivo Nacional de Chile, Ministerio de Justicia e Instrucción Pública, Vol. 3056, 1912.

extreme conditions that do not naturally occur on Earth, or a visual or graphic exhibition. This ambiguity, however, is a great virtue for the study of scientific instruments in that it allows us to see technology in action. In this sense, the installation of the meridian circle in the National Astronomical Observatory of Chile opens up a field of meanings, assemblages, and articulations.

An instrument undergoing the process of installation, such as that analyzed in this case study, allows us to observe that an object cannot function and fulfill its purpose in isolation. Here we have seen how protocols, technical personnel, the site where it was to be used, and auxiliary devices form a structural part of what allows the instrument to function—especially to function well or, rather, precisely.

The case reviewed here, as it is based on correspondence between the manufacturer and the user, hides other elements of local stabilization. We have the vision of the astronomer and, through him, of the role played by the technician, but this source tells us little about other actors involved in the instrument's installation. For his part, Ristenpart mistrusted local resources, which explains his inclination to rely on his compatriots. Ristenpart supervised the construction of the building where the meridian circle was installed, but without the labor of local architects and construction workers the instrument would not have functioned with the precision required. While local knowledge was insufficient, as Chile lacked a tradition of experts in precision instruments, this does not mean it did not exist and play a part.

In 1917, more than six years after the arrival of the Repsold meridian circle, this German instrument measured the exact geographic latitude of Chile. In 1926, using the instrument, the National Astronomical Observatory of Chile finally determined the geographic longitude through radiotelegraphic signals transmitted by the Annapolis Station in the United States.

To this day, the instrument remains at the National Observatory, where it marks the official meridian of Chile (see Figure 5).