# SCIENCE AND SOCIETY, 2022

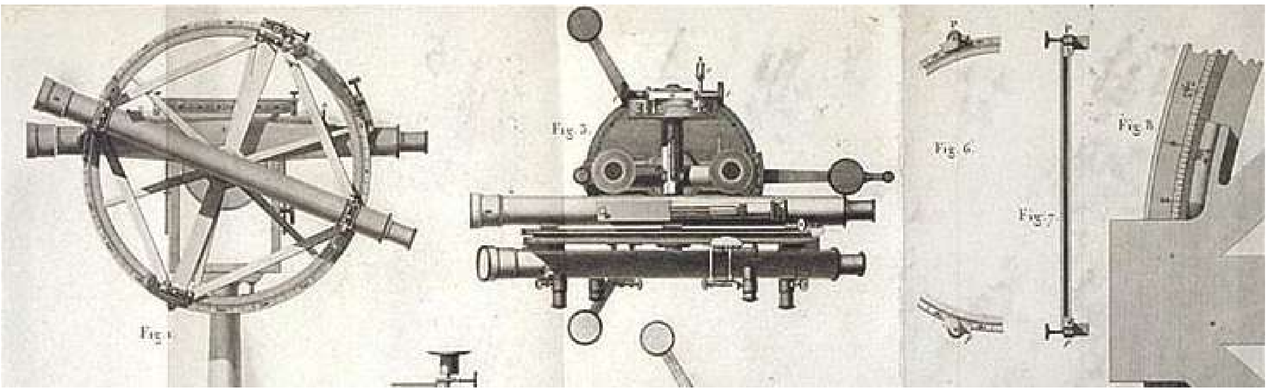
# STAR WARS

## Revolutions in Astronomy and Politics in the 19th-century

a corpus constituted by Thomas Tari

FORCCAST

Formation par la Cartographie de Controverses à l'analyse des sciences et des techniques



# SUMMARY

# 1. Introduction

*Guidelines for the readings :*

- Does an astronomer's political orientation influence his or her scientific opinions? And vice versa?
- What is the role of the use of instruments in scientific work? What is the impact of these technical objects on society?
- Are the choices of instrumentation purely scientific, or also social and political? Can astronomical instruments be considered as sociotechnical objects, and if so, why?
- How do the scientific institution, society and public authorities interact? How do the scientific institution and the people within it interact?
- Are the power relations between them unilateral? How are they characterized?
- What tensions may emerge between these different groups, and why?
- Is it possible to analyze scientific instruments and institutions in a purely scientific way?
- What does the way of conducting scientific work (with objects, in places, according to given theories) reveal about the society in which the scientist lives and works?

# Who was going to be allowed to speak for the heavens?

In : *David Aubin. On the Cosmopolitics of Astronomy in Nineteenth-Century Paris. Astro-Morphomata: Sternenwissen und Weltbürgertum in Medien und Kultur, Nov. 2011, Köln*

Gods, stars and governments have been tightly linked throughout human history. But the long nineteenth century in Europe was the seat of a profound anthropological shift. In that period, the belief in a cosmos created and ordered by God was not only challenged by some scholars in the elite, but it became widespread belief in the French population that the Universe exhibited first and foremost a materialistic order that was by and large independent from the God idea. This momentous shift, I claim, is intimately linked with the development of representative democracy and, as Walter Benjamin clearly saw in his *Passagenwerk*, Paris was one of its epicenters. The violence of the political debates among astronomers was a reflection of the high stakes indeed involved in the process of deciding who was going to be allowed to speak for the heavens.

Up to now, historians have focused on the history of nineteenth-century astronomy mostly from the perspective of scientific and instrumental developments. The internal organization of astronomical research has drawn much attention. Recently, we argued that the rise and fall of astronomy as a central science (leaving natural history and medicine altogether aside) in the nations of the Western hemisphere was linked to the services it rendered to the State (Aubin, Bigg et Sibum 2010). By this we meant that those countries set up a very extensive network of richly-endowed observatories at a time when other scientific research institutions were seldom funded to the same level by the state.

The observatory saw the development of a coherent set of scientific techniques we have called “observatory techniques” which were used in a variety of scientific disciplines, like physics, mathematics, statistics, meteorology, geodesy, and so on. Observatory techniques played a crucial part in enabling the European colonial domination of the world, as well as the participation of a wider public in the metropolis to the scientific enterprise. Observatory techniques, in short, structured an epistemological domain at the same time as its wide impact upon the world. Already by the end of the nineteenth century, the coherence of the observatory sciences was breaking apart: physical and chemical laboratories were lavishly funded by the state; observatories became more en more specialized in positional astronomy, astrophysics, meteorology, etc., each domain at the expanse of the other. As a coherent locus for a representation of science and its impact on the wider world, the observatory had played out much of its earlier significance. By that time, the aftershocks of the French Revolution were also dying out. It is a cliché to say that French Revolution was a political rupture in Western Europe, which building up on ideas developed by the philosophes of the Enlightenment completely upturned the order of the Old Regime. Historians as different in their perspectives as François Furet and Arno Mayer have shown that the change in the socio-political order brought about by the events of 1789 was worked out over the whole of the next century, if not longer.

Now, from the anthropological perspective that I wish to develop, we may assume that any socio-political order has to be, if not based on, at least consistent with, a higher order which is cosmic. In this sense, the fact that a Bourgeois society based on however imperfect democratic principles was able to take roots in the Western world over the nineteenth century must be linked with the emergence, development, and diffusion of an atheistic cosmos. In other words, to establish a durable democracy, not only kings needed to be ousted from their palaces (or at least stripped of much of their power) but also God (or gods) from the heavens. The notion that the cosmic and the social orders have a profound link with one another is very old indeed, but it was nicely brought to the fore and analyzed by the French anthropologist Maurice Godelier. Studying the Baruya people in Papua New Guinea, a tribe that was "discovered" only in the 1950s and "pacified" in 1960, Godelier was struck by the series of representations and practices instituting the violent domination of adult males on females and younger males which he established was the foundation of their society and modes of thinking. Godelier was able to study the way in which this society was constituted two or three centuries ago by the aggregation of several tribes. He paid great attention to the social rituals that had made possible to establish the Baruya society and keep it alive. In the anthropologist's classical manner, Godelier described in great details initiation rituals, sexuality, gender dynamics, and kinship structures, as well as the economy of giving and keeping identifying the key role of certain sacred objects in this society. "The social relations that allowed the Baruya to constitute themselves as a new society, and then insured its reproduction up to our days," Godelier concluded, "were of political-religious order... This is not only a society that is reproducing itself, but at the same time a cosmic order that is made manifest and brings its support to human enterprises. The social order is inscribed in a cosmic order" (Godelier 2007, 199).

Of course, nineteenth-century French society was immensely more complex than Baruya society, if only because it had a much bigger population. But it faced very similar problems. Both the Genesis and Plato's Timaeus required the intercession of a creator. What cosmic order could replace the old one? I believe that to adopt the anthropological view from afar is enlightening in order to understand better the way in which cosmologies were reinvented and popularized in the nineteenth century. As new foundations for social order were being sought after by various regimes, so were ways for construing the cosmic order explored in wholly new directions. To reconstitute itself as a new society, France needed to build a cosmic order that was congruent with the ideals it now proclaimed as the foundations of the social order. The most important of these ideals was the fact that every citizen should partake in the new order. [...]

Astronomy was the science of the nineteenth century for the same reasons that Paris was its capital, as Walter Benjamin would have it. The convulsion brought about by revolution, industrialization and the rise of the bourgeoisie were mirrored in debates about astronomical politics and political astronomy. Astronomy in nineteenth-century Paris (and presumably much beyond it) was political not only because of hierarchical fights and the tight link it had with the State and government; it was political because it offered it was about to become the foundation of the mainstream opinion about the cosmic order. Fights within the astronomical community seemed to be mostly about trivial points: the inner organization of the observatory, research agendas, etc. But they are the reflection of deeper conflicts. In such fight, the State often served as the arbiter. It was drawn to this role because it found itself dependent on the expert knowledge astronomers offered in the domains of navigation, cartography or meteorology. Encounters between astronomers and a larger public often seem to be based on misunderstandings, but, here again, they reflect deeper issues. They were about the role the people would be allowed to play in the construction of a new cosmic order and thereby about their role in the new social/political order. Whether and to what extent astronomy itself was democratic can be understood as the litmus test for the new order. In these debates, religion played a much more prominent role than previously considered. This role needs to be studied more closely, but it seems to me that the religious concerns about modern astronomy and cosmology are a great battle ground to study the great anthropological shift in nineteenth-century cosmopolitics.

# Adversarial Cosmologies at the Paris Observatory

| | <br>**François Arago**<br>**(1786-1853)** | <br>**Urbain Le Verrier**<br>**(1811-1877)** |
|---|---|---|
| Head of the Observatory | 1834 - 1853 | 1853 - 1870<br>1873 - 1877 |
| Political Allegiance | | |
| Specialization in Astronomy | | |
| Instruments | | |
| Organization of Scientific Labor | | |
| Skills Required for Astronomers | | |
| Epistemic Model | | |
| Their “Science-Society” Relationship | | |

# 2. Revolutions in the Social and Celestial Orders: Astronomy as a Public Good

# The Observatory as Public Enterprise

In : *Theresa Levitt, 'I thought this might be of interest…: The Observatory as Public Enterprise' (chap.10), in David Aubin, Charlotte Bigg and H. Otto Sibum (eds.),* The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture*. Durham : Duke University Press, 2010.*

In 1862 Victor Hugo set down to record what he called one of his "deepest memories." Twenty-eight years earlier, in 1834, he had paid a visit to the Paris Observatory. The director, François Arago, was in, and led him to one of the large telescopes with the instruction to look through it. As Hugo remembered it, they then had the following conversation:

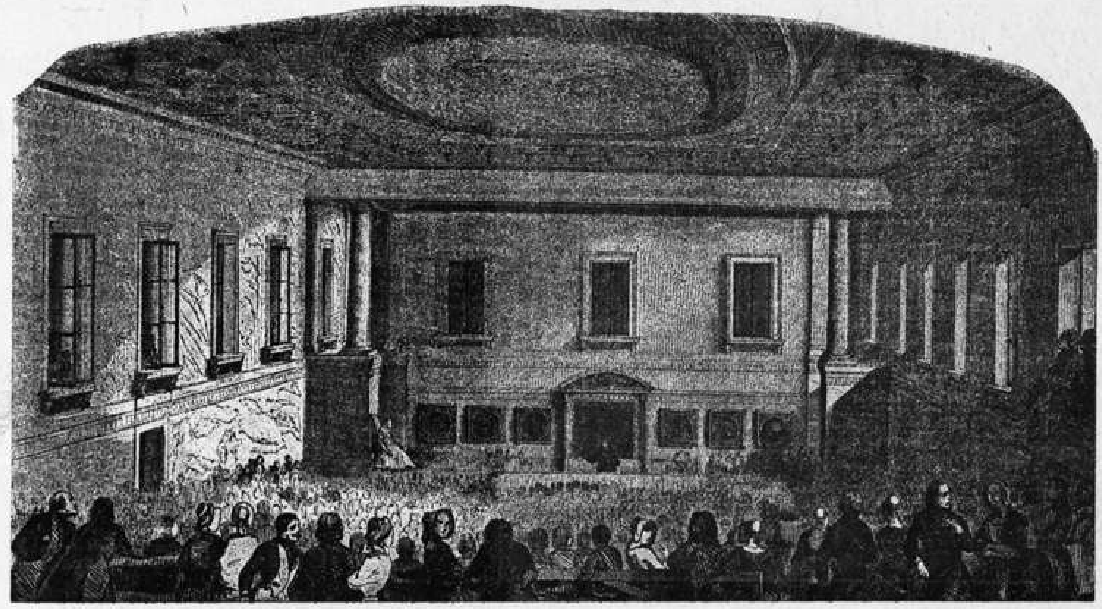
- "I see nothing," I said.
- Arago replied: "you see the moon."
- I insisted: "I see nothing."

Arago maintained: "keep looking."
Arago then explained to Hugo that he had just undertaken a voyage. Where before he had been, like all inhabitants of the earth, 90,000 leagues from the moon, he was now, because of the enlarging power of the telescope, only 225 leagues away. Hugo again claimed that he saw nothing, and Arago again instructed him to keep looking. Then, said Hugo, "I followed the example of Dante with respect to Virgil. I obeyed." Hugo marveled at the vision of the moon before him. Suddenly a streak of light appeared on the dark surface. The sun was rising on the moon. As Hugo looked, Arago listed the lunar features as the light revealed them: the volcano Messala, the Promontorium Somnii, Mount Proclus, Mount Céomèdes, Mount Petavius. "There is no more mysterious spectacle than the irruption of dawn in a universe covered in obscurity," Hugo later wrote. "One seems to be witnessing the payment of a debt of infinity." [...]

If Hugo was an astronomer, we should be better off thinking of the Paris Observatory not as consisting strictly of trained scientists but as a more porous entity encompassing a wide range of people not on the observatory's payroll. The building on the Avenue de l'Observatoire was not a self-contained and inviolable machine works of observation but more like the center node of a far-flung network of informants. More generally, the observatory sciences relied in an essential way on similar networks. The republic of letters had long provided a model of coordination, and it remained so in extensive correspondences between observatory directors. More and more, though, the egalitarian model was replaced by hierarchies for which military organizations provided not only the model but a principal resource. In the transitional period that followed the French Revolution, wide voluntary participation to observatory networks was both encouraged and channeled in specific ways for humans. Popularization therefore lay at the center of the scientific networking activities of some observatory directors.

At the center of the network dealt with here was the figure standing beside Hugo: the Paris Observatory director Arago. Arago's role in Hugo's story was twofold. He was chiefly responsible for allowing Hugo, whom he knew personally and politically, to have access to the space. But he also had a part to play in the act of observing itself. When Hugo saw nothing, Arago urged him to keep looking. When Hugo saw only indistinct shapes, Arago guided his sight to recognize the moon. It is useful, I think, to take these two things together: on the one hand Arago sought to open the activity of observation as wide as possible and make it a truly public enterprise, but he also tried to maintain control over the process and in so doing help the public, more generally, learn to see. This chapter treats Arago's double agenda in reverse order. I start with his efforts at public education. Through his free astronomy course at the observatory and his widely read popular essays, he tried to mold an astronomically literate French public, with the study of the heavens as a model for rational debate. I next turn to Arago's efforts to include the public within the practice of astronomy itself. I examine several of his instructions for observing, which outlined what sort of data would be useful to the observatory, and how to go about collecting them. I also examine the role of amateur observation in one specific instance, the total eclipse of 1842.

*Educating the Public*



*Arago faisant son cours d'astronomie à l'Observatoire.*

One of the first things we learn about Combeferre, the most philosophical of Victor Hugo's young revolutionaries in *Les Misérables*, is that he loved to attend public science lectures, where he "learned from Arago the polarization of light." This fact headed up a list of cultural markers intended to paint the portrait of a student revolutionary in Paris of the 1830s. We learn also that he read passionately the works of Claude Henri de Saint-Simon and Charles Fourier, although he could never keep the two apart in his mind, and that he believed in all the nineteenth-century dreams of progress: the railroad, the suppression of pain in surgical operations, the fixation of the image in the camera obscura, the electric telegraph.

The fictional Combeferre was not the only one to learn from Arago's public lectures. From 1813 to 1848 Arago's free astronomy course at the observatory was a local institution. Hugo and Auguste Comte spoke of going. George Sand wrote to Louis Blanc, begging him to accompany her when her usual escort was indisposed. "All of Paris runs to hear them," an English paper wrote in 1840. The courses stood as a public testament to Arago's "obstinate ardor in the cultivation of what the learned in x and y call the subaltern interests of the country and humanity." Arago gave his lectures once a week before a consistently large crowd in a specially built auditorium at the observatory. Although he began teaching the course in 1813, he always traced it back to its revolutionary origins. The course was born, in principle at least, on 7 messidor Year III, or as everyone besides Arago put it, 25 June 1795. The Convention created the Bureau des Longitudes on that date, and included as one of its duties the teaching of a public astronomy course. The bureau only decided to begin honoring the statute on 11 November 1812. It appointed Arago to give the lectures and allotted fifteen hundred francs a year for the cause. He delivered the first lecture in February 1813.

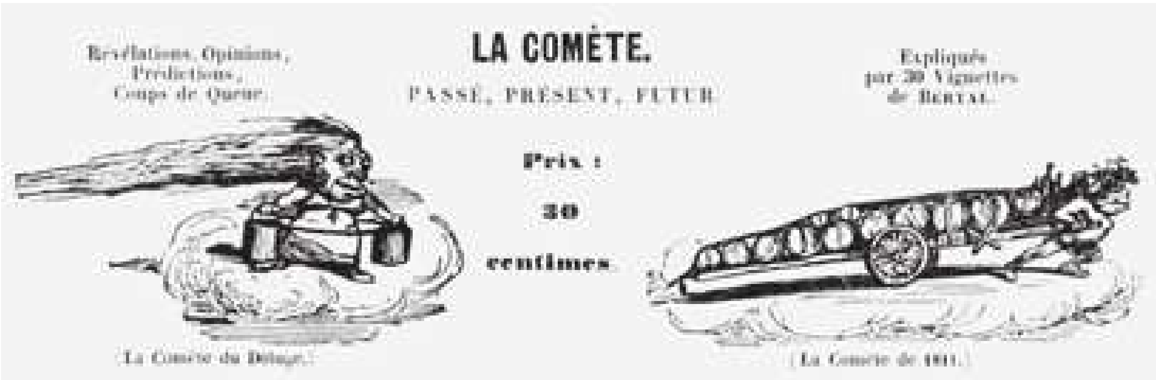
In addition to the lectures Arago also affected his campaign of public science through the bureau's publication *the Annuaire*. The bureau originally intended this publication for the use of sailors. But when Arago was put in charge he also began including general-interest articles, and its readership expanded to include a wide swath of the literate public. "*The Annuaire* of the Bureau of Longitudes," a commentator wrote, "is read throughout Europe, and the articles of Arago on lightning, steam and the most delicate questions of astronomy have given it immense vogue." Stendhal counted himself "an assiduous reader," and wrote to Arago asking about his work on the various effects of moonlight.

One of the crucial questions for both *the Annuaire* and the observatory lectures was the appropriate level of mathematics. Arago was adamant throughout the thirty years that he taught the course: no prior mathematical knowledge whatsoever was required of his audience. This policy became something of a war cry. Laplace, Lagrange, and most of the other first-generation members of the Bureau des Longitudes had turned astronomy into a showcase for the power of advanced analytical mathematics. Many of them claimed that the subject could not be taught without this mathematical apparatus. Arago treated his course as a proving ground against the claim of the necessity of analysis. "It is thus a great, a solemn experiment that we are undertaking together," Arago informed his audience at the opening of the course in 1846: subjecting the principles of science to the critical reason common to mankind.

In the course Arago laid out a template for reasoned discourse. Just because he assumed no prior knowledge did not mean that he would let up on the rigor. The first several lectures were spent establishing the principles of geometry, optics, and mechanics that he would use later. Arago emphasized that these principles were not part of the mathematical "obscurity" intended to "drive away the ignorant." Rather, the theorems that he used were the "the geometry, optics, and mechanics of common sense." The intent was to establish a common ground for discourse that placed every participant at an equal level. Then one could proceed according to the rules of reason. Arago acknowledged that his pedagogical stance was at heart an issue of sociability. "Clarity," he quoted from Fontenelle at the opening of his course, "is the etiquette of those who speak in public." Arago's requirement that his course be comprehensible to any intelligent listener was a statement about how people should interact as a public.

The "public opinion" that Arago sought to shape with his astronomy lessons was a category that had crystallized in the late eighteenth century and the early nineteenth. The term "opinion" shed its connotation of uncertainty and came to stand for the critical judgments of a public capable of relying on its own reasoning power. It had above all a political resonance. Public opinion would serve as a check on state power. In 1813, when Arago began his lectures, the public participating in civic discourse offered its critique from a position largely outside of state power. With the expansion of constitutional representation in 1830, this began to change.

The July Monarchy had opened as a great experiment in incorporating public opinion into the framework of the state. Within two years, however, a palpable unease had spread. “The year 1832,” Hugo wrote, “began with an air of ominousness and looming danger.” The papers began warning of a comet whose scheduled return brought it dangerously close to the earth. The comet in question had first been spotted in late 1826 by the astronomer Wilhelm von Biela. Soon after, the director of the Marseilles Observatory, Gambert, calculated its trajectory and determined that it had a period of six years and nine months. Although its trajectory could be calculated exactly using celestial mechanics, its presence came wrapped in a discourse of portentous destruction. A first pass at the calculations revealed that the comet would pass directly through the ecliptic of the earth’s orbit, and the alarm went out that it might run into the earth. Even if there were no collision, the papers mentioned the possibility that the earth could pass through the nebulous material making up the tail of the comet.




*An ad for a pamphlet entitled “The Comet: Past, Present, Future.” On the left is a comet carrying water buckets entitled “The Comet of the Flood.” On the right is a comet pulling wine casks entitled “The Comet of 1811,” presumably recalling the year’s exceptional harvest. L’Illustration 1, no. 7 (15 April 1843): 111.*

These dire forecasts closely followed another comet scare. In January 1831 Arago had reported at the Academy of Sciences that one of his provincial correspondents had spotted a new comet around the constellation of Ophincus. Shortly after, the opposition paper *Le National* picked up the story and continued tracking the comet’s progress through the sky. A nervous concern over the unknown consequences of the earth’s passage through the nebulous tail of the comet coincided with reports of a mysterious dry fog appearing throughout Europe, a series of disastrous crop failures, and the worst outbreak of cholera ever seen. Over the next twenty months France seemed under the influence of some dark star, as nature itself seemed to conspire against the fledgling regime. Poor weather led to crop failures. Wheat prices soared. Grain riots were endemic. Protests broke out against the forestry administration. The stock market collapsed with a spectacular crash. Things only went downhill from there, sliding into what became known as the great fear of 1832. Agricultural and economic crisis became mixed with meteorological aberrations. [...]

In 1832 Arago began a massive campaign to debunk pernicious forms of ignorant superstition. His favorite topic was comets. He first tackled the subject with an article of several hundred pages that dominated *the Annuaire* of the Bureau des Longitudes of 1832. The daily papers, he claimed, were spreading fear with their announcements that the comet would imminently strike the earth and smash it to bits. He felt compelled to counter these claims with “everything that science has uncovered” about the trajectory of the comet, “whose proximity, we are assured, will surely be so fatal to Earth and its inhabitants.” It was true, Arago admitted, that according to the equations of celestial mechanics the comet would pass directly through the ecliptic of the earth’s orbit. Yet a more thorough investigation, he added, revealed that there was no cause for fear. One could calculate the point at which the comet would cross the ecliptic, which turned out to be a distance equal to four and a third earth radii away from the orbit of the earth. This distance was certainly close enough to allow for the possibility that the earth would at least pass through the nebulous portion of the comet. But, Arago pointed out, the comet was scheduled to pass by this spot on 29 October, while the Earth would not get there until 30 November. Given that the earth traveled at a speed of 674,000 leagues a day, one could see that it would never be less than twenty million leagues from the comet. [...]

*The Observing Public*

Arago did not intend for his public audiences and readership to remain in “the passive role of contemplators.” He felt rather that the proper form of education could allow them to be useful and active participants in the observatory’s operations. The observatory was responsible, after all, for a complete survey of the heavens and earth, requiring observations from all points on the globe. Arago relied at least in part on the efforts of a well-instructed public to provide these observations.

*Public participation in astronomy. The child begs, “Papa, let me look.” The father, looking at a kite through his telescope, responds, “Quiet, I see the nucleus! We beat the Observatory!” L’Illustration 1, no. 5 (1 April 1843): 77.*

Arago wrote up instructions outlining both what sort of observations he was interested in and how these observations should be made. At the beginning of one of these sets of instructions, Arago invoked the eighteenth-century monument to accumulated knowledge, *the Encyclopédie*. He recounted that someone had once complained to d’Alembert about its size, only to receive the reply that the reader was lucky he did not have an encyclopedia of everything that was not known in front of him, as that would no doubt run into the hundreds of volumes. This response, Arago felt, was “more clever than exact.” Although there were no doubt many things that people didn’t even know they didn’t know, there were also “many important questions, well defined, well characterized, that one can, with confidence, recommend to observers.” This was the project he undertook in 1835, when he wrote up a set of instructions for the captain of the Bonite to make meteorological measurements as the ship completed its circumnavigation of the globe. “It thus appeared to me,” he wrote, “that this genre of publication could become extremely useful, that a foule of people instruites and désœuvrées would receive from it an excitation that would transform them from the passive role of contemplators to the top ranks of militant science.” For this reason Arago published the instructions, giving detailed directions on how to record data in such a way that they could be usefully compiled by the observatory. The instructions ran to several hundred pages, detailing such things as when and how to take readings with thermometers and barometers, and which features to look for and record with phenomena such as meteor showers and the aurora borealis. Arago repeated this procedure several times, first writing up instructions for the captains of ships sailing around the world, then publishing the instructions with the thought that others might be able to contribute their observations as well. [...]

To see how these events played out in a particular instance, I shall focus on the eclipse of 1842. A total eclipse of the sun was scheduled to pass through southern France, cutting a swath across the Midi from the Pyrenees to the Alps. The event was a convenient one for Arago. One of the cities on the path of the eclipse was Perpignan, his hometown and the district he had represented in the Chamber of Deputies from 1830. And 1842, it turned out, was an election year, with Arago's seat up for grabs. The observing expedition that he arranged for himself and his élèves astronomes coincided with campaign celebrations. [...]

If Arago and his students had Perpignan covered, there was still the question of the rest of the eclipse's path. For this Arago turned once again to the French public. He wrote up a set of instructions to those viewing the eclipse on their own, which he published in the widely read *Annuaire*, as well as in the *Comptes rendus of the Academy of Science*s and the *Annales de chimie et de physique*. Arago began with a description of the phenomenon of the total eclipse, and a list of known eclipses throughout history. There had been only one total eclipse seen in France in the eighteenth century, and the one in 1842 was the only one due to occur in the nineteenth century, so Arago looked toward the opportunity for data collection with some excitement. The bulk of Arago's article was a section entitled "*Réflexions et recommandations soumises aux observateurs*." He listed dozens of questions regarding eclipses that were still unresolved by astronomers and could be fruitfully investigated by anyone on the path of the eclipse. For example, he stated, it was of central importance to know whether the corona was centered on the moon or on the sun. Past observers disagreed on this issue, which was crucial for deciding whether a solar atmosphere existed. The question could be resolved, Arago claimed, by carefully measuring the size of the corona at both the beginning and the end of an eclipse. He specified the instruments appropriate for these measurements: reflection telescopes, *lunettes de Rochon* with birefringent prisms, or refraction telescopes of moderate enlarging power whose lenses have the minutes marked with fine wires. Each of these methods would have its advantages, and all would complement one another. Arago recommended many other observations that could be made without any particular equipment. "It goes without saying," he wrote, "that in each location one will seek to determine the number and size of the stars that become visible to the naked eye during the total darkness." This observation would be a means for determining just how dark the darkness was. Another observation of interest was the slight coloration that the atmosphere and terrestrial objects took on. Here Arago gave a special warning to amateurs to guard against the effects of color contrast, and to be very careful about any light sources that they might have in the vicinity. Arago collected the diverse sets of observations and published the conclusions he drew from them in his popular textbook on astronomy, *Astronomie populaire*.

*Conclusion*

After Napoleon III assumed power after his coup, he went about completely restructuring the Paris Observatory. Long known as a nest of Republicanism, it would be remade into a properly imperial institution. The first step was to get rid of Arago, a step obviated in 1854 when Arago died after an extended illness. Also implicated in the observatory's republican character was the group of élèves astronomes responsible for recording astronomical data. They regularly attended reform banquets and radical political meetings. One of them, obligingly enough for future historians in search of smoking guns, seems to have passed the time when not looking through his telescope by executing doodles that betrayed his political allegiances. But is there a way to talk about the Republican observatory that does not simply make reference to the Republican politics of its employees? I think there is, but it involves looking beyond the observatory as a fixed spatial location with limited personnel. If I have chosen to concentrate on Arago's efforts to involve the public in the operations of the observatory, it is because I think that for him the public was the platform for both his astronomical and political visions. Arago saw his public instruction as a means of shaping the rational critical French public necessary for the proper functioning of a republic founded on public opinion. His willingness to allow this public into the activity of science, and his easy confidence in the reported observations of his distant correspondents, rested upon the possibility of universal communicability. Although both Auguste Comte and Adolphe Quetelet, two heralds of personal difference in observation, studied astronomy under Arago, Arago himself showed little interest in how one person might see differently from another. Transparency was the cornerstone for the observatory that Arago directed and the Universal Republic of 1848 that he helped to found. The rapid dismantling of both, in the middle of the nineteenth century, heralded the end of the dream of easy coordination.

# Cyclic Cosmology and Radical Insurrection

In : *Louis-Auguste Blanqui,* Eternity by the Stars*, 1872. (Introduction words from David Aubin)*

*Auguste Blanqui (1805-1881) is well known as one of the most committed revolutionaries of nineteenth-century France, having spent several of his years in jail. In 1870, he was imprisoned again for having conspired against the nascent Republic of Adolphe Thiers. While incarcerated, Blanqui wrote a unusual tract called* Eternity by the Stars *[L'éternité par les astres]. In this remarkable booklet, Blanqui drew radical consequences that he thought were the logical conclusion of recent advances in science:*

> What I am presently writing in my cell of the fort of Taureau, I have written it and I will write it again in all eternity, at a similar table, with a similar pen, under similar clothes, in similar circumstances. And so, for each of us.

*After the bloody failure of the Paris Commune, the "astronomical hypothesis" might have offered a ray of hope to the old revolutionary. This text is remarkable because it resorts to astronomy to suggest a pacific resolution of close to a century of political violence. To design the resolution, Blanqui deftly used the most recent scientific advances such as spectroscopy which had emerged over the last ten years. Clearly, Blanqui was well informed of active areas of research, perhaps by followers of Arago as science popularizers. This astronomical vision of society appears as the gospel of a new age. It also indicated that the astronomical sky was for the common people to reclaim as its own.*

> Only a few years ago, such a contrast kept wide open the realm of fantastical speculation over the structure of the celestial bodies. The only thing that no one deemed doubtful was that they should not resemble our planet in any way. We were mistaken. Spectral analysis allowed us to dissipate this mistake, and demonstrate, in spite of strong evidence to the contrary, that the composition of the universe was unified. The forms are innumerable, but the elements are the same. Here we come to the fundamental question, a question that soars high above all others and dwarfs them ; we must therefore explore it in detail by moving from the known to the unknown.
>
> Until further notice, on our globe nature has at its disposal the 64 simple bodies named below. We say "until further notice" because the number of such bodies was only 53 a few years ago. Every now and again, their nomenclature gets enriched with the discovery of some metal, painstakingly extracted by chemistry from the stubborn bonds that link them to oxygen. In all likelihood, the 64 will reach the 100. But the serious agents are hardly more than 25. The rest share the bill only as stooges. They are called simple bodies, because hitherto, they have been found to be irreducible. [...]
>
> Till recently, those elements were held to be specific to our globe. What debates took place about the sun for example, about its composition, the origin and the nature of its light ! The great controversy opposing emission and waves is now only just settled. Only its last rear-guard gunshots are still being heard. The victorious waves had built a rather fantastical theory upon their success : "The sun, a

simple & opaque body just like any other planet, is enveloped in two atmospheres, the one, which resembles ours, serves as an umbrella that protects the indigenous peoples against the second, called photosphere, which is the eternal and inexhaustible source of light and heat.” This widely accepted doctrine has long reigned over science, in spite of all the analogies it contradicts.

Spectral analysis has dissipated such errors. It is no longer a question of inexhaustible and perpetual electricity, but more prosaically it is a matter of hydrogen burning, here like there, in conjunction with oxygen. The pink protuberances are formidable spurts of flaming gas, which exceed the disc of the moon during total solar eclipses. As regards the sunspots, one was right to conceive of them as large funnels opening into gaseous masses. It is the hydrogen flame, swept by storms over immense surfaces, and offering a glimpse of the core of the star, be it in a liquid or in a greatly compressed gaseous state, not as a dark opacity, but rather as a relative obscurity.

So, no more chimeras. Here we see two terrestrial elements providing light to the universe, just like they provide light to the streets of Paris and London. It is their combination that spreads light and heat. It is the product of this combination, water, which creates and entertains organic life. No water, no atmosphere, no flora or fauna. Nothing but the cadaver of the moon. [...]

The universe as a whole is composed of stellar systems. In order to create them, nature has only one hundred simple bodies at its disposal. In spite of the prodigious wealth that she is able to draw from these resources and of the incalculable number of combinations that make its fecundity possible, the result is surely a number as finite as the elements themselves, and in order to fill the expanses, nature must repeat every one of her original combinations or types.

Any celestial body, whatever it is, exists in infinite numbers in time and space, not only under one of its aspects, but such that it appears at every second of its life span, from its birth till its death. Every being great or small, live or inert, that is spread over its surface, shares the privilege of this immortality.

The earth is one of these celestial bodies. Therefore every human being is eternal at every second of its existence. That which I am writing at this moment, in a dungeon of the Fort du Taureau, I have written and shall write again forever, on a table, with a quill, under clothes and in entirely similar circumstances. And so it is for all of us.

All of these earths stumble, one after the other, into the rejuvenating flames, so as to be born again and to stumble again, in the monotonous flow of an hourglass eternally turning itself over and emptying itself. What we have is ever old newness & ever new oldness. [...]

Yet, there is one shortcoming: there is no progress. Alas ! no, these are vulgar reissues, repetitions. So too are the copies of past worlds, so too are those of future worlds. Only the chapter of bifurcations remains open to hope. Let us not forget that everything we could have been on this earth, we are it somewhere else. Progress on this earth is reserved only to our nephews. They are luckier than us. All the beautiful things that our world will see, our future descendants have already seen them, are seeing them now and will see them always, of course, in the form of doubles that preceded them and will follow them. As sons of a better humanity, they have already properly humiliated and defamed us on the dead earths, in passing there after us. They continue to denigrate us on the living earths from which we have disappeared, and they will forever continue to hunt us with their scorn on the earths yet to be born.

Like them and like all the other guests of our planet, we are reborn as prisoners of the time and place which fate assigns us in the series of our planet's avatars. Our immortality is an annex of our planet's own. We are but the epiphenomena of its resurrections. Men of the 19th century, the hour of our appearance is fixed once and for all, and always assigns us the same incarnation. At best, it gives us the perspective of lucky variations. Nothing here to flatter the thirst for improvement much. What can we do ? I haven't sought my pleasure; I have sought the truth. There is neither revelation here, nor prophet, but a simple deduction drawn from spectral analysis and the cosmogony of Laplace. These two discoveries make us eternal. Is it a blessing ? Let us take advantage of it. Is it a mystification ? Let us resign ourselves.

# 3. Establishing Scientific and Social Order

# The Fading Star of the Imperial Observatory

In : *David Aubin, "The Fading Star of the Paris Observatory in the Nineteenth Century: Astronomers' Urban Culture of Circulation and Observation," Osiris 18 (2003): pp. 79-100*

On a bright Sunday afternoon, take a walk in the Luxembourg Gardens, in 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, modem 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. [...]

*Monks And Machines: Creating And Defending Precision In The City*

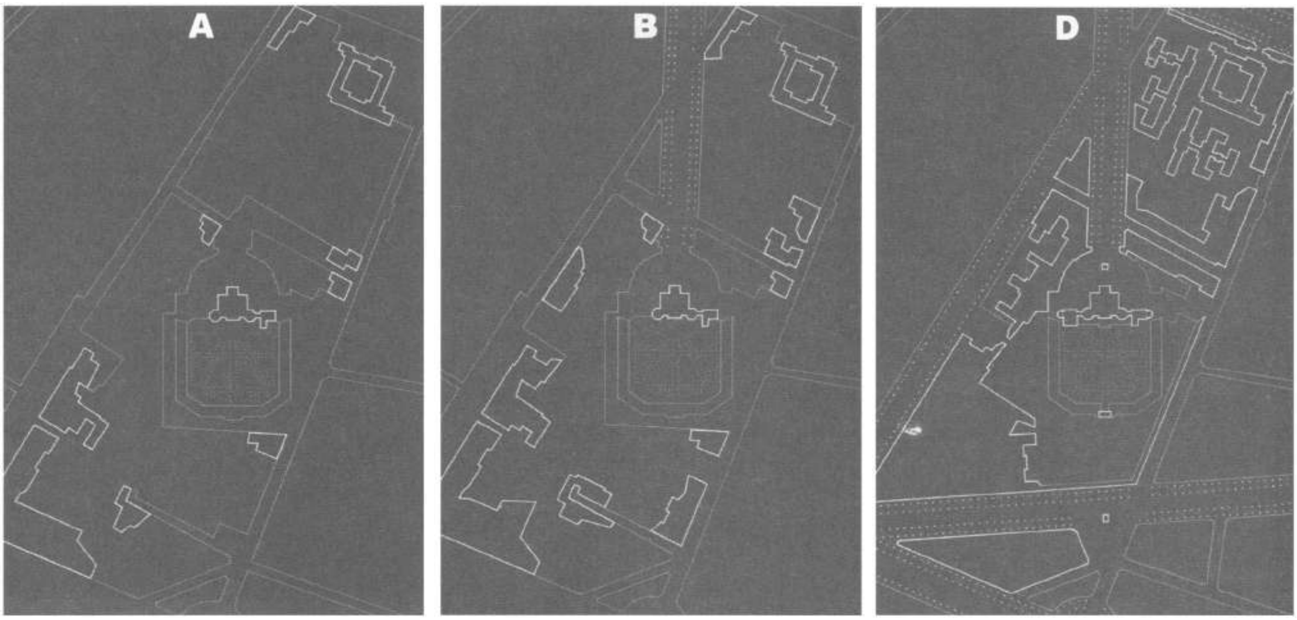
If cities came to trouble observatories, it was as a direct consequence of the latter's culture of high precision. After Arago's death, Le Verrier, who succeeded him as director, emphasized "how important the precision of observation [was] for the future of science." For every planet of the solar system,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

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.' " [...]

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'etat, "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. 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. [...]

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. More interestingly, in order to reduce vibration, adjacent streets were among the first ones 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.”




Transformation of the Neighborhood of the Observatory, (a) 1666-1683, (b) 1793-1800, (d) 1867-1873.
From B. Fortier, *La Métropole imaginaire: un atlas de Paris* (Liege: Pierre Mardaga, 1989)

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!" 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." Machines could work perfectly well in a metropolitan environment.

*The Transfer Debate at the End of the Second Empire*

Under the Second Empire, the prefet Georges Eugene Haussmann accelerated and changed the meaning of urbanization. Thus in 1860, the assaults of Paris on the observatory took a more modem shape. To ease access to the center of Paris from the four cardinal points, Haussmann wished to extend the boulevard Sebastopol (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. From there, a new boulevard named after Arago would be opened to link the place d'Enfer to the gare d'Orleans (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. [...]

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. In the afternoon, he would stroll down the rue de

Seine to the academy seance (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."

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 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 lycee 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." [...]

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. [...] Only within the city could the observatory hope to play that role. [...]

*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. [...]

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.

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. 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." 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. The observatory, already at the geographic center of France, thus found itself sitting at its spatio-temporal center as well.

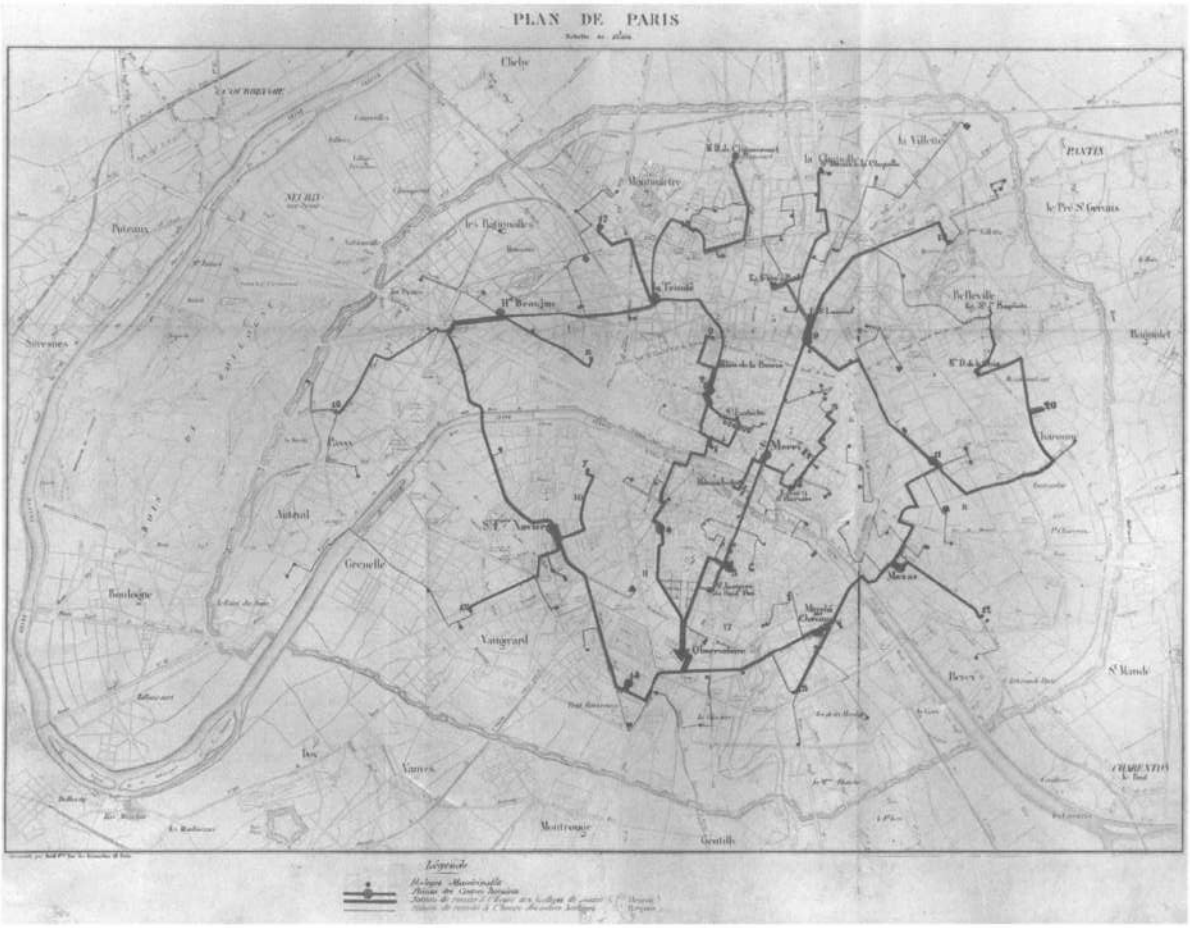



***Figure 3.*** *The Observatory at the Center: The Electric Network for Adjusting Public Clocks in Paris as Projected in 1878. From 'Avant-Project du Réseau des centres horaires et de la remise à l'heure des horloges des 20 mairies et des principaux établissements municipaux. Plan d'ensemble. Juin 1878,'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

# Disciplining Astronomy and the 19th-Century Society

In : *Simon Schaffer, “Astronomers Mark Time: Discipline and the Personal Equation”, Science in Context, 1998, 2(1), pp. 115-145.*

It is often assumed that all sciences travel the path of increasing precision and quantification. It is also assumed that such processes transcend the boundaries of rival scientific disciplines. The history of the personal equation has been cited as an example: the "personal equation" was the name given by astronomers after Bessel to the differences in measured transit times recorded by observers in the same situation. Later in the nineteenth century Wilhelm Wundt used this phenomenon as a type for his experiments on reaction times. For historians of psychology, this has been taken to be an exemplary case where quantified laboratory science rescued astronomy by showing that this was really a psychological phenomenon measurable only in complication experiments. This paper challenges this story. Astronomers neither ignored, nor despaired of, the personality problem. Instead, the managers of the great observatories developed a new chronometric regime of vigilant surveillance of subordinate observers. The astronomers' solution was thus intimately connected with social and material changes in their way of life: a division of labor in the observatories, a network of observing sites, a mechanization of observation. The paper documents these changes and then presents a study of one case where managers, amateurs, and psychologists clashed for authority over the personality problem. Measurement is given its meaning when situated in specific contexts of styles of work and institutions. Disciplines give meanings to values, and often resist attempts by others to redefine these meanings or to gain authority over measurement. Quantification is not a self-evident nor inevitable process in science's history, but possesses a remarkable cultural history of its own.

**Psychology and the Personal Equation: A Simple Tale**

The term "personal equation" appeared in the early nineteenth century as a label for the worrying fact that astronomers seemed to differ from each other in the times they recorded for transits. The difference varied with time and with the type of observation: for example, personal equations might differ for lunar as opposed to stellar transits. [...] The great German astronomer Friedrich Bessel, preoccupied with the reduction of the Greenwich catalogues of observations during the 1810s and 1820s, was then credited with the initiation of the term "personal equation" to characterize this difference, and with the inauguration of a systematic program to ascertain characteristic relative differences between pairs of astronomical observers. "No-one knew at the time," Boring explained, "why there should be these individual differences" [...] Boring argued that "the discovery of the personal equation by the astronomers and their later success in measuring absolute personal equations led into both the complication experiment and the reaction experiment of the new scientific psychology." That is, the history of the personal equation is colonized by a teleological account of the emergence of "the experimental dynamic psychology of motivation." [...]

The formation of a discipline is simultaneously the process of organizing work to produce these values and the system of knowledge which gives the values their meaning (Shapin 1984). Attention to discipline suggests different questions about the personal equation. The new measures introduced by Bessel and his German colleagues into early nineteenth-century positional astronomy were accompanied by a new variable whose meaning was ill-defined. The chronometric techniques developed by Airy and his contemporary observatory managers were designed to answer this need. How did these technologies change the regime of the observatory? The personal equation directly calibrated the disciplined performance of the observer. As H. M. Collins has suggested, calibration "is the use of a surrogate signal to standardize an instrument" (Collins 1985, 100-106). The surrogate is supposed to have the same effects as the signal whose character is ill-defined and disputed. The status of calibration depends on the plausibility of this identity. If the identity can be accepted by members of the relevant group then the possible strategies which members can use to investigate and describe the troubled source are more closely constrained. This constraint is a social process in the organization of experimental work. Precisely this feature emerges inside nineteenth-century astronomy. The observer was part of the "instrument" to be calibrated. Artificial stars and galvanic clocks substituted eye-and-ear methods. The act of observation was destroyed and then painstakingly rebuilt through a range of surrogates for some notional "direct" experience. This rebuilding accompanied a process of social reorganization. The observatory became a factory, if not a "panopticon." "Mere" observers were relegated to the base of a hierarchy of management and vigilance, inspected by their superiors with as much concern as were the stars themselves. Observation was mechanized, and observers transformed into machine minders. At Greenwich, such workers clocked in, kept regular hours, and were supervised by an ever-watchful management. The same fate was meted out to the calculators. Division of labor demanded precise control over an increasing range of menials.

Intriguing aspects of these changes include the moral and social connotations of the observatory hierarchy. "Personality" could be disciplined through the right moral conduct of the workplace and right moral habits of the work force. The stratification of and collaboration between astronomical workers are highly comparable with the coherence of experimental cultures and styles of work traced in more modern large-scale laboratories (Pickering 1984; Pinch 1986; Galison 1987,267-70; Galison 1988). A further question also emerges: astronomy displayed itself to its public as the science of the empiricist, the hero, and the solitary. At least part of its astonishing status in the nineteenth century relied upon the image of the nocturnal stargazer locked up in his tower. But astronomy's command demanded the interchangeability of observers, not their isolation. Because of factors such as personality, observers separated in space and time had to be calibrated with complex social and material technology. How did astronomy's spokesmen reflect this fact? The question of the observatory as workplace and that of the astronomer's public image connect the problem of personality with the wider issue of control. Who was to manage observation? Who could be trusted? The well-known troubles of professionals and amateurs intersect our concerns here.

**Disciplining the Observer**

When Maskelyne died at Greenwich in 1811 his observatory staff contained but one assistant, a replacement for the unfortunate Kinnebrook. By the end of the century the staff had expanded to fifty-three, including ten assistants, six established and twenty-four supernumerary computers (Maunder 1900, 98,137-39; Meadows 1975, 7-14). The method of recording transits had changed too. William Ellis, a retired worker at Greenwich, reminisced about the traditional eye-and-ear method, in force until 1854. Using the beats of a nearby pendulum clock as the image of the star crossed the wires of the eyepiece, "it was in all cases my custom to take the second off the clock as the object approached the first wire, count through the transit without looking at the clock, and invariably check the counting after passage at the last wire" (Ellis 1897, 313-14). Airy's new transit circle and his electric barrel-chronograph dictated a new regime. A detailed description was provided by Walter Maunder, assistant at Greenwich Observatory from 1873: a galvanic button was pressed to initiate the timing of the transit when the star's image crossed each of ten vertical wires in the field, and a separate signal was used to record the position of a moveable horizontal wire coinciding with the image's path. A second observer read seven circle microscopes penetrating the pier of the telescope to record declinations of arc. In total, measurement of right ascension, declination, air pressure, and temperature required twenty-two recorded numbers (Maunder 1900, 188-92; Howse 1975, 45-46; Meadows 1975, 35-38).

The coordination of self-registration, prompt and accurate reduction of observations, and a rigid timetable for assistants' work, including the practice of clocking on introduced by Airy for all his subordinates, promoted a severe disciplinary regime at Greenwich (Airy 1896, 203). Maunder recalled that under Airy's "remorseless sweating," assistants would not survive the strain past the age of forty-six. The computers were typically started as teenage boys, later dismissed at short notice at the age of twenty-three. Promotion was possible on obtaining a certificate of competence at observation. "The system of combining the labour of unattached computers with that of attached assistants tends materially to strengthen our powers," Airy noted, pointing out how division of labor aided the observatory's productivity. Such concerns were not solely Airy's prerogative. During the 1820s, the mathematician Charles Babbage worked hard to win government support for his efforts to mechanize the calculation of astronomical tables. In his analysis of political economy and machinery published in 1832, Babbage used the French tactics of dividing computation into a hierarchy of skilled and unskilled workers as his chief example of the virtues of control over a disciplined work force. Unskilled computers "were usually found more correct in their calculations than those who possessed a more extensive knowledge of the subject." Astronomical computation should ape "that of a skilful person about to construct a cotton- or silk-mill, or any similar establishment" (Babbage 1835, 191-96; Berg 1980, 182-91). At Greenwich, in the same period, Airy's immediate predecessor, John Pond, had already demanded "indefatigable, hard-working, and, above all, obedient drudges" as assistants and computers. Airy's criticism of Pond's regime was not its observational but its administrative failings. The ideal observatory became indistinguishable, according to Maunder, from a Whitehall office, with its ledgers full not of "income tax schedules" but stars (Airy 1896,216; Laurie 1976; Maunder 1900,100,137,140; Meadows 1975, 9-10). [...]

Historians of the Airy regime have rightly stressed the "factory mentality" which dominated the observatory (Chapman 1985). Its significance is not limited to Airy's astonishing disciplinary vigilance and moral rectitude. The connection between division of labor at the observatory, the self-registering instruments, and the electric telegraph was one aspect of a process by which networks of observatories were established, and by which these international networks began to be coordinated and allied with the powerful grid of commerce and empire (Headrick 1981). The great European observatories, such as Arago's at Paris and Quetelet's in Brussels, were key nodes of this grid. Both Arago and Quetelet were early managers of systems for minimizing the effect of personality. Arago sought to separate optical and auditory components of recording, and to make a trigger mechanism for marking elapsed time on the chronometer (Arago 1853). [...]

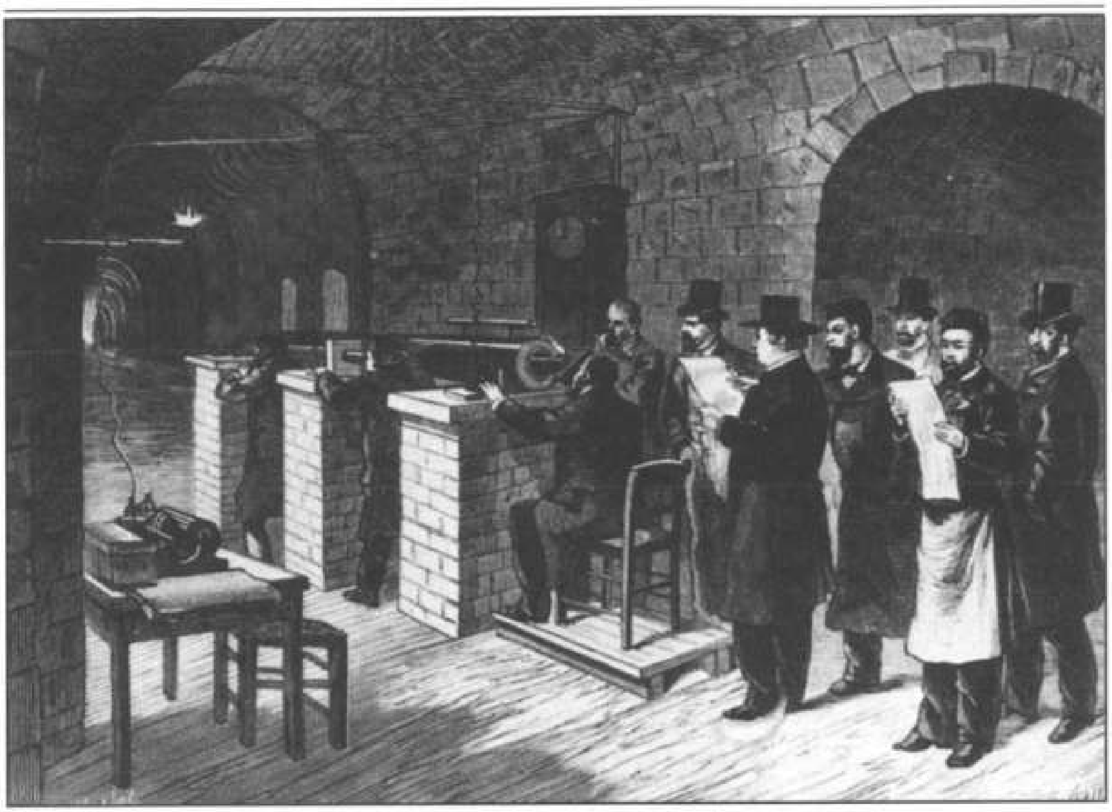


**Figure 2.** Tests of observers' relative personalities in Paris in preparation for the Venus transit in 1876. A model of the planet's transit across the Sun's face is 100 m away at the far end of the tunnel; a galvanic barrel recorder is at front left. Subjects were expected to depress the galvanic buttons when timing the apparent transit, yielding measures of their differences. (Source: *L'Illustration* 68:392.)

Discipline and hierarchy inside the observatories went hand in hand with the formation of a disciplined world outside their walls. Latour argues that scientists make this external world susceptible to measurement by changing it to conform to the regime within their laboratories. Pasteur's heroic vaccine trials involved the transformation of a farm into a field station (Latour 1983). Astronomers faced the same task. This was the context for their construction of techniques to manage the personal equation. In assessments of the difference in observatory positions, in comparisons between observatories' data, and in celebrated international collaborations such as eclipse expeditions or the transit of Venus in 1876 (see figure), astronomers carried with them their disciplined regime, with its new complex technology. Herschel said that "a ship is an itinerant Observatory." Such mobile field stations had to be made susceptible to the management imposed in the metropolitan headquarters (Herschel 1846, xxxv) [...]

At the end of the century, Maunder described Kinnebrook as "a martyr of science." The problem of personality was an aspect of human character, but it was therefore manageable by astronomical discipline:

> *There will be a constant difference between the eager, quick, impulsive man who habitually anticipates, as it were, the instant when he sees star and wire together, and the phlegmatic, slow-and-sure man who carefully waits till he is quite sure that the contact has taken place, and then deliberately and firmly records it. These differences are so truly personal to the observer that it is quite possible to correct for them. (Maunder 1900, 177)*

Between the time of Maskelyne and that of Maunder, the concept of the personal equation emerged. But this emergence did not involve a loss of authority by the astronomical community over the observer's personality. That authority became even more secure. It did involve a loss of the observer's authority within the discipline of astronomy. That loss was of immense importance for astronomers' styles of work and for their public image.

**Between the Watchtower and the Workshop**

Expense, status, and the evaluation of observers demarcated a relatively novel community of "technical astronomers." Their work was contrasted with that of the humble. Like other observatories, Lord Rosse's giant reflector, the "Leviathan" at Parsonstown in Ireland, received streams of fascinated sightseers. In 1854 Airy told a female amateur that "if a night is fine, it is wanted for [Rosse's] use or for the use of professional astronomers. If it is not fine, it is of no use to any body ... the appropriation of the telescope on a fine night to any body but a technical astronomer is a misappropriation of an enormous capital of money and intellect which is invested in this unique instrument" (Airy 1896, 221-22). [...]

The history of the personal equation is marked by astronomy's nineteenth-century legitimation crisis. In 1851 Mitchel staged a demonstration of the accuracy and efficiency of his galvanic chronometry when the American Association for the Advancement of Science visited Cincinnati. The simplicity and permanence of the astronomical enterprise, and the identity of all apparently variant individual observers, formed Mitchel's theme:

> *Let it be remembered that the astronomer has ever lived, and never dies. The sentinel upon the watchtower is relieved from duty, but another takes his place, and the vigil is unbroken. No - the astronomer never dies. He commences his investigations on the hill-tops of Eden - he studies the stars through the long centuries of antideluvian [sic] life. The deluge sweeps from the earth its inhabitants, their cities, and their monuments; but when the storm is hushed, and the heavens shine forth in beauty, from the summit of Mount Ararat the astronomer resumes his endless vigils. (Mitchel 1850, 5.)*

Astronomers seemed to be isolated observers on their watchtowers, but they lived as managers of mathematical workshops. It seemed necessary to minimize the mechanization of observation in order to preserve the astronomer's empiricist prerogative and win public support. But this support was needed to fund the expensive technology upon which astronomy's standing depended. [...]

This machine needed a history which differentiated itself from the mythical empiricism of the watchtower. Mitchel used the watchtower image to summon up the continuity of astronomical records and the invulnerability of the observatory to outside interest, whether in the form of political strife or more mundane perturbation. Even the architectural figure to which Mitchel made reference was becoming outdated. The last tower observatory was probably that built at Bogota in 1802. Instead, the fashionable new model had a central dome in which the telescope took pride of place, situated firmly on massive piers and supported with rooms for the subsidiary staff of mechanics, calculators, and observers under the gaze of the observatory manager.

# 3. The Coproduction of Astronomical Knowledge and Colonial Powers

# Paramatta Observatory and the Colonial Mastery of Australia

In : *Simon Schaffer, “Keeping the Books at Paramatta Observatory”, in David Aubin, Charlotte Bigg and H. Otto Sibum (eds.), The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture. Durham : Duke University Press, 2010.*

[Lord] Brisbane and many of his colonial colleagues were pupils of Edinburgh masters in exact science, economic reform, and evangelical piety. Promotion of “agrarian patriotism” owed much to Scottish accounts of colonial economy. Enlightened sciences could help global government. At university the future governor [of Australian penal colony, in New South Wales] sat at the feet of eminent political economists, preachers, and astronomers, and “would leave gay society to make his observations” at a nearby instrument maker’s workshop. In an oft-told anecdote of spiritual conversion, Brisbane described his early realization of precision astronomy’s virtues while facing shipwreck on a colonial military expedition. His accuracy allegedly saved the vessel: “Providential interference saved us. I reflected that in the course of my life I might often be placed in a similar situation in a ship where the reckoning was not accurately kept.” Spiritual and economic accounts reminded Brisbane how to run the world from a distance. “If Galileo laboured successfully in the bringing the most distant heavenly bodies near to us, our countryman Watt has no less immortalized himself by bringing the most distant countries near to us.” Steam engineering accelerated British productivity and allowed British cotton to undercut Indian markets: similar economics would work in Australia. In Brisbane’s spiritual diary, the quick tallying in a chapel pew of the future population of the British Empire took him to reflections on the inhabitants of other planets, thence to divine grace. Critics saw a fatal gap between the governor’s observatory work and his administrative duties, but Brisbane saw the intimacy of accounts of heavenly government, colonial administration, and individual salvation.

Paramatta observatory had to be assimilated to this disciplinary regime to prevent its assimilation by parasites and wasters. According to Herschel’s memo on the observatory, “a new country peopled by a most energetic race of men,” emancipists, and currency would soon degenerate into “endless litigation” without firm boundaries. A reformed observatory would help beat the bounds. Brisbane backed a trigonometric survey when the Colonial Office suggested a meridian arc be laid down in New South Wales in 1824. The economic meaning of secure observatory techniques was obvious. Herschel saw stellar surveys as “one of those great masses of scientific capital laid up as a permanent and accumulating fund.” Here astronomical work was fantasized as capitalist enterprise, with prudent ledgers, patient accountants, disciplined observers, well-oiled machinery, and precision values as sources of profit. Simon Werrett shows elsewhere in this book how serf-based feudal systems provided resources for the tsarist political technology of Struve’s Pulkovo. In similar manner, colonial observatories were elements in imperial systems of government and in the imagination of what empire might mean. […]

Colonial projects organized numbers in arrays which displayed and made ways of governing. One Scottish astronomer praised Brisbane because “through his munificence British science was made co-extensive with British dominion.” Precise celestial knowledge had long been a tool of colonial power, a sign of that power’s legitimacy, and a rationale for its exercise. The colony in New South Wales had a history entangled with astronomical enterprise. William Dawes, astronomer on the First Fleet in 1788, set up a short-lived observing station overlooking the new settlement. Royal Society committeemen, led by the astronomer royal, recalled past British naval expertise in astronomy as part of their campaign to get funds for new survey and longitude projects in the South Seas. Exchanges between the Polynesian priest-navigator Tupaia and British mariners were crucial in enabling their journeys, then used to judge Polynesian cultural development by the standards of European astronomical history. These judgments offered precedents for violent denial of rights to Aborigines in the terra nullius of Australia by European surveyors who reckoned that its inhabitants lacked accurate notions of space and time. These expeditions got their meaning from accounts of astronomy's past and mod- ern imperium. Such accounts were a passion of the master historian of early-nineteenth-century observatory sciences, Alexander von Humboldt, whose public enterprises matter so much in this book. Humboldt's stories linked geopolitics with geophysics through a subtle account of the classical progress of the astronomical sciences in Europe and the New World. His understanding of Mayan and Aztec astronomical knowledge helped to place these territories in narratives of socioeconomic development, while his understanding of European observatory sciences helped place the Americas in narratives of physical development. Humboldt's contemporaries pursued similar programs: in principle, histories and maps could be produced worldwide.

Astronomy became a "pattern science" for nineteenth-century tales of scientific and political development. "Epoch," "period," "revolution," and "zenith" became historians' terms. Some wrote of an "astronomical conception of society." Observatory techniques were used to exemplify utilitarian governance and rationalist politics. Charles Dickens's dark satire of panoptic calculation imagined "an astronomical observatory made without any windows" where "the astronomer within should arrange the starry universe solely by pen, ink and paper." […] When Herschel proposed reform of the newfound southern constellations, his friend Thomas Maclear from the Cape Colony agreed that "the present assemblages are a hindrance in observatory book-keeping." Some saw the overhaul as "a Reform Bill for the stars, improving the representation of the skies, arranging the boundaries according to their star population."

Savants cultivated surveys, censuses, and reviews to manifest good order. Measures of seconds pendulum lengths worldwide would fix the earth's shape and reform national metrology. Surveys of magnetic force and direction would reveal laws of compass behavior. Censuses of double stars would provide measures of stellar parallax, proper motions, and the universality of gravitation. With the right hardware astronomical rule might even reach distant nebulae and star clusters. The new observatory sciences depended on visionary maps of a civilized world. Their data were incorporated in reformist almanacs by metropolitan outfits such as the Society for the Diffusion of Useful Knowledge (SDUK) to teach number, weight, and measure. In New South Wales, where print was effectively a government monopoly, settlers used almanacs to cope with the continent's unfamiliar weather, seasons, and geography. Against disreputable currency interest in astrological lore and sensational gossip, the colonial regime encouraged newfangled statistical calendars and weather surveys. Brisbane set up the colony's first meteorological review from Paramatta, extending west of the Blue Mountains and south to Van Diemen's Land. [...] John Leslie, a controversial natural philosophy professor from Edinburgh, offered Brisbane his own meteorological kit: "a general survey would immortalize you."

Many public observatories with similar layout and hardware were founded in these few years, at Edinburgh (1818), the Cape (1821), Cambridge (1823), and elsewhere. […] Colonial enterprise nourished these projects. Herschel believed that “a perfect knowledge of the astronomy of the southern hemisphere is be- coming daily an object of greater practical interest now that civilization and intercourse are rapidly spreading through those distant regions — that our colonies are rising into importance.”

Paramatta’s stock was designed to make these projects into a permanent part of the penal colony’s science. […] Paramatta’s layout, with securely separate sites for transit and mural instruments, clocks installed centrally, and the neoclassical design favored by meridian observers, testified to Brisbane’s aims. Transit observations by the received “eye and ear” method demanded that the observer listen to the clock while watching a star’s image cross the wires in the eyepiece, checking the pendulum beats as each wire was passed. Workers at the mural circle and the transit instrument had to be kept apart so that the noise of the clock would not disturb this crucial ritual. At some observatories transit observations were made before dinner, “lest over-anxiety interfere with the salutary function of digestion.” Columns on Brisbane’s printed forms were then supposed to discipline data entry. Space was left for pressure, temperature, refraction, clock-rate, and each microscope reading. But the meridian system was a judgmental ideal—as the workers at Paramatta found out the hard way, it was tough to realize. It relied on local improvisation never easily accounted. Entries could not easily be made at the eyepiece, a basic puzzle for observatory accountancy. Rümker explained that “the observer who is more settled and less agitated, [even] if he can write down his observations without leaving his Transit, cannot do this there satisfactorily in his book with ink, at all events he will do it more slovenly, particularly if attending mural circle and transit at the same time.” Two expert observers were needed, working simultaneously on each observation, then entering data the next day into the books. The surplus value of an observatory was proverbially proportional to the number of staff above two. In his memo on Paramatta, Herschel urged that “no astronomer can possibly do his duty as a public servant without an assistant who should be an excellent and practised astronomical computist.” […]

Observatories cultivated an image of perfected instruments and of a well-aligned workforce run from metropolitan workshops and colonial offices by machine-like delegates regulated by error analysis and reduction. Airy argued that “the principle of division of labour” should govern them. To Herschel, “every astronomical observatory which publishes its observations becomes a nucleus for the formation around it of a school of exact practice.” But in the meantime, behind their workplaces’ façades, meridian astronomers tried converting messy artfulness into imposing castles in the sky.

# Colonial Legacies, Social Struggles and Technical Progress in Hawaii

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**Executive summary**

Maunakea, the proposed site of the Thirty Meter Telescope (TMT), is a lightning-rod topic for Native Hawaiians, Hawaiʻi residents, and the international astronomy community. In this paper we — Kanaka ʻŌiwi (Native Hawaiian) natural scientists and allies — identify historical decisions that impact current circumstances on Maunakea and provide approaches to acknowledging their presence. Throughout this paper, we expand dialogue and inform actions utilizing a native Hawaiian concept known as kapu aloha, which "helps us internationalize our thoughts, words and deeds without harm to others". Our aim is to provide an Indigenous viewpoint centered in Native Hawaiian perspectives on the impacts of the TMT project on the Hawaiian community.

In this paper we provide a summary of the current Maunakea context from the perspective of the authors who are trained in the natural sciences (inclusive of and beyond astronomy and physics), the majority of whom are Native Hawaiian or Indigenous. We highlight three major themes in the conflict surrounding TMT: 1) physical demonstrations and the use of law enforcement against the protectors of Maunakea, nā kiaʻi o Mauna-a-Wākea; 2) an assessment of the benefit of Maunakea astronomy to Native Hawaiians; and 3) the disconnect between astronomers and Native Hawaiians. We close with general short-and long-term recommendations for the astronomy community, which represent steps that can be taken to re-establish trust and engage in meaningful reciprocity and collaboration with Native Hawaiians and other Indigenous communities. Our recommendations are based on established best principles of free, prior, and informed consent and researcher-community interactions that extend beyond transactional exchanges. We emphasize that development of large-scale astronomical instrumentation must be predicated on consensus from the local Indigenous community about whether development is allowed on their homelands. Proactive steps must be taken to center Indigenous voices in the earliest stages of project design.

To this end, we provide seven major recommendations for ongoing and future astronomy research on Maunakea and other sacred Indigenous lands:

1.Immediately halt Thirty Meter Telescope progress and work with Native Hawaiian cultural knowledge holders to restart dialogue with the goal of obtaining informed consent. Construction cannot proceed without consent from Native Hawaiians; the astronomical community must be willing to accept that a "no deal" outcome may ultimately be requested by Native Hawaiians or the State of Hawaiʻi.

2.Establish a Cultural Impact Assessment process that is viewed as legitimate by standards determined within the Native Hawaiian community.

3.Require that every observational astronomer learn Hawaiian history and culture, regardless of whether they are physically present in Hawaiʻi.

4.Establish equitable, iterative dialogue with Native Hawaiians.

5.Invest in support for Native Hawaiian astronomy students.

6.Develop astronomy-specific ethical guidelines and accountability structures.

7.Funding agencies must hold PIs [Principal Investigators] accountable for the research environments they create.

**Background**

Maunakea is Kanaka ʻŌiwi ancestral land. The Mauna—also known as Mauna Kea and Mauna-a-Wākeai—is one of the most sacred places in the Hawaiian Islands, and stands as a place of worship, an ancestor to Native Hawaiians, and a piko (umbilicus, or site of convergence) for the lāhui Hawaiʻi (Hawaiian nation) […] KūKiaʻi Mauna is a Native Hawaiian hui (collective) whose goal is to protect Maunakea by preventing construction of the Thirty Meter Telescope (TMT) on the summit. […] These events have catalyzed state-wide and world-wide movements centered on a fundamental question: do Indigenous people have the power to decide what happens to their own homelands? […]

Tensions between Native Hawaiians and astronomers arise from Maunakea's status as one of the best places in the world for ground-based astronomy. The pristine atmospheric conditions present on Maunakea has led to the construction of 13 telescope complexes, which produce the majority of data collected in the Northern Hemisphere. Yet astronomy's presence on Maunakea has directly resulted and benefited from the United States (U.S.) takeover of Hawaiʻi and appropriation of the personal lands of the last reigning monarch of the Hawaiian Kingdom (crown lands, or "ceded lands"). Current efforts to protect Maunakea have generated renewed attention around the United States' role in the illegal overthrow of Queen Liliʻuokalani in 1893, when the U.S. Minister and military representatives conspired with American and European businessmen to persuade armed U.S. forces to invade the sovereign Hawaiian Kingdom. These unlawful actions towards an independent nation established a provisional government that eventually transitioned into the State of Hawaiʻi in 1959, and led to the taking of Hawaiian lands, cultural resources, and self-determination with long-lasting detrimental impacts on Hawaiian political, social, economic, and value systems.

Dispossession of Native Hawaiians from their homelands remains a primary issue threatening Hawaiian identity and well-being, and the separation of Hawaiian cultural practitioners from spaces such as Maunakea heightens this intergenerational trauma. The relationship between institutional astronomy and Native Hawaiians has been unbalanced and prioritized research since the construction of the first telescopes in the late 1960s, and uneven dynamics on the Mauna are encapsulated in the viewpoints held by some members of these communities. Many astronomers who use data from telescopes on Maunakea view their work as inherently nonviolent and in the common interest of humanity. In contrast, many Native Hawaiians assert that their Indigenous rights to self-determination are under siege, while astronomers directly benefit from the disenfranchisement of Hawaiian […].

Native Hawaiians have the right, as expressed in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), "to self-determination." Of particular importance in the UNDRIP framing of

Indigenous rights is the requirement that projects receive explicit, informed, and ongoing consent from Indigenous peoples—we emphasize that this requires more than involving Indigenous individuals in consultation. The recent developments on Maunakea, as well as the history of legal challenges to TMT and earlier endeavors (e.g., the Keck Outriggers), demonstrate that TMT currently lacks consent from the local Indigenous community. As such, the TMT project must reconsider its position: is there a path forward, or should they withdraw and consider an alternate location? Though these questions are difficult, astronomers must consider their obligations to the Indigenous people of Hawaiʻi if they hope to do astronomy on Maunakea in an ethical and non-violent manner. Native Hawaiian cultural knowledge holders, including those not affiliated with the fields of astronomy, must consent — not merely be consultants to — further development. Inherent in the consent process is the ability to lead in decision-making. […]

**Distinct Worldviews**

The controversy surrounding astronomy on Maunakea, including the TMT process, must be positioned within a historical context. Frustrated communications result in part from fundamental differences between the worldviews held by some astronomers (“mainstream science”) and those held by Native Hawaiian cultural practitioners (“Indigenous knowledge systems”). Indigenous nations and peoples have explored the world and universe for far longer than western astronomers have had telescopes; while these knowledges are not uniform, Indigenous knowledge systems build upon a deep connection with the land, the water, and the sky through consistent observations. These systems utilize axioms that differ from traditional western science, and as a result may center different values than those of mainstream science.

The public prioritization of the goals, values, and concerns of professional astronomers over those of the Indigenous inhabitants of Hawaiʻi insinuates that Native Hawaiian viewpoints on Maunakea are unimportant, or that only certain Native Hawaiian views are acceptable. As an example, portrayals of Native Hawaiians as “anti-science” have long been used in popular discourse regarding the movement for Maunakea: While some astronomers portray their science as “universally beneficial” to humanity, kiaʻi who stand in kapu aloha are portrayed as impediments to progress. To illustrate this, Native Hawaiian scholar Iokepa Casumbal-Salazar writes:

*One scientist told me that astronomy is a “benign science” because it is based on observation, and that it is universally beneficial because it offers “basic human knowledge” that everyone should know... Such a statement underscores the cultural bias within conventional notions of what constitutes the “human” and “knowledge.” In the absence of a critical self-reflection... the tacit claim to universal truth reproduces the cultural supremacy of Western science as self-evident. Here, the needs of astronomers for tall peaks in remote locations supplant the needs of Indigenous communities on whose ancestral territories these observatories are built... “Why would anyone oppose astronomy? Why are Hawaiians standing in the way of progress?” they ask. “Can’t astronomers and Hawaiians coexist on the mountain?” These frames decontextualize the historical relations in which the TMT controversy has emerged and dehistoricize the struggle over land and resources in Hawaiʻi by vacating discourse on settler colonialism in favor of problematic claims to universality. When the opposition to the TMT is misrepresented as an arbitrary disregard for science, Hawaiians appear unreasonably obstinate.*

The characterization of Hawaiians as, e.g., “backwards” and “[unmoved] by logic” is discriminatory language, and should be interrogated as such when this language emerges from institutions of higher education. The 2015 demonstrations were described as “attack on TMT by hordes of Native Hawaiians who are lying about the impact of the project... and who are threatening the safety of TMT personnel.” A tenured faculty member at the University of Hawaiʻi wrote in 2015 that “in no way should we go back a few centuries to a stone age culture, with a few (illegitimate) Kahunas telling everyone how to behave.” While these statements were denounced by pro-TMT groups, these types of comments continue to emerge from frustrated tenured physics and astronomy faculty. This sends the message that astronomers on Maunakea, and the astronomy community at large, are dismissive of raised concerns and see Native Hawaiians and supporters as subhuman. Further, because these raucous ideals typically come from senior faculty who are in positions of power and authority, they act to silence and alienate Indigenous astronomers, who are overwhelmingly in junior positions.

**Do Native Hawaiians significantly benefit from astronomy on Maunakea?**

Within the last few years, a number of successful Hawaiian-centered and Hawaiian-led education programs have been piloted at the Maunakea Observatories and ʻImiloa in an attempt to push a “collaboration with integrity” model that combines Indigenous knowledge systems with mainstream science .However, this outreach is targeted at a select few; the lack of outreach programs in marginalized rural communities only compounds the decades-long view that the University and state of Hawaiʻi and astronomers are unresponsive to community concerns regarding the development and management of the Maunakea summit. Programs such as A Hua He Inoa are more effective at bringing Hawaiian language to the global astronomy stage than as outreach and service in alignment with Native Hawaiian and local needs, unevenly distributing their benefits. The conflict over TMT construction on Maunakea highlights the pressing need for reciprocal dialogue with the Native Hawaiian community. Yet instead of engaging, the University leadership and astronomy community have stepped back to allow state and county law enforcement agencies to intervene on behalf of private astronomical interests. Moving forward, cultural programming and other community-based efforts should center on Hawaiian values, including aloha ʻāina, and be conducted with meaningful and iterative dialogue about the issues that are tearing at the social fabric of Hawaiʻi and beyond. A substantial amount of work is required to establish trust, develop content, and produce accountability, and significant funding must be allocated to meaningfully facilitate this work.

Both in the Hawaiian Islands and on a broader scale, astronomy education and public outreach relies on narratives that curiosity about space is a uniting “human” experience (e.g., “...that is what makes astronomy beautiful. To study something—not because we’re looking to gain anything in particular, but out of sheer curiosity—is what makes us human”). However, these notions are antithetical to the colonial behaviors the astronomy community has engaged in and reinforced by denying the humanity of Native Hawaiians for the past 50 years. In this context, outreach efforts claiming a shared humanity are not only unconvincing, they ultimately undermine the perception of astronomers’ integrity. Critically, astronomy funding is dependent on this perception: “the generous public support for NASA’s astronomy research stems largely from astronomers’ success in making the fruits of their research accessible and appealing to many people”. Indeed, astronomers enjoy being able to share the results of their research and many now engage in education and public outreach as a central career path, evidence of broad support for these efforts within the astronomy community. However, astronomers wishing to share the results of their scientific efforts cannot expect to have receptive audiences indefinitely: millions of people across the world have witnessed our elders being arrested in July 2019 on social media and major news outlets. These visual records of astronomer complicity with state violence have indelibly marred astronomy's claims to a shared humanity. If astronomers wish to return to sharing the results of their research with a receptive public, and to the opportunities for public support (both intangible and financial) they have previously enjoyed, they must find a path forward that centers the legitimate concerns of Native Hawaiians.

**Conclusion**

The situation on Maunakea provides an opportunity to examine our relationships, especially among the intersecting groups of Indigenous people and the scientific community. In this paper, we have outlined how the potential construction of the Thirty Meter Telescope is a point of extreme tension. Protectors at the base of Maunakea remain steadfast in their commitment to prioritize the well-being of land above their own physical safety—so much so that some are prepared to die in order to stop TMT construction. Demonstrations in solidarity are continuously being held across the state of Hawaiʻi and around the world. Given that there is no Indigenous consent for TMT, the project must halt construction, reconsider its position, and restart the process of engaging in reciprocal dialogue with Native Hawaiians. Crucially, the TMT project must enter into these negotiations willing to accept the choice made by Hawaiʻi's Indigenous people, even if this means that the project must withdraw and consider an alternate location.

The astronomical community must take this conversation very seriously. At this moment, we have an opportunity to shape the future of the field, and to work towards a practice of science that is truly ethical—one that upholds human and Indigenous rights. We are at a point in history where the construction of large-scale scientific instruments requires re-evaluation of the way in which the field of astronomy engages with local and Indigenous communities. Our present actions will inform the processes through which we construct future instrumentation—thus, we must carefully consider the values we hope to promote. The recommendations we outline can serve as first steps towards building reciprocal and equal relationships between astronomers and the Indigenous people on whose land they work. Ethical science is predicated on and informed by the values and morals of society, including those that may be beyond Western traditions. In upholding the core Hawaiian values of kapu aloha and aloha ʻāina in our practice of science, we can reaffirm our commitment to an ethical scientific practice.