techniques. The urban environment shaped the kind of knowledge available to the naturalists, but, in tandem, scientific research also redefined the urban quarters. A regular fish market became a site of scientific investigations. In the contact zones of an entrepôt, British naturalists and their Chinese associates participated in knowledge production in the intersecting spheres of collecting, aesthetics, commerce, science, and other overlapping social and cultural activities.

Finally, this essay demonstrates that even a localized study of an entrepôt points to the broad theme of science and the city in world history. Through transoceanic trade, a Chinese city extended its influence to Europe and vice versa. Like tea, silk, and porcelain, ornamental plants from China and other parts of the world helped change the face of London. After successful cultivation, exotic novelties appeared on the markets and added colors to English gardens. The efforts to introduce plants and animals from one part of the world to another, or the enterprise of transporting and transplanting "nature," depended on the infrastructure of maritime trade and the entrepôts. The movement and redistribution of wealth, commodities, material culture, knowledge, and nature was inextricably linked to what has been called the making of the modern world, the formation of the world system, or the process of globalization. It was a process of enormous social, political, and ecological impact. This episode of Old Canton thus illustrates a chapter of world history.

The Fading Star of the Paris Observatory in the Nineteenth Century:

Astronomers' Urban Culture of Circulation and Observation

*By David Aubin**

ABSTRACT

Engulfing the Observatoire de Paris around 1860, the modernizing city clashed with the increasing precision required by astronomy. Suggestions to transfer the observatory to the suburbs gave rise to intense debates; these provide an enlightening standpoint for studying changes in observation and circulation regimes central to the mutations of both urban cultures and astronomical scientific practices. Moreover, these regime changes took place in a context of constant interaction between the city and the observatory. At practical levels, the changing experience of circulation and observation led to a parceling of the various tasks previously filled by the Paris Observatory and gave rise to an epistemology reminiscent of Latour's network theory.

INTRODUCTION

"The ground of Paris shakes, the feverish life agitating the big city that never sleeps stirs buildings to their foundations."[1] By 1868, the rapidly sprawling city had definitely caught up with the Paris Observatory. Struggling to preserve the observatory's isolation from noise, light, and vibrations, some astronomers pondered whether to transfer it beyond city limits. The lively debates this suggestion sparked reveal the complex and problematic relations that, as is well known, experimental science has often had with urbanization. On the face of it, the outcome of the conflict seems clear: the city has won. Now that modern cities have become synonymous with cacophonies, flashy light displays, and constant agitation, many observatories have been forced to take refuge on remote mountaintops, if not in space.

And yet, on a bright Sunday afternoon, take a walk in the Luxembourg Gardens, in

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[1] Rudolph Radau, "L'Observatoire de Paris depuis sa fondation," *Revue des deux mondes* 73 (1868): 740–68, on 766.

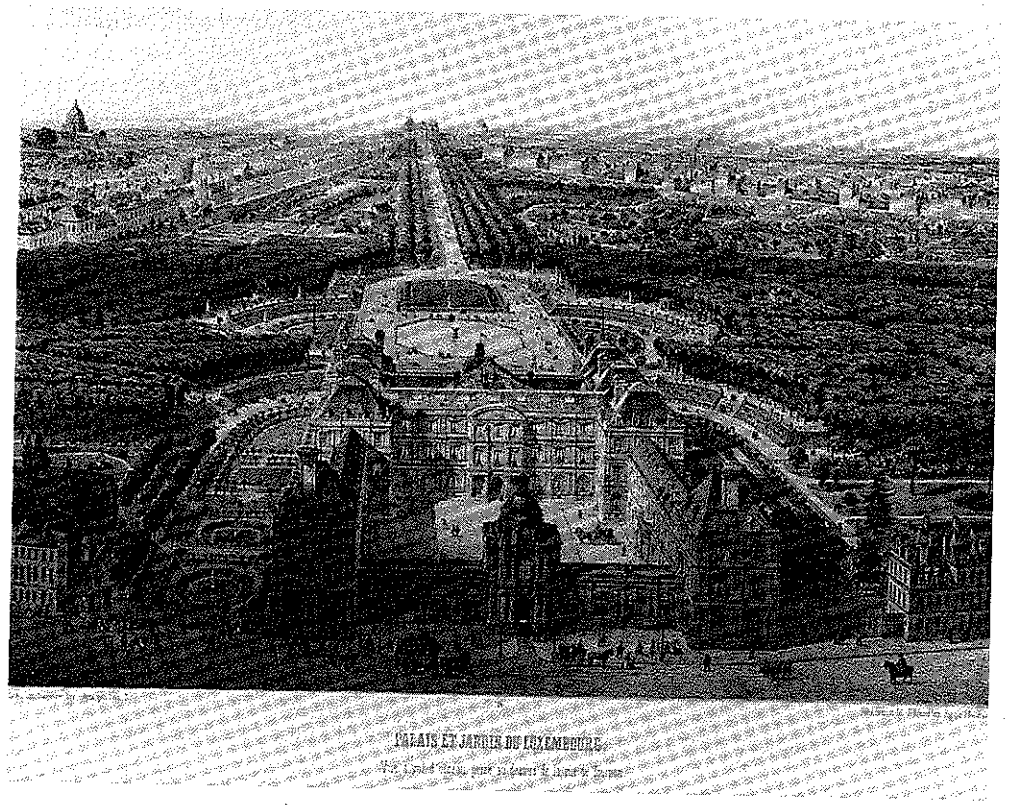

Figure 1. *A Bird's Eye View of the Luxembourg Palace and Gardens, with the Observatory in the Background, 1860. Philippe Benoist,* Paris dans sa splendeur *(Paris: Charpentier, 1861), figure no. 16, facing p. 46. Photo © Bildarchiv Preußischer Kulturbesitz.*

Paris, turn your back at the Senate, and direct your gaze to the southern horizon. Between alleys of trees, above fountains and golden gates, the white cupola topping the classical stone building to which your eye is unavoidably drawn will betray its past, if not its present, function: this is the Observatoire de Paris. Of course, the main seventeenth-century building has been turned into a museum and library. But around it, modern buildings accommodate dozens of astronomers, who still manage to work efficiently in the very spot from which, more than a century ago, urban development threatened to expel them. Meanwhile, vibration, noise, and light pollution have hardly abated. Surely something—other than pleasant Sunday walks—must keep astronomers in Paris. (See Figure 1.)

The Paris Observatory, having had to react and adapt directly to the local challenges posed by the expanding city, offers an especially relevant case, a local probe, so to speak, for a fine-grained study of science-city relationships. Three main themes will run through this essay: physical issues concerning the disturbances the urban environment presents for the conduct of astronomy; epistemological ones concerning changes in knowledge-production practices as a result of the observatory's presence in the city; and cultural issues about the ways in which the observatory was woven into the social, political, and economical fabric of the city (thereby making its removal difficult).

I want to take the rapidly growing historiography on science's place not just out of the laboratory (and the observatory) but beyond the "science in the field" framework as well.[2] When the city is involved, the historian of science must pay as close attention to it as to the science conducted there. Not only do specific cultural and geographic issues deserve to be finely analyzed, but so does the very way of conceptualizing the city and its metamorphoses. As will become clear, it was not so much the "old Paris" that threatened the observatory as it was the characters most valued by Haussmann's modernizing enterprise. One especially appropriate way to capture these transformations, I will argue, is to focus on the regimes of observation and circulation (or *Verkehr*).[3] By this, I mean a set of technologies, a material culture, together with specific discourse (representations and metaphors), disciplining practices, and forms of social organization associated with their use. What makes both regimes especially relevant is their close link with the city as well as with astronomical practices. Finally, changes in regimes of observation and circulation, in the city and the observatory, partly hinged, I will argue, on constant exchanges between the two sites.

In the political economy of science, as far as contacts with both the state and the bourgeois polite culture were concerned, the observatory indeed played a crucial role throughout the nineteenth century. From the observatory and its associated constellation of savants and instrument makers radiated various technologies, experimental setups, and ideological constructs that helped to remold not just the public understanding of precision science but the very experience of observing, circulating, and communicating. By reshaping cultural expectations with respect to circulation and observation, the observatory itself contributed to the pressures placed upon it. At the same time, I will contend, transformations in observation and circulation practices provided the key factors behind the reorganization of the spatial conditions of work in the astronomical community and a parceling of the various tasks previously filled by the Paris Observatory.

Two final remarks are in order. First, the following discussion will be centered on three directors of the Paris Observatory, men who towered over French astronomy in the nineteenth century: François Arago (1786–1853), Urbain Le Verrier (1811–1877), and Ernest Mouchez (1821–1892). (Charles Delaunay headed the observatory briefly, from 1870 to1872, between Le Verrier's two directorships.)[4] Second, let me underscore

[2] For an examination of astronomy as the intersection of three sites of science production, see David Aubin, "Orchestrating Observatory, Laboratory, and Field: Jules Janssen, the Spectroscope, and Travel," *Nuncius* 17 (2002): 143–62. For the historiography of space in science studies, see Steven Shapin, "The House of Experiment in Seventeenth-Century England," *Isis* 79 (1988): 373–404; Adi Ophir, Steven Shapin, and Simon Schaffer, eds., *The Place of Knowledge, Science in Context*, special issue, 4 (1991): 3–218; Crosbie Smith and John Agar, eds., *Making Space for Science: Territorial Themes in the Shaping of Knowledge* (London: Macmillan, 1998); and Peter Galison and Emily Thompson, eds., *Architecture of Science* (Cambridge: MIT Press, 1999).

[3] By circulation, here, one should really understand the German *Verkehr*, today mostly construed as automobile traffic, but which means both circulation and communication. Note, however, that to one German author, the word *Zirkulation* seemed more appropriate: Wolfgang Schivelbusch, *Geschichte der Eisenbahnreise* (Munich: Hanser, 1977). This article owes much to the discussions of nineteenth-century Parisian culture in Walter Benjamin, *Das Passagen-Werk*, ed. Rolf Tiedemann, 2 vols. (Frankfurt am Main: Suhrkamp, 1983).

[4] Maurice Daumas, *Arago: La Jeunesse de la science*, 2d ed. (Paris: Belin, 1987; orig. Gallimard, 1943); Francoise Lamotte, *Urbain Le Verrier: Savant universel, gloire nationale, personnalité cotentine* (Coutances: OCEP, 1977); Robert Mouchez, *Amiral Mouchez, marin, astronome, et soldat* (Paris:

that, in this period, the tasks of astronomers, especially at the Paris Observatory, never were restricted to astronomy proper. On the contrary, the observatory was the institutional embodiment of a global science of the heavens and the earth, whose practice tightly linked physics, meteorology, and geography with astronomy.

LE GRAND REGARD: ISOLATION AND POWER

As early as 1832, Jean-Baptiste Biot suggested that the observatory should be moved well outside the capital to the Mont-Valérien or Châtillon: "The large city, from which it was previously almost separated, has been extended beyond its limits. It has surrounded [the observatory] with populous streets constantly crisscrossed by countless carriages."[5] Monks of modern times, astronomers, like their religious predecessors, generally sought peace and isolation to contemplate the heavens.[6] Tycho Brahe's Uraniborg, on the island of Hven, was isolated on purpose: "[A] continual coming-and-going of noblemen and friends," Tycho argued, "would disturb the peace necessary for philosophical study and so impede it."[7] But other factors had to be weighed as well. By erecting his observatory platform on the roof of three houses in central Gdansk, Johannes Hevelius made it clear that for personnel, housing, printing, and the construction of instruments, he found it more convenient to rely on the concentration of skills and resources already extant in the city.[8] When imperial powers France and England founded their observatories in the seventeenth century, the isolation of the Tychonic observatory was everybody's ideal, while the Hevelian model stood as proof that valuable astronomical observations could be carried out in a city, at lower cost, at greater convenience, and at arm's length from the monarch.

The site of the Paris Observatory had been chosen with great care. The academicians set their eyes on a domain, appropriately named Le Grand Regard, on the Saint-Jacques hill, just outside the southern limits of the city. Since northern winds were rare, it remained clear of city smoke. The hill's surroundings were sparsely occupied by religious establishments and gardens. From the small elevation, the horizon was visible in three directions. To the south, a country landscape peppered with windmills lent itself perfectly to observation. In spite of all this, isolation was deemed so crucial that a wall was erected around the domain, costing three times as much as the ground it enclosed. Furthermore, it stood at the intersection of two important axes, which would thus ease communication with the nearby university and the city center. Founded at the same time as the Academy of Sciences, the Paris Observatory was supposed to serve as the centralized site of academicians' experimental and observational

Cujas, 1970); and Arsène Thévenot, *Charles-Eugène Delaunay, membre de l'Institut, directeur de l'Observatoire de Paris (1816–1872)* (Troyes: Dufour-Bouquot, 1878).

[5] Reported by Le Verrier, "Considérations sur la position topographique de l'Observatoire de Paris," *Comptes-rendus des séances de l'Académie des sciences* (hereafter cited as *CRAS*) 65 (1867): 776–81, on 779.

[6] J. Le Goff, *Les Intellectuels au Moyen-Age*, 2d ed. (Paris: Seuil, 1985).

[7] Quoted in Owen Hannaway, "Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe," *Isis* 77 (1986): 585–610, on 590–1. See also Jole Shackelford, "Tycho Brahe, Laboratory Design, and the Aim of Science," *Isis* 84 (1993): 211–30; and John Robert Christianson, *On Tycho's Island: Tycho Brahe and His Assistants* (Cambridge: Cambridge Univ. Press, 2000).

[8] C. Leeson Prince, ed., *The Illustrated Account Given by Hevelius in the "Machina Celestis" of the Method of Mounting His Telescopes and Erecting an Observatory* (Lewes, Sussex: privately printed, 1882), 55.

practices. But this was not to happen. As a later director observed, "Indeed, the meetings of the Academy of Sciences could hardly be held in a site so far away from the center of the capital."[9]

The character of the neighborhood changed dramatically after the French Revolution, when the Jacobin government seized the church properties that had sheltered the observatory. In 1811, a wide *allée* from the Luxembourg gardens to the observatory was completed. This 1,400-meter-long leisurely promenade physically connected the scientific institution with a new site of power, the Senate. The result of the contingency of history, this alignment exemplifies the way in which science can be symbolically mobilized by political power. (See Figure 2.)[10]

From the observatory, now more accessible from political and academic seats of power, François Arago, named director of observations in 1834, managed to rule over Parisian science and politics by exploiting this juxtaposition of sites.[11] In Arago's *Oeuvres complètes*, the editor Jean-Augustin Barral compiled a "cosmic table" of geographic and celestial entries, among which the entry for Paris occupied several dense pages that can offer a glimpse of how Arago perceived the city outside his observatory. For him, Paris was first and foremost the name of a place on earth about which many, many numbers were known. Some were interesting in themselves (longitude, latitude, distance from center of the earth, declination of magnetic field), while others could be compiled, tabulated, and averaged (meteorologic data, water level). Many qualitative phenomena could be studied in or from Paris (geology, storms and atmospheric electricity, auroras). This was also the chief location for various instruments, giving rise to the possibility of performing scientific and technological experiments (electromagnetism, steam engines, Artesian wells). The city itself, finally, provided numerous occasions for experimenting and quantifying (height of main buildings, water consumption), and as a member of Parliament and president of the City Council, Arago was involved in urban planning. It was a place where many savants had lived or worked, a place they visited, a place they left or came back to between scientific voyages. Thus, while Arago's geographic location in Paris influenced the data he could amass and treat, the obvious cultural and political center that it was gave him many occasions to use his rhetorical skills and his expertise as scientist and mathematician.

Arago had become a fixture of Parisian elite culture from the earliest days of his career. In 1813, he had been put in charge of the statutory astronomy course of the Bureau des Longitudes, with the goal, Pierre-Simon de Laplace had specified, of training observatory directors for the provinces and astronomers for overseas expeditions.

[9] Jacques-Dominique Cassini, quoted in Ernest Maindron, *L'Académie des sciences: Histoire de l'Académie* (Paris: Alcan, 1888), 8. For the history of the Paris Observatory, see Charles Wolf, *Histoire de l'Observatoire de Paris de sa fondation à 1793* (Paris: Gauthier-Villars, 1902); René Taton, "Les Origines et les débuts de l'Observatoire de Paris," *Vistas in Astronomy* 20 (1976): 65–71; Jacques Lévy, Suzanne Débardat, and Solange Grillot, *L'Observatoire de Paris, son histoire (1667–1963)* (Paris: Observatoire de Paris, 1984); and Jimena Canales, "The Single Eye: Re-Evaluating *Ancien Régime* Science," *History of Science* 39 (2001): 71–94.

[10] Bruno Fortier, *La Métropole imaginaire* (Liège: Mardaga, 1989); and Bruno Latour and Émilie Hermant, *Paris ville invisible* (Paris: La Découverte, 1998).

[11] For a discussion of the intersecting spaces of science, politics, and literature along the allée de l'Observatoire, see John Tresch, *Mechanical Romanticism: Engineers of the Artificial Paradise*, (Ph.D. diss., Cambridge Univ., 2001). On the ideal of juxtaposition and its decline in the late nineteenth century, see S. Forgan, "'But Indifferently Lodged . . .': Perception and Place in Building for Science in Victorian England," in Smith and Agar, *Making Space for Science* (cit. n. 2), 195–215.

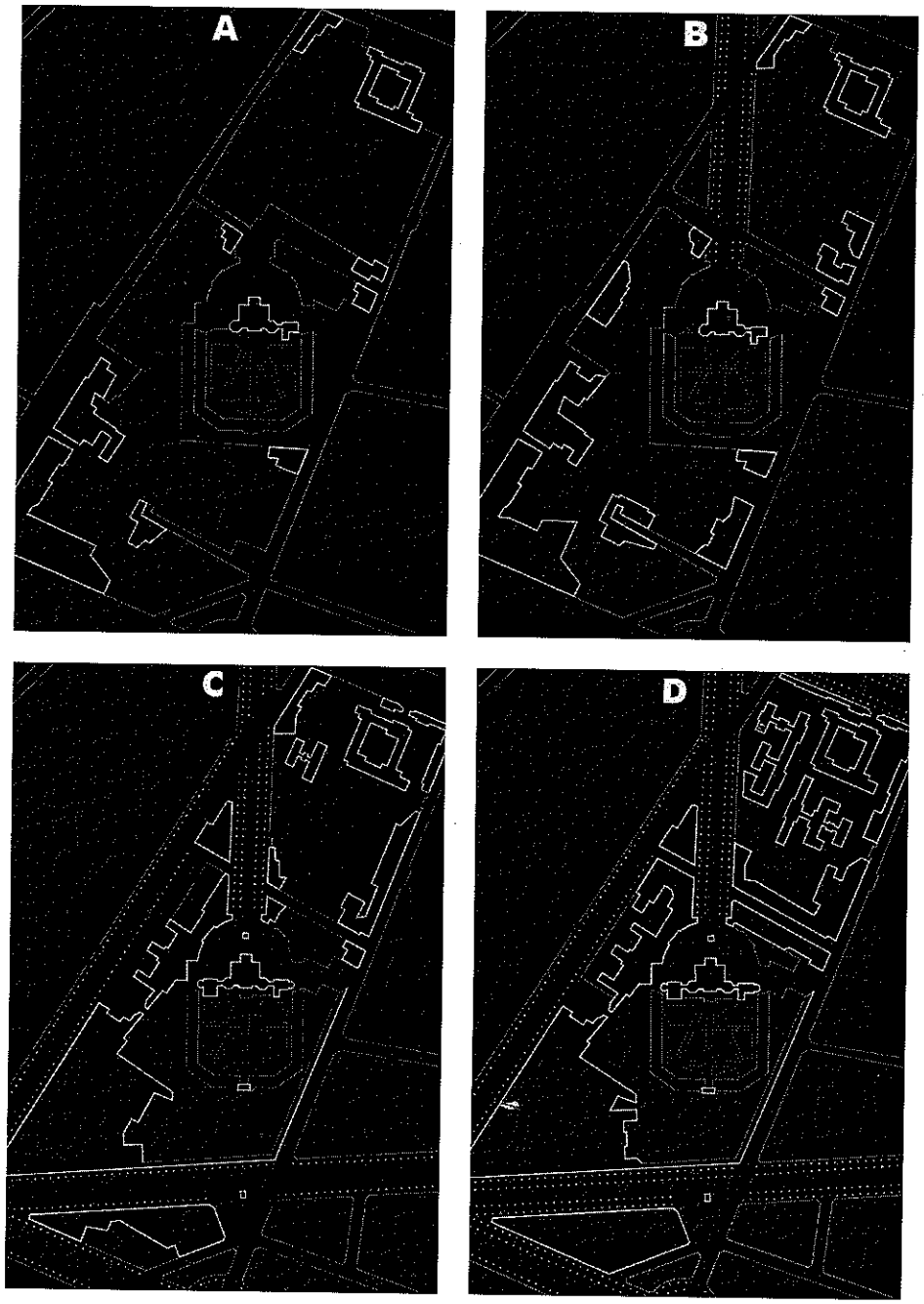

Figure 2. *Transformation of the Neighborhood of the Observatory, (a)* 1666–1683, *(b) 1793–1800, (c) 1852–1867, (d) 1867–1873. From B. Fortier,* La Métropole imagininaire: un atlas de Paris *(Liège: Pierre Mardaga,* 1989*),* 186: *repr. Bruno Latour and Émilie Hermant,* Paris ville invisible *(Paris: Institut Synthélabo; La Découverte, 1998),* 128–129.

In Arago's hands, however, the course had evolved toward "popular astronomy," designed to attract large audiences, and it became a highpoint of Parisian cultural life.[12] In what Pierre Larousse described as "one of the best memories of his youth," savants and Republicans of Louis-Philippe's regime would gather among a crowd of several hundreds to hear "*une parole libre*."[13] Better educated, impressed by industrial applications presented as stemming from science, cultivated audiences were attracted to Arago's skilled popularization by curiosity and a need, surely, to make better sense of the technological mutations affecting their lives.

Parisians' enthusiasm for the wonders of astronomy was just as clear in 1846, when Arago announced at the Paris Academy of Sciences that Le Verrier had calculated the position of a previously unknown planet, Neptune. But why should anyone care about the "discovery of a world located millions of miles from ours, of a planet unknown yesterday without anyone feeling worse [about it], . . . of a bright point in space that can only be glimpsed at through a telescope by a few savants who stay awake when everyone else sleeps?" Yet "despite its indifference to things that cannot immediately be applied to industry, luxury, or the well-being of life," wrote *Le Correspondant*, "our century [is] sensitive to this speculative discovery."[14]

In short, for Arago Paris represented more opportunity than problem. But what exactly was the city as far as his fellow astronomers were concerned? Like physical scientists, if asked many would have answered simply: a nuisance, jeopardizing the very possibility of pursuing their work. This attitude became more prevalent as the century wore on. In 1833, the area around the observatory had still seemed, to Honoré de Balzac, a "neutral space, . . . a desert."[15] By midcentury, Paris had thoroughly invaded.

MONKS AND MACHINES: CREATING AND DEFENDING PRECISION IN THE CITY

If cities came to trouble observatories, it was as a direct consequence of the latter's culture of high precision. After Arago's death, Le Verrier, who succeeded him as director, emphasized "how important the precision of observation [was] for the future of science." For every planet of the solar system, any discrepancy between its observed position and that deduced from theory could reveal "an unknown cause, and . . . become the source of discovery."[16] This was the trick Le Verrier himself had pulled off when he had computed the position of Neptune.[17] For astute observers,

[12] Daumas, *Arago* (cit. n. 4), 292 n. 27. A famous 1845 representation of the lecture hall showed an attendance of several hundreds; cf. *L'Illustration*, 25 Jan. 1845, reprinted in ibid., 90–1.

[13] Pierre Larousse, *Grand Dictionnaire universel du XIX^e siècle,* s.v. "Astronomie populaire" (Paris: Larousse & Boyer, 1866), 1:840. On the relation between Arago's science and politics, see John Carwood, "François Arago, Homme de science et homme politique," *La Recherche* 16 (1985): 1464–71.

[14] Dr. P., "Planète Leverrier," *Le Correspondant* 16 (1846): 950–8.

[15] Honoré de Balzac, *Histoire des Treize*, vol. 1, *Ferragus* (Paris: Gallica, 1998).

[16] U.-J. Le Verrier, "Rapport sur l'Observatoire impérial de Paris et projet d'organisation," *Annales de l'Observatoire impérial de Paris* 1 (1855), 1–68, on 9–10. See M. Norton Wise, ed., *The Values of Precision* (Princeton: Princeton Univ. Press, 1995); and H. Otto Sibum, "Exploring the Margins of Precision," in *Natural Standards*, by H. Otto Sibum and Richard Staley, Max-Planck-Institut für Wissenschaftsgeschichte preprint, 172 (2001).

[17] On the discovery of Neptune, the literature is abundant, but as far as Le Verrier is concerned, little has come to challenge the picture made public by contemporaries. See F. Arago, "Historique de la découverte de Neptune," *Astronomie Populaire* 4 (Paris, 1857): 509–23; and G. B. Airy, "Account of Some Circumstances Historically Connected with the Discovery of the Planet Exterior to Uranus," *Memoirs of the Royal Astronomical Society* 7 (1846): 121–52. The classic account is Morton Grosser, *The Discovery of Neptune* (Cambridge: Harvard Univ. Press, 1962).

this discovery was striking because of the exemplary way in which it interwove three threads of the precision culture of contemporary science: the precise control over computations, instruments, and observing personnel.

First, the incredible computational skills and patience Le Verrier had to deploy could be seen in his perturbation analysis, which was developed to the seventh order and involved 469 distinct terms. Second, the discovery brought home the high degree of precision of observation now attainable, due not only to great instrumental advances but also, as the work of Friedrich Bessel had shown, the careful reduction of observations (instrument theory, earth motion theory, personal equation, error analysis). Finally, the sequence of events leading to Le Verrier's triumph illustrated the precise organization of work in astronomy and regularity in observation regimes (not only for tracking down planets but also for mapping fixed stars). The lesson was clear: Neptune was the child of discipline and precision.

For Parisians, it was hard to understand why their observatory should have failed to observe Le Verrier's planet first. The satiric journal *Charivari* complained that there was in Paris no telescope capable of reaching further than 60 million leagues from the Earth.[18] The director of the Russian Central Observatory in Pulkovo, Friedrich von Struve, had no qualms about writing Le Verrier that while theoretical astronomy owed much to France, the country was far behind in observational astronomy.[19] What, exactly, was required to reverse this unfortunate situation?

Three factors could work against the ideal of precision in astronomical observation: lack of discipline in observational routines, obsolete instrumentation, and imperfect location. Looking for models, Le Verrier took his cue from the organizational reforms instituted in 1836 by the astronomer royal George Biddell Airy in Greenwich. According to American astronomer Simon Newcomb, Airy had "introduced production on a large scale into astronomy, . . . [in which] the astronomer became a mere operative." Under this regime, as Simon Schaffer has put it, "[t]he observer was part of the 'instrument' to be calibrated." In the nineteenth century, the visual experience in European culture was being uprooted from stable and fixed relations, and, according to Jonathan Crary, "given an unprecedented mobility and exchangeability." Yet at the same time, observation was turned into an instrument of homogenizing control and discipline. In this new regime, spectacle and surveillance collapsed into one another. Observers themselves were disciplined and regulated. To quote Schaffer again, "The observatory became a factory, if not a 'panopticon.'"[20]

Yet the Paris Observatory under Arago had rather clung to features of the traditional workshop. There, family relationships played prominent parts. For instance, Arago's closest collaborator was Claude-Louis Mathieu, his brother-in-law, who in part because of this familial relationship expected to take over the observatory after Arago's death. A younger astronomer, Ernest Laugier, was married to Mathieu's daughter, Lucie. Other relatives haunted the observatory, such as Arago's sister who cared for his

[18] "Nous avons une planète," *Charivari*, 10 Oct. 1846, 1.

[19] Struve to Le Verrier, 7 Dec. 1847, Ms. 1072, 12. Paris Observatory Archives (hereafter cited as AOP).

[20] Simon Newcomb, *The Reminiscences of an Astronomer* (Boston: Houghton Mifflin, 1903), 288; Simon Schaffer, "Astronomers Mark Time: Discipline and the Personal Equation," *Science in Context* 2 (1988): 115–43, on 118–9; Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge: MIT Press, 1990), 112. Cf. also Michel Foucault, *Surveiller et punir* (Paris: Gallimard, 1975).

children and Alexis Bouvard's retarded brother, nicknamed "Lézard." As was also traditional in artisans' households, they all lived together in dark, humid apartments in the main building of the observatory. Bouvard's nephew, Eugène, and Joseph Liouville's son, Ernest, also worked there. For young astronomers, climbing the hierarchy took a long time. One had to accept working assignments distributed by Arago, the undisputed master, and carry them out diligently and to his satisfaction. When Bouvard the elder's computations showed discrepancies between theory and observation in the motion of Uranus, his nephew was assigned the problem. But after disappointing Arago with his poor measurements of the 1842 eclipse, Eugène Bouvard never regained his master's trust. Three years later, Arago forced him to resign and reassigned Uranus to Le Verrier.[21]

Upon taking on the directorship, Le Verrier's first task was to reform labor regimes at the observatory. In the politically loaded atmosphere that followed Napoleon III's coup d'état, "anarchy" was the enemy and "perhaps in no other place than in an observatory [were] its fateful effects more glaring." For Le Verrier, the observer was "a true bivouacking soldier" who had to be submitted to almost military discipline.[22] Not surprisingly, this new organization of labor was resisted by Arago's "family," almost all of whom resigned, while one (Victor Mauvais) even committed suicide.[23]

Strict discipline, however, was not enough to make observation sufficiently precise. Better instruments were also needed. Le Verrier could not help noticing the heavy investment consented to by the czar for Pulkovo: a "true astronomical Eldorado" that was a "model superior to all that was ever built."[24] In Paris, admittedly, Arago had already accomplished much toward the modernization of the observatory by reequipping it with the latest instrumental technology. As a result, the French optical industry, with the likes of Nicolas Fortin, Henri-Prudent Gambey, Robert-Aglaé Cauchoix, and Noël-Jean Lerebours, had caught up with foreign competition.[25]

But modern instruments were highly sensitive. What was most luxurious about Polkovo, Struve claimed, was its system of walls and vaults that sheltered instruments from vibration and heat.[26] Stability was the issue around which hinged the very

[21] Daumas, *Arago*, 141–2, 226–7, 233–6.

[22] Jean-Baptiste Vaillant, "Rapport fait au nom de la Commission, chargée par le ministre de l'Instruction publique d'examiner les améliorations à apporter dans l'organisation scientifique et administrative de l'Observatoire de Paris et du Bureau des Longitudes," *Moniteur universel*, 3 Feb. 1854; repr. in *Recueil des lois et règlements sur l'enseignement supérieur comprenant les décisions de la jurisprudence et les avis des conseils de l'instruction publique et du conseil d'État*, ed. A. de Beauchamp, 3 vols. (Paris: typographie Delalain Frères, 1882), 2:306–11, on 308; Le Verrier, "Rapport sur l'Observatoire impérial de Paris" (cit. n. 16), 62.

[23] Camille Flammarion, "Bureau des longitudes et l'administration astronomique en France," *Le Siècle*, 10 Feb. 1866, 3. At least two stayed, Antoine Yvon Villarceau and Emile Goujon. Goujon died unexpectedly in 1856. According to Flammarion, he went mad; see Flammarion, *Mémoires biographiques et philosophiques d'un astronome* (Paris: Flammarion, 1912), 210. Yvon Villarceau was, until 1867, as we shall see below, one of Le Verrier's most faithful collaborators.

[24] J.-B. Biot, review of *Description de l'observatoire astronomique central de Poulkova*, by F. G. W. Struve, *Journal des savants* (1847): 513–33, 610–20, on 613; repr. in Biot, *Mélanges scientifiques et littéraires*, 2 vols. (Paris: Michel Lévy frères, 1858), 2:293–334; Le Verrier, "Rapport sur l'Observatoire impérial de Paris" (cit. n. 16), 12.

[25] F. Arago, "Observatoire de Paris," and "Pied parallactique de la grande lunette de l'Observatoire de Paris," in *Oeuvres complètes*, ed. J.-A. Barral, 17 vols. (Paris: Gide & Baudry, 1854–1862), 6:564–85 and 585–95. On instrumental development in the nineteenth century, see Allan Chapman, "The Astronomical Revolution," in *Möbius and His Band*, ed. John Fauvel, Raymond Flood, and Robin Wilson (Oxford: Oxford Univ. Press, 1993), pp. 35–77.

[26] Radau, "L'Observatoire de Paris" (cit. n. 1), 767.

possibility of observing. Since the beginning of the century, however, traffic in the vicinity of the observatory had greatly increased. The atmosphere had become worse due to vapor, dust, and smoke, not to mention erratic temperature gradients that refracted light in uncontrollable ways. Was the conduct of modern astronomy at all possible "in a polluted atmosphere and on an agitated ground"?[27] Was it at all compatible with the modern city?

In 1854, Le Verrier and the government committee appointed to overhaul the observatory's organization seriously contemplated its transfer to a more isolated spot but concluded that, provided some arrangements were made, such a move was unnecessary. To enhance the stability of the instruments, the pillars supporting the Fortin and Gambay circles were made independent from building vaults. To make sure the observatory was insulated "from the noise and motion of the populous neighborhood where it is located," Le Verrier paid special attention to the gardens.[28] More interestingly, in order to reduce vibration, adjacent streets were among the first ones in Paris to be macadamized by the government, making clear that the observatory's demands could impact city planning. A process consisting in layering down successive strata of broken stones that were consolidated under the pressure of ordinary traffic before the next was laid upon it, macadamization was reviled by Parisians because it turned into mud when it rained, but highly praised by astronomers for reducing vibrations. As a result of these various measures, Le Verrier reported in September 1854 that "vibrations are considerably damped," but he warned that it would take years before he could "sustain the concurrence of so admirably built observatories as Greenwich or Pulkovo."[29]

So astronomy, after all, was possible in Paris. With up-to-date instruments well insulated from their busy neighborhood, Le Verrier could now focus on the question of personnel. With most of Arago's collaborators gone, he needed to find the kind of astronomers who would perform well under the strict disciplinary regime he wished to enforce. Organization of personnel was the main difficulty Biot, too, had mulled over when he daydreamed about uprooting the observatory and putting it in the country. "[O]ne would have had to gather talented, active, laborious men resigned to live philosophically with their family in this solitude. Try to find, among us, monks for such a convent!"[30] But Le Verrier had no need of monks. In the words of the director of the Geneva Observatory, Emile Plantamour, Le Verrier looked not for "collaborators, but only subordinates, machines."[31] Machines could work perfectly well in a metropolitan environment.

[27] Vaillant, "Rapport fait au nom de la Commission" (cit. n. 22), 308. Greenwich never had the same problem as Paris. In 1675, the king decided to establish the Royal Observatory "within our park at Greenwich," well outside the city of London. Quoted in Eric G. Forbes, *Greenwich Observatory: The Royal Observatory at Greenwich and Herstmonceux*, vol. 1, *Origins and Early History* (London: Taylor & Francis, 1975), 22. Greenwich director Airy, however, had to battle against railways; see G. B. Airy, *Autobiography*, ed. Wilfrid Airy (Cambridge: Cambridge Univ. Press, 1896); and Edwin Dunkin, *A Far Off Vision: A Cornishman at Greenwich Observatory* (Truro: Royal Institution of Cornwall, 1999), 86–7.

[28] Emile Bourdelin, "L'Observatoire de Paris," *Le Monde Illustré*, 1 Feb. 1862, 69–71, on 71.

[29] Quoted in François Moigno, "Académie des sciences, séance du 4 septembre," *Cosmos* 5 (1854): 308–9, on 309.

[30] Reported by Le Verrier, "Considérations" (cit. n. 5), 779.

[31] E. Plantamour to Laugier, 4 March 1854, quoted in G. Bigourdan, "Le Bureau des longitudes," *Annuaire du Bureau des longitudes* (Paris, 1932), A89.

THE TRANSFER DEBATE AT THE END OF THE SECOND EMPIRE

Under the Second Empire, the *préfet* Georges Eugène Haussmann accelerated and changed the meaning of urbanization.[32] Thus in 1860, the assaults of Paris on the observatory took a more modern shape. To ease access to the center of Paris from the four cardinal points, Haussmann wished to extend the boulevard Sébastopol (today boulevard Saint-Michel) up to the carrefour de l'Observatoire. From there, the old rue d'Enfer (today Denfert-Rochereau) would be widened to give way to the *barrière* d'Enfer and the road to Orleans. One of the former gates of Paris, with a train station, this site was transformed into a star-shaped *place* typical of the multicentered city geography favored by the Second Empire.[33] From there, a new boulevard named after Arago would be opened to link the place d'Enfer to the gare d'Orléans (today Austerlitz). The boulevard, however, encroached on the observatory's domain.

After examining the plan, Le Verrier countered with one that would better ensure the observatory's isolation. Development stopped, and for seven years a fragile status quo was maintained. Then late in 1867, the municipal authority drafted another plan, one that, according to Le Verrier, still "took symmetry conditions into consideration more than the needs of astronomy." On November 11, the astronomer seized the occasion of the observatory's bicentennial to raise the issue in front of the Academy of Sciences. For the first time, the observatory's problems with the city were publicly exposed. "On street sides, we feel the embarrassment of noise, dirt, vibrations, and above all lighting. This last obstacle is in truth the most considerable. Observing above a line of gas lampposts located too close, it would be impossible to see weak stars, let alone to measure their motions." Between the two symmetric, converging streets planed by Haussmann, instruments would be "between two lines of fire." Consequently, the projected transverse boulevard should be pushed twenty meters back, and a public square should be built.[34]

Now, the observatory stood in the way of urban development. A handwritten note by the minister of public instruction, Victor Duruy, dated October 4, 1867, reads:

> New conflict between the Observatory and the City of Paris. There is a radical solution, [which is] good, and even *necessary* for science, but troublesome to [some] people, this is the transfer of the observatory to Meudon.
>
> The Emperor to whom I just spoke would be favorable to this [solution]. Provided the *old* Observatory can pay for the *new* one.[35]

An expert committee headed by the vice admiral Léon-Martin Fourichon was set up by Duruy to study the question; in its January 1868 report, the committee recommended

[32] Hervé Maneglier, *Paris imperial: La Vie quotidienne sous le Second Empire* (Paris: Armand Colin, 1990); Patrice de Moncan and Christian Mahout, eds., *Le Paris du Baron Haussmann* (Paris: Editions SEESAM-RCI, 1991); Jean des Cars and Pierre Pinon, eds., *Paris-Haussmann: Le Pari d'Haussmann* (Paris: Edition du pavillon de l'Arsenal; Picard Editeur, 1991).

[33] The multicentered geography of Paris is discussed by Jeanne Gaillard, *Paris, la ville* (Paris: Champion, 1976).

[34] Le Verrier, "Considérations" (cit. n. 5), 779–80. A street that would be symmetric to rue Saint-Jacques between boulevard d'Enfer and boulevard Arago was envisioned. It encroached on the observatory's domain; grounds on the north were offered as compensation—"useless," Le Verrier responded.

[35] File "Question de la translation de l'Observatoire de Paris (1867–1868)," French National Archives (hereafter cited as AN) F^{17} 3720, document no. 1.

the move.[36] Rather than accepting the recommendation, the minister chose to solicit the advice of the Academy of Sciences, which sparked another year of bitter discussions.[37] These several and often overlapping debates were caused by various factors: Le Verrier's conflicts with some of his subordinates, his personal enmity with Charles Delaunay, the emergence of astrophysics, and the administrative organization of astronomy within the observatory and on a national level.[38] My aim here is not necessarily to disentangle these debates, but to use them to enlighten issues pertaining to relationships with the city.

Among those issues, let us note once again a clash between precision requirements and urban conditions. While the Fourichon committee drafted its report, one of Le Verrier's most faithful employees, Antoine Yvon Villarceau, recently elected to the Academy of Sciences, expressed his conviction that the observatory should be transferred out of Paris. The opinion of Villarceau, an experienced observer, carried more weight than those of Le Verrier's personal enemies. He argued that vibrations in mercury baths made it impossible to determine the vertical except after one in the morning, that irregular air refraction gave rise to errors five to ten times larger than those expected from "*the most precise* instruments in the hands of *experienced observers*," and that all this meant that telescopes with potential magnifying power above 1,000 could never even reach 600.[39] Villarceau did more than detail the inconveniences caused by the city and recommend a move; he also came up with a destination: tests he had conducted led him to believe that a hill in Fontenay-aux-Roses, south of Paris and easily accessible by rail, would be ideal for setting up a new observatory.

These debates brought to the fore another aspect of the issue of work organization in astronomy. As mentioned earlier, Le Verrier, acting as a perfect French counterpart to Airy, endeavored to discipline the observer by inserting him in a strict social order. Not surprisingly, while Le Verrier had often expressed the wish that France benefit from more observing sites, he had also insisted on placing them under the strong guidance of Paris. Then in 1862, the observatory physicist Léon Foucault completed an eighty-centimeter telescope, the most powerful ever built in Paris. Wanting to exploit the instrument to its fullest, Le Verrier resolved to set up a branch of the Paris Observatory outside Marseilles. Arago's former colleagues Mathieu and Ernest Laugier opposed this: they held that *all* types of observation should be possible at the Imperial Observatory. "I am not in favor of branches," Laugier declared later, "it would not be desirable that in the first French observatory, there be a single observation that could

[36] Léon Martin Fourichon, "Rapport adressé à Son Exc. le Ministre de l'Instruction publique par M. le vice-amiral Fourichon, au nom de la Commission instituée en exécution du décret du 30 janvier 1854 pour rendre compte de la situation scientifique et des besoins de l'Observatoire impérial de Paris," AN F[17] 3720.

[37] Institut de France, *Commission de l'Observatoire: Procès-verbaux des séances, rapports à l'Académie et pièces annexées* (Paris, 1868–1869), Bibliothèque de l'Institut (hereafter cited as BIF). See also *Registre du Comité secret*, no. 3 (1857–1869), Archives of the Academy of Sciences (hereafter cited as AAS).

[38] Conflicts between Le Verrier and Emmanuel Liais, as well as the latter's successor as the observatory meteorologist, Edme Marié-Davy, and with physicist Léon Foucault, had reached the minister of public instruction. Starting on 10 February 1866, Camille Flammarion, fired by Le Verrier in 1863, mounted a virulent public campaign against the director of the observatory in Havin's *Le Siècle*. For an early account, see E. Rank, "Revue des sciences," *Revue des deux mondes* 85 (1870): 1040–7. See also Philippe de la Cotardière and Patrick Fuentes, *Camille Flammarion* (Paris: Flammarion, 1994).

[39] A. Yvon Villarceau, "De la nécessité de transporter l'Observatoire hors de Paris," *CRAS* 65 (1867): 1060–73, on 1066.

not be made."[40] Despite objections, the Marseilles observatory was established as Le Verrier desired. He may not have appreciated all the results, however. Though Marseilles was placed under the direct authority of Paris, this solution to the problem of Foucault's telescope suddenly reversed the strong centralization process that had hitherto marked nineteenth-century French astronomy.

Still, Marseilles was a branch observatory; the proposal for an independent one was another matter. At the Academy of Sciences, in a field where precision was everything, the discussions were shockingly sloppy. As Hyppolite Fizeau expressed it, "everything bears the mark of uncertain logic, of a constant concern . . . to bend facts for the requirements of predetermined systems, in a very dangerous manner that, I believe, has little to do with the spirit of rigor, wisdom, and caution to which we are accustomed in this assembly."[41] While some experiments to assess the influence of the city were carried out, careful numerical studies—except, notably, for Le Verrier's—remained strangely absent from the polemic. In the end, academicians resolved, on April 5, 1869, that the present Paris Observatory should be preserved without cutback and that a *second* first-rank observatory, independent from Paris, be built outside the capital city. Yet without the means to implement the decision of building a new establishment, the academy could only recommend, and for Le Verrier, it was a clear victory. He would, until the political flavor of the regime changed in 1870, remain the undisputed leader of French astronomy, content within the confines of the city.

THE OBSERVATORY'S ICONIC ROLE IN THE POLITICAL ECONOMY OF SCIENCE

Up until now, I have argued that the outward expansion of the city raised serious problems for precise observations at the observatory and that, on several occasions, this prompted lively debates about its being transferred beyond city limits. An attempt by the observatory to disentangle itself from the city would, however, be a dramatic strategic reversal. To understand the motives behind Le Verrier's strong resistance to the idea, one has to understand two important points. First, the capital city, because of its close association with science and power, exerted on astronomers an attraction few had the power or character to withstand. Universities, academies, and libraries, as well as ministers and kings, were to be found there. On Monday mornings, for example, Le Verrier left the observatory for the Senate, a convenient ten-minute walk along the allée de l'Observatoire and through the garden. (See Figure 1.) In the afternoon, he would stroll down the rue de Seine to the academy *séance* (often arriving late), which he would then proceed to inflame with bouts of his epic fights against Delaunay, whose moon theory, personal acrimony aside, he objected to. For astronomers, the city was both crucial and convenient, as it lay "at the center of scientific life and close to the instrument-makers who are always needed."[42]

Second, the observatory, in turn, held a central place in the political economy of public and professional science in nineteenth-century Paris. Arago's popular courses reflected that fact. Though Le Verrier put an end to those when he took up the directorship in 1854—installing his lavish apartment in Arago's lecture hall—he channeled public curiosity in other directions. Attentive to the symbolic power, and

[40] Institut de France, *Commission de l'Observatoire*: *Procès-verbaux des séances* (cit. n. 37), 32.

[41] "Opinion émise par M. Fizeau dans la discussion relative à l'Observatoire de Paris, le 15 février 1869," in Institut de France, *Commission de l'Observatoire*: *Procès-verbaux des séances* (cit. n. 37).

[42] Le Verrier, "Considérations" (cit. n. 5), 779.

political value, of astronomy, Le Verrier officially inaugurated the refurbished observatory in a grandiose soiree in August 1858. Three ministers, members of the Institut, university and lycée professors, literary figures, and students of the grandes Ecoles wandered through the rooms previously used for astronomers' housing, now cleared and reverted to science, while "a multitude—the word is no exaggeration—of elegant servants circulated everywhere . . . carrying rich trays loaded up with ice creams, sorbets, petits fours, punch glasses, etc."[43] Such public visits were ritualized into annual events. In "his house, unique in the world," Le Verrier was the gentlest of hosts. His astronomers were on duty by their instruments: "obliging and patient ciceroni, they offered the profane a splendid exhibition of the firmament."[44]

In 1864, Le Verrier devised a plan to tap this public interest in order to advance astronomy and meteorology. Together with a handful of savants, he founded the Association française, modeled, he claimed, on the British Association. For a few francs, bourgeois members received the periodic *Bulletin* and once a month were welcomed to the observatory, treated to various lectures, and allowed to peek through instruments displayed on the terrace. By December 1864, the association comprised 2,453 members.[45] Le Verrier's critics promptly argued that it was disingenuous of him to complain about city nuisances while he had thus—in part—turned the observatory into a public space. Le Verrier ignored them. He had chiefly established his association not for social events but to raise money to sponsor scientific research at the observatory and elsewhere, and by 1867, it had distributed close to seventy-five thousand francs, an amount roughly equal to half the annual budget of the observatory.[46] Only within the city could the observatory hope to play that role.

By and large, the importance of the city connections for the observatory was widely recognized. As Duruy explained to the emperor in 1868:

> In no other city in the universe [than Paris] is there a similar set of first-rank establishments gathered in so small a space. Every working instrument needed for the highest literary and scientific studies can be included in a circle whose radius is just a few hundred meters. . . . We need not upset this harmonious, complete whole.[47]

In 1867–1869, it was in fact quite extraordinary, considering the polemical tone, that the Academy of Sciences mostly debated technical issues—whether or not the observatory's location hindered observations. Only the respected astronomer Hervé Faye once raised crucial social points:

> Paris . . . is, above all, an intellectual center and, it must be said, is the sole powerful source of light existing in this country. . . . If its Observatory were removed from Paris to be put far away, be it only at the end of a small railway line in Sceaux, Versailles or Saint-Germain, this would only break the powerful network of scientific establishments that we have taken great pains to organize in Paris, and whose counterpart exists nowhere else in the world.[48]

[43] F. Moigno, "Nouvelles de la semaine," *Cosmos* 13 (1858): 141–4, on 144.
[44] F. Moigno, "Nouvelles de la semaine," *Cosmos* 16 (1860): 645–9, on 645.
[45] Camille Flammarion, "Astronomie: *Nature et constitution physique du Soleil* (suite); M. Emile Gautier, de Genève—*Association scientifique de France* (séance du 8 juin); M. Wolf," *Cosmos*, 2d ser., 1 (1865): 649–54; Le Verrier to Dumas, 16 Dec. 1864, Le Verrier Biographical File, AAS.
[46] F. Moigno, "Nouvelles scientifiques de la semaine: Association scientifique de France," *Les Mondes* 14 (1867), 353–4.
[47] Victor Duruy, *Notes et souvenirs, 1811–1894*, 2 vols. (Paris: Hachette, 1901), 1:304.

As Duruy and Faye had noted, Paris had, for all its noise and agitation, important advantages. Not only did scientists of every specialty and all prominent astronomers in France live there, but also "all distinguished opticians, all trained and capable photographers":

> While the observatory constantly needs their cooperation, in turn scientists and instrument-makers need to have an easy and daily access to the observatory. It is not only useful to astronomers, but also to navigators, travelers, and officers who come to gather information, ask for computations, and train in observation, to physicists whose work now has so many points of contact with astronomy, to the State for geodesy and telegraphy, to the whole city, finally, for the exact determination of time. In a word, it is a center of information, data, testing and experiments of all kinds, so necessary to the capital's scientific life that, if you transferred it outside Paris, it would not be long before someone asked for its re-establishment.[49]

It was Faye's defense of their city, I believe, that convinced most academicians that, despite the need to establish other observatories, the Paris Observatory had to remain where it was. Its iconic place in the political economy of science demanded it.

OBSERVATION AND *VERKEHR* IN HAUSSMANN'S PARIS: THE ROLE OF ASTRONOMERS

Haussmann's Paris was no generic city: it was the capital of a highly centralized imperial state. I have already hinted at how important this aspect is to the understanding of the history of French astronomy. But Paris also was an industrial city in the process of reinventing itself, forcing its inhabitants to come to terms with the changing experience of living there. It would be no exaggeration, I believe, to characterize Haussmann's transformation of Paris as a gigantic enterprise aimed at changing regimes of observation and circulation there. Astronomers were ambivalent about the practical consequences of the ideals of the modern city, but on the whole they shared those ideals and in some cases contributed to them.

Under the Second Empire, mutations were especially spectacular in two interrelated domains: the remolding of urban centers and the revolution in communication with the growth of railways and telegraphy. When Louis-Napoléon Bonaparte penciled a map of Paris with colorful straight lines, his main concern admittedly was to ease traffic. The *grande croisée* was intended to effortlessly bring incoming cars to the giant market in the center, les Halles. Facilitating troop movements and linking the new train stations of the city by wide, straight boulevards, where future barricades would be vulnerable to artillery attacks, ranked chief among his concerns. Whether troops, *flâneurs*, or workers; trains, omnibuses, or cars; gas, water, or sewage; letters or telegraphic messages, ease of circulation was the unavoidable ideal of modernity. In his grandiose study of Paris, Maxime du Camp saw the city as an organism or a gigantic mechanism whose different parts were in constant communication. Pierre

[48] "Note lue par M. Faye après la lecture du rapport dans la séance du 25 janvier 1869," in Institut de France, *Commission de l'Observatoire: Procès-verbaux des séances* (cit. n. 37).
[49] Ibid.

Larousse similarly emphasized circulation (of food mainly) when he considered the reasons for the "superiority of Paris." In 1869, he wrote that "the political power of a nation, its civilization, its social well-being, the degree of its civic and political freedoms . . . are tightly linked to the state of its *communication channels* [*voies de communication*]."[50] While both railroad and telegraphic lines came to crisscross the countryside, it is important to underline that they linked *cities*; such communication systems broke down the spatial continuity between the city and the country. Panoramic vision distanced train travelers from country landscapes.[51]

Haussmann's transformation of Paris also reformed the observation regime in the city. Cultural historians have emphasized the disciplining of observation in enclosed spaces but have failed to take their argument beyond the balcony.[52] By paying close attention to public lighting, Haussmann had, at the end of the Second Empire, "transformed the nights of Paris."[53] Like the railway, gas lighting was a technical innovation that "reigned supreme as symbol of human and industrial progress."[54] To clear out *perspectives* in the city, allowing gazes at iconic monuments, and to reconstruct people's optical experience through stereoscopes, kaleidoscopes, and photography, were two faces of a significant trend in European cultural history. At inauguration ceremonies for newly opened boulevards, veils across the street were raised to disclose to the eye "a church, a train station, an equestrian statue, or any other symbol of civilization." As the utopian philosopher Charles Fourier had theorized, straight avenues directed sights toward monuments. An attempt to ease circulation, Haussmann's "strategic embellishment" of Paris also was, like museum and international exhibitions, a technology for disciplining the gaze.[55]

As we have seen, not all forms of the ideals of the modern city suited the observatory. While hygienists' call for air and sun appealed to astronomers, cars, trains, and lampposts did not. It was not the fact that the city now surrounded the observatory, not the "vieux Paris" as such, that bothered astronomers, but Haussmann's very modernization of the city. The city authorities were willing to accommodate the observatory. As president of the City Council, the chemist Jean-Baptiste Dumas repeated that "the City . . . will do everything to improve the situation."[56] A friend of Le Verrier's whose invention had doubled the lighting power of gas lanterns, Dumas had lampposts around the observatory equipped with reflectors that deflected light toward the ground, and one surmises that he was influential in speeding macadamization of roads and halting the building of too many houses in the area.

[50] Larousse, *Grand Dictionnaire* (cit. n. 13), s.v. "Paris," 12:226–88; and ibid., s.v. "Communication," 4:751; Maxime du Camp, *Paris, ses organes, ses fonctions et sa vie dans la seconde moitié du XIX^e siècle*, 5th ed., 4 vols. (Paris: Hachette, 1875).

[51] Cf. Schivelbusch, *Geschichte der Eisenbahnreise* (cit. n. 3).

[52] Cf. J. Crary, *Suspension of Perception: Attention, Spectacle, and Modern Culture* (Cambridge: MIT Press, 1999), 82; and Robert Michael Brain, *The Graphic Method: Inscription, Visualization, and Measurement in Nineteenth-Century Science and Culture*, (Ph.D. diss., Univ. of California, Los Angeles, 1996).

[53] Moncan and Mahout, *Le Paris du Baron Haussmann* (cit. n. 32), 74.

[54] Wolfgang Schivelbusch, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century*, trans. Angela Davies (Berkeley: Univ. of California Press, 1988), 152. See also Simone Delattre, *Les Douze heures noires: La Nuit à Paris au XIX^e siècle* (Paris: Albin Michel, 2000).

[55] Benjamin, *Passagen-Werk* (cit. n. 3), 74, 203. See also Richard Sennett, *The Fall of the Public Man* (Cambridge: Cambridge Univ. Press, 1974).

[56] "Procès-verbal de la séance du 11 mars 1869," in Institut de France, *Commission de l'Observatoire: Procès-verbaux des séances* (cit. n. 37), 72. Cf. U.-J. Le Verrier, "L'Observatoire impérial de Paris, sa situation et son avenir," *CRAS* 65 (1867): 1073–81.

Ironically, as members of the techo-scientific elite, astronomers sometimes contributed to the technologies that prompted the very changes in regimes of observation and circulation threatening to expel them from the city. Haussmann's architects, engineers, surveyors, and mapmakers shared much of astronomy's technical culture and concerns for precision, and even sometimes relied on data provided by the observatory.[57] By providing meteorological services, distributing accurate time, and lending its facility for scientific testing, the observatory had become inseparable from the city.

While Arago's exaggerated concerns with the dangers of train travel are now famous, the vigorous defense of railway bills by Le Verrier, when he was *député* of the Second Republic, though much more influential, has received far less attention.[58] As for telegraphy, astronomers, as well as their instrument makers, played important roles. Whatever his feeling about trains, Arago, by imagining the electromagnet, and by discovering (with Louis Breguet) that the ground could serve to close electric circuits, can be counted among those who made electric telegraphy possible. When in 1846 the first telegraphic line from Paris to Lille was planned, he was, in Parliament, among its strongest defenders.[59] Later, Le Verrier presented the case for the establishment of the network linking Paris to several cities in the west and allowing private correspondence.[60] In 1867, the French telegraphic administration used around six thousand units of a battery invented by Edme Marié-Davy, the observatory's meteorologist, whose daily work would have been unthinkable without telegraphy.[61]

Finally, among the institutions where observers were disciplined—arcades, museums, botanical gardens, railway stations, and department stores—the observatory figured as well.[62] Where Arago gave lectures, Le Verrier had bourgeois members of the Association française peer through telescopes. Announcing Louis Daguerre's discovery of photography in 1839, Arago pointed at its astronomical value (for lunar maps or solar spectrum). (Unfortunately, while daguerreotypes of the sun and of solar eclipses were produced at the observatory, Daguerre tried without success to photograph the moon in 1840.)[63] Nearly all paradigmatic optical instruments discussed

[57] One example among dozens of the services rendered by the observatory to the city of Paris: L. Foucault, "Du pouvoir éclairant des produits gazeux fournis par distillation de la tourbe," *Cosmos* 6 (1855): 593–7.

[58] Arago, "Les chemins de fer," in *Oeuvres complètes* (cit. n. 25), 5:233–466. For the Legislative Assembly, Le Verrier wrote a "Rapport sur le projet de loi tendant à autoriser le Ministre des Travaux publics à prélever, sur les fonds mis à sa disposition pour les travaux de chemins de fer, une somme de 40.000 fr.," in Assemblée législative, *Impressions* 8, no. 850 (1850); and "Rapport fait au nom de la Commission chargée d'examiner le projet de loi portant demande d'une allocation de 4.810.000 fr. pour l'exécution de la partie du chemin de fer de Paris à Strasbourg," in Assemblée législative, *Impressions* 10, no. 976 (1850).

[59] Arago, "Télégraphes électriques et télégraphes de nuit," in *Oeuvres complètes* (cit. n. 25), 5:467–83.

[60] Du Camp, *Paris* (cit. n. 50), 1:133–4. See Le Verrier, "Rapport fait au nom de la Commission chargée d'examiner le projet de loi relatif à une demande de crédit sur l'exercice 1850, pour l'établissement de nouvelles lignes de télégraphie électrique," in Assemblée législative, *Impressions* 8, no. 746 (1850); and "Rapport fait au nom de la Commission chargée d'examiner: 1 le projet relatif à une demande de crédits pour l'établissement de sept nouvelles lignes de télégraphie électrique; 2 la proposition de M. Collas sur l'établissement de nouveaux télégraphes électriques," in Assemblée législative, *Impressions* 37, no. 2095 (1851).

[61] Du Camp, *Paris* (cit. n. 50), 1:136.

[62] Cf. Xiang Chen, *Instrumental Traditions and Theories of Light: The Uses of Instruments in the Optical Revolution* (Dordrecht: Kluwer, 2000).

[63] Arago, "Le Daguerréotype," in *Oeuvres complètes* (cit. n. 25), 7:455–517; and E. Mouchez, *La Photographie astronomique à l'Observatoire de Paris et la Carte du ciel* (Paris: Gauthier-Villars, 1887).

by Jonathan Crary were, of course, developed in close relationship with astronomers and their instrument makers. In the 1860s, stereoscopy became a prominent instrument for both astronomical research and public display, where projection devices were often first developed and used.[64] Finally, as is well known, observation regimes within the observatory, especially in relation to the "personal equation," influenced the way techniques of the observer mutated.[65]

When focusing on regimes of observation and *Verkehr*, therefore, the cultural match between Haussmann's Paris and Le Verrier's observatory is striking. The observatory was put at the center of bourgeois polite scientific sociability, and the French state and the city of Paris had come to rely increasingly on the services it provided. This in part explains why it was impossible to transplant the observatory to another location. Furthermore, as I will now examine, not all practical consequences of the new circulation regime proved troublesome to observatory scientists.

NETWORKS AND CENTERS OF CALCULATION: THE CULTURAL ROOT OF AN EPISTEMOLOGY

In the last third of the nineteenth century, changes in observation and circulation regimes gave rise to new opportunities that ultimately helped astronomers design a way out of the conundrum of having to conduct their research from within a city. Not surprisingly, astronomers' technical contributions to changes of regimes of observation and circulation were intimately linked with the way in which, throughout the century, they endeavored to make themselves useful to the city and the state.

In 1854, under the influence of Napoleon III, the observatories at Greenwich and Paris were linked telegraphically and their difference in longitude precisely determined.[66] The Paris Observatory also collaborated closely with the telegraph administration in the areas of meteorology and of time distribution. At first, meteorology may not strike one as being especially linked with the city. Repeatedly said to be useful to nonurban sectors such as agriculture and navigation, this science was a national matter that required wide international collaboration. There are two arguments that go against this view. First, the study of the weather played a part in the broad scientific offensive against those illnesses and epidemics that were characteristic of the urban environment. The physicist Jacques Babinet, for instance, expected "meteorological hygiene," that is, the study of the influence of the atmosphere on human health, to become a fundamental science for city planning.[67] Second, forecasting was something conceivable only within the regimes of disciplined observation and easy communica-

[64] Danielle Chaperon, *Camille Flammarion* (Paris: Imago, 1998). Cf. Quentin Bajac and Agnès de Gouvion Saint-Cyr, eds., *Dans le champ des étoiles: Les Photographes et le ciel* (Paris: Musées nationaux, 2000). For Crary, see Crary, *Techniques of the Observer* (cit. n. 20); and idem, *Suspension of Perception* (cit. n. 52)

[65] J. Canales, "Exit the Frog, Enter the Human: Physiology and Experimental Psychology in Nineteenth-Century Astronomy," *British Journal for the History of Science* 34 (2001): 173–97; Alex Soojung-Kim Pang, "Victorian Observing Practices, Printing Technology, and Representation of the Solar Corona," parts 1 and 2, *Journal for the History of Astronomy* 25 (1994): 249–74; 26 (1995): 64–75; and Simon Schaffer, "On Astronomical Drawing," in *Picturing Science, Producing Art*, ed. Caroline A. Jones and Peter Galison (New York: Routledge, 1998), 441–74.

[66] G. B. Airy and U.-J. Le Verrier, "Nouvelle détermination de la différence de longitude entre les observatoires de Paris et de Greenwich," *CRAS* 39 (1854): 553–66.

[67] Jacques Babinet, "La Météorologie en 1854 et ses progrès futurs," *Revue des deux mondes* 8 (1854): 170–82, on 173.

tion that I have associated with nineteenth-century scientific urban culture. As the science journalist Auguste Laugel perceptively commented, peasants and seamen were "better appreciators of the weather than city-dwellers" and had little need for the reconstructed observation practices of meteorology.[68] This forceful reconstruction of the way in which people looked at the weather was carried out through an extensive network rooted in the *Verkehr* regime I have described. Meteorological data were gathered from a wide variety of sources: navy meteorological stations, ship logbooks, teachers' schools, chambers of commerce, telegraphic bureaus, private contributors, and foreign observatories. As promoter of telegraphy during the Second Republic, Le Verrier realized that it could be applied to forecasting. Stations sent daily cables to the Paris Observatory, where employees compiled them, published daily maps, and distributed forecasts—a "center of calculation" if ever there was one.[69]

In return for the free use of cables, the observatory offered *time*. Even within a city such as Paris, considerable differences existed among public and church clocks. After the bells of religious establishments near the observatory were set to standard time, a commentator explained, "it will not happen anymore that an astronomer hears the same hour tolled by various clocks for half an hour," not a negligible advantage when observations hinged on listening to faint pendulum ticks.[70] Within the new regime of circulation impelled by railways, the unification of time over France was the indispensable complement to train punctuality. In absence of proper synchronization systems, railway clocks had to be adjusted using train timetables! In 1854, Le Verrier foresaw the need to "put the rule in agreement with practice [and extend] the same hour to the whole Empire." It was, in fact, a traditional service provided by the observatory to synchronize naval chronometers with astral time, and Arago had started to cable time to ports. Le Verrier "took advantage of the telegraphic wire linking the observatory with the Administration of Telegraphs to set up, in the Central Post, . . . a clock whose needles, powered by electricity, reproduced the indication of our pendulum clock."[71] For most of Le Verrier's tenure, experiments were carried out by Emmanuel Liais and Charles Wolf in order first to unify time *within* the observatory. In 1877, still only four clocks in the city—at the gate of the observatory, the CNAM, the Luxembourg Palace, and the Central Telegraphic Bureau—were electrically regulated by the observatory. In the 1880s, an electric network was finally established by the city administration in collaboration with the observatory.[72] The observatory, already at the geographic center of France, thus found itself sitting at its spatio-temporal center as well. (See Figure 3.)

In this same decade, a project to extend the railway line from the place Denfert-Rochereau to the Luxembourg (today the RER B line), only 150 meters away from the observatory, caused alarm among the city's astronomers. Ernest Mouchez, who had

[68] Auguste Laugel, "Progrès et découvertes de la météorologie," *Revue des deux mondes* 28 (1860): 32–57, on 34. For a portrait of an amateur meteorologist, see Champfleury [Jules-François-Félix Husson], *Les Bourgeois de Molinchart* (Paris: Librairie nouvelle, 1855).

[69] John L. Davis, "Weather Forecasting and the Development of Meteorological Theory at the Paris Observatory,"*Annals of Science* 41 (1984): 359–82; Alfred Fierro, *Histoire de la météorologie* (Paris: Denoël, 1991), 102–16; and Fabien Locher, *L'Observation météorologique dans les Ecoles normales d'instituteurs* (DEA thesis, EHESS, Paris, 2000).

[70] Bourdelin, "L'Observatoire" (cit. n. 28), 71.

[71] Le Verrier, "Rapport sur l'Observatoire impérial de Paris" (cit. n. 16), 49, 46.

[72] Charles Wolf, *Projet d'unification de l'heure dans Paris*, Rapport de la Commission des horloges (22 Jan. 1879), Archives of the City of Paris, VONC 219.

Figure 3. *The Observatory at the Center: The Electric Network for Adjusting Public Clocks in Paris as Projected in 1878. From 'Avant-Projet du Réseau des centres horaires et de la remise à l'heure des horloges des 20 mairies et des principaux établissements municipaux. Plan d'ensemble. Juin 1878,' Archives de Paris, VONC 219.*

succeeded Le Verrier as director in 1878, unsuccessfully tried to implement the recommendation of the Academy of Sciences to set up a suburban observatory. "The Paris Observatory thus seems to be condemned for a long time, if not forever, to remain in this exceptionally unfavorable situation [and] to be locked up inside a city."[73]

Once again the observatory relied on the new observation and circulation regimes to overhaul its working strategies. Mouchez instigated the international *Carte du ciel* project. The idea was to take 22,054 photographic pictures of the whole sky to constitute an extensive star catalog. As Charlotte Bigg has argued, this was a bold initiative to take advantage of the poor location of the Paris Observatory.[74] The project capitalized on new observation technologies, specifically the photographic techniques developed by the Henry brothers, which enabled astronomers to detect stars otherwise invisible, and on extensive networking capabilities made possible by easy travel and communication. A call was sent to observatories around the world in 1886 and a large congress gathered in Paris the following year. To date, this was the most ambitious program of permanent international scientific collaboration, one showing, among other things, that photographic pictures could even take the place of direct observation and make astronomy possible literally *anywhere*. The *Carte du ciel* had profound impact on the practice of astronomy by promoting photographic methods, furthering the reconstruction of astronomical observation along industrial models of division of labor, tightening international cooperation in astronomy, eventually paving the way for the International Astronomical Union, and yet decentralizing astronomy as well. From the constraints imposed by the city, new scientific practices had emerged.

Bruno Latour has popularized a description of techno-science explaining that, in spite of its diluteness, it has power because of its structure—that of a network whose resources are concentrated in a few nodes (called "centers of calculation") linked with one another by frail lines of communication.[75] From the study of nineteenth-century astronomy in Paris, it is tempting to see the pressures Haussmann's modernizing city placed on Le Verrier's observatory as a significant cultural environment that has fostered the emergence of this epistemology. The Ecole des Mines, after all, is around the corner from the observatory.

CONCLUSION: DISTRIBUTING OBSERVATORIES, DIVERSIFYING ASTRONOMY

From Arago's first move to the Paris Observatory in 1805 to Mouchez's death in 1892, the venerable institution had to suffer many upheavals, often triggered by its problematic location within the city. As the city itself was transformed by changes in observation and circulation regimes in part due to the activity of observatory scientists, labor was reorganized around this center of calculation (the observatory) and through the networks (the telegraph especially) of which it formed an essential node. But concomitant with the new circulation regime was a crucial reevaluation of the very notions of center and periphery. In Haussmann's Paris, what was central was reexamined and, as we have seen, train stations became the nodes of a new geography. In the new fourteenth arrondissement, which took the observatory's name, a city developed,

[73] Mouchez, *La Photographie astronomique* (cit. n. 63), 97.
[74] Charlotte Bigg, "Photography and the Labour History of Astronomy: The *Carte du Ciel*," *Acta Historica Astronomiae* 9 (2000): 90–106.
[75] B. Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge: MIT, 1987).

"ceaselessly narrowing the circle of our horizon and visible sky, and disturbing the purity of our atmosphere, precisely on the side where the majority of our observations are carried out."[76] With the establishment of international networks, the notion of center was problematized. In modern cities, in telegraphic and railway networks, as in astronomical organizations, decentralizing trends gave way to conscious efforts at recentering networks around selected nodes, such as the Paris Observatory. And Villarceau's dire prediction became reality: the observatory had become a "Ministry of Astronomy."[77]

Around it, the tasks that used to fall under its jurisdiction were redistributed in at least two important ways. First, changes in observation and circulation regimes allowed the multiplication of observing sites whose cooperation was simultaneously tightened. Timid attempts at coordinating the work of astronomical observatories had already been organized by Arago and Humboldt. Under Le Verrier, the task of charting the orbits of asteroids was split between Greenwich and Paris. But decentralization was unthinkable without a multiplication of observing sites. No doubt the foundation of Jules Janssen's astrophysical observatory in Meudon in the mid-1870s and the establishment of observatories in Toulouse and Bordeaux were partly a consequence of the debate about the transfer of the Paris Observatory. Significantly, some new observatories now shunned cities and were set up on mountaintops (Puy de Dôme in 1869, Pic du Midi in 1878).

Second, the epistemic unity of the Humboldtian science of the earth and the heavens was broken apart. Meteorology freed itself from its older sister, and a "physical observatory" was set up in the Montsouris Park by the city of Paris in 1868, to be followed soon by many more across France and its colonies. Similarly, geodesy and *physique du globe* slowly gained their independence. But perhaps the case of astrophysics captures this process most nicely. Closely integrated with positional astronomy in Arago's vision, astrophysics was somewhat neglected by Le Verrier (but perhaps less than historiography has tended to portray it). Although the subdiscipline of astrophysics hinged on new experimental practices in some respects foreign to the traditions of the Paris Observatory, its separation from the "old astronomy" is a revealing icon of the intellectual and physical division of those tasks that could no longer be properly carried out from the Saint-Jacques hill.[78] Meanwhile, the Paris Observatory would remain a fixture of the urban landscape. Not as empty shell, to be sure, but in a much reformed way. In part a consequence of its objects of study, its precision culture, and its old international networks, the distribution process of astronomy was nothing specific to the Paris Observatory, but it emerged in no accidental way from constraints and opportunities provided by the city's environment and culture.

[76] E. Mouchez, "Rapport annuel sur l'état de l'Observatoire de Parie adressé au Conseil" (1889), 6. AOP. 520.1 (44) PARIS.

[77] A. Yvon Villarceau, "Remarques au sujet de la note insérée dans le dernier *Compte rendu*," *CRAS* 65 (1867): 1099–102, on 1101.

[78] Cf. S. Schaffer, "Where Experiments End: Tabletop Trials in Victorian Astronomy," *Scientific Practice: Theories and Stories of Doing Physics*, ed. Jed Z. Buchwald (Chicago: Univ. of Chicago Press, 1995), 257–99; and David Aubin, "La Métamorphose des éclipses de Soleil," *La Recherche* 321 (June 1999): 78–83.

Organizing Sight, Seeing Organization:
The Diverging Optical Possibilities of City and Country

By Theresa Levitt*

ABSTRACT

This paper contrasts the optical possibilities of a single instrument, the polarimeter, within and without the location of the city. It follows the work of François Arago and Jean-Baptiste Biot in the years after 1821, when, following an explosive argument between the two men, Biot retired to the country and Arago became a prominent figure of Parisian salon life. The different cultural spaces they inhabited had distinct rules of communication in place, which governed how the visual products of their instruments circulated and in turn what these visual effects represented. Arago's public polariscopic displays, subject to a process of collective viewing, became the basis of a new color theory of immediate expression, while Biot's own use of the instrument to distinguish between organized and unorganized matter relied upon personal authority to make claims about the ultimately undepictable mystery of life.

INTRODUCTION

Paris has rarely had to argue for its position as the capital of French science. The sheer density of brainpower and resources seems to elevate this status to natural fact. What I want to examine here, however, is not so much the city as a physical space of forced proximity, but the city as a cultural space that allowed for certain forms of communication not available elsewhere. It is not just that like-minded people had the opportunity to get together and converse in the city, but also that the *way* they conversed, the way they assigned meaning to things, was profoundly conditioned by city life. This paper tries to get at the role of place in scientific practice by examining the representing function of a particular scientific instrument, the polarimeter, within two different sites: one distinctly urban (the Paris salon), and one distinctly rural (the country estate). The brightly colored images that marked this instrument's optical product could be found in both locations. But the different forms of sociability that each environment offered resulted in striking differences in how this visual evidence circulated and what meanings viewers assigned to it.

François Arago created the polarimeter in 1811, after discovering that polarized light, when passed through a doubly refracting prism and a piece of mica, divided into two, complementary-colored beams. This new instrument, whose colorful images

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