7

Mapping the Heavens

Astronomy rather than natural philosophy was *the* eighteenth-century science. It was the science that set the standard to which others aspired. The phenomenal success of Newton's *Principia* in setting the study of celestial motions on an apparently secure and certain mathematical footing had made astronomy the archetypal science. Newton's triumph in reducing the night sky's complexities to a simple law set the standard for achievement throughout natural philosophy. There were other reasons for astronomy's high status as well. As Europe's maritime nations squabbled over conquered territories in the New World and the Indies, mastery over the seas became crucial. Solving the problem of longitude—to be able to know one's position on the high seas with precision—was essential and astronomy seemed to be the key. Observatories were founded to map the sky with increasing accuracy. Expeditions set out to study celestial phenomena from outposts of empire—with the aim of positioning those outposts more securely on the terrestrial globe. William Herschel's discovery of Uranus demonstrated the power of new telescopes to push back the frontiers of the unseen. Herschel's ambition was to produce a natural history of the heavens—to produce a map of the skies that charted each celestial object and put it securely in its place. Astronomy's high status and evident utility at the end of the eighteenth century meant that it was one of the few sciences to attract substantial state patronage. As such, it was a fruit ripe for the picking to ambitious young radicals as the new century commenced.

In England, astronomers were at the forefront of opposition to Sir Joseph Banks's corrupt and despotic rule (as they saw it) over the Royal Society and English science. Banks had his fingers tightly wrapped around the government's purse strings and astronomers were determined to get a piece of the action. This was what lay behind the foundation of the Astronomical Society in 1820. With George Bidell Airy's appointment as astronomer royal in 1835, the Greenwich Royal Observatory became the focus of an industrialized science. Greenwich was reorganized as a factory system with banks of computers (of the old-fashioned human variety) toiling away producing numbers in industrial quantities. One of the projected functions of Charles Babbage's ill-fated calculating engines was to be the production of astronomical tables. Other observatories throughout Europe emulated Airy's schemes at Greenwich. Far from being ivory towers, nineteenth-century observatories were at the center of industrial culture. With the advent of the electric telegraph they could be linked together as well. Simultaneous telegraphic observations of celestial events across Europe led to ever more accurate determinations of those observatories' place on Earth. As an afterthought, they gave the world the Greenwich time signal as well. These were in many ways the model institutions of nineteenth-century science.

Not only could astronomy provide an accurate map of the Universe, it had the capacity to provide a chart of its history as well. Looking through a telescope at the heavens was like looking back through time. Clues to the origins of the Solar System could be found by searching the night sky. The nebular hypothesis was one of the most popular—and most controversial—constructions of nineteenth-century science. According to the hypothesis, the Solar System in its present state had developed through the operations of natural law from a cloud of gaseous matter just like the nebulae that Sir William Herschel had glimpsed through his telescopes. The nebular hypothesis—the term was coined by the polymathic William Whewell—bore the imprimatur of no less a figure than the illustrious Laplace, who had speculated on planetary origins in his *Exposition du Système du Monde*. In the hands of popular expositors such as Robert Chambers and John Pringle Nichol, the nebular hypothesis was a powerful argument in favor of a progressive, evolving Universe. Evolution in the heavens was convincing evidence of evolution on Earth and an inducement to favor social progress as well. Proving (or disproving) the nebular hypothesis was one of the many motives behind Lord Rosse's construction of his massive telescopes in an effort to determine whether nebulae were truly gaseous or not.

While laboratory physicists looked to Europe's observatories as models of how to organize their own fledgling institutions, astronomers picked up on the latest laboratory technologies as well. Astronomers turned in particular to photography and spectroscopy to provide them with new tools to analyze the heavens. Photography, according to its supporters, could provide new standards of objectivity in the representation of celestial phenomena. It replaced the subjective vagaries of the naked eye and the draughtsman's pen with the cold certainties of light and chemistry. It cut out the middleman as well. Astronomers no longer needed to depend on the whims of painters and engravers. With photography, astronomical objects could draw pictures of themselves. Spectroscopy opened up the possibility of resolving heavenly bodies into their constituent elements. The Sun's spectrum could be compared with that produced by any number of terrestrial elements to give a definitive breakdown of its makeup. The introduction of these new technologies meant that astronomy could take place on a tabletop as well as through ever more massive telescopes. It also made what had been a quintessentially observational science subject to the disciplines of experiment. Astronomical laboratories had to be transportable as well. Astronomers trotted the globe with their apparatus, chasing and capturing the latest celestial apparitions wherever they appeared.

One question that ran through nineteenth-century astronomy is still very much alive today. Victorians were fascinated by the possibilities of extraterrestrial life. William Herschel had speculated publicly about the existence of life on the Moon and even in the Sun. He suggested sunspots might be windows in the hot exterior through which might be glimpsed the cool interior where the Sun's inhabitants could be found. For many Victorians this was an issue with real theological significance. Some commentators argued that since there were indisputably other worlds—the Moon, planets, and stars—they must be inhabited since otherwise their creation could have fulfilled no purpose. Others countered that the existence of life on other worlds would rob the Christian revelation of its uniqueness. By the end of the century, the question had moved beyond the abstract. The rise of new communication technologies like wireless telegraphy raised the possibility of actually communicating with the mysterious inhabitants of Mars or the Moon. Science fiction writers such as Jules Verne and H. G. Wells speculated concerning the possibility of travel to the stars. Astronomers such as Percival Lowell and Giovanni

Schiaparelli claimed to have observed canals on Mars—conclusive proof of extraterrestrial life.

Astronomy was transformed during the course of the nineteenth century, setting the standard for collaborative, multidisciplinary science on a massive scale. Observatories had never really been lonely watchtowers where solitary sentinels scanned the skies, and by the nineteenth-century observatories were centers of intensive mass labor. Airy at Greenwich imposed the division of labor as ruthlessly as any Victorian mill owner. Astronomy combined a reputation as the archetypal exact science—mathematical and abstract—with an enviable capacity to draw on state patronage. Astronomy mattered for imperial governance. Astronomy demanded resources on a massive scale as well. Its practitioners needed access to glassmakers, instrument makers, electricians, mathematicians, accountants and bean-counters, and a host of others. Managing an observatory was very much like managing a factory and needed the same kinds of disciplinary surveillance. Men such as Airy and Adolphe Quetelet in Belgium and Johann Franz Encke in Berlin needed to deploy and manage their forces efficiently not just in their observatories but across whole continents to achieve their goals. As astronomers taught physicists valuable lessons about managing large institutions, so physicists provided astronomers with a whole panoply of new resources for studying the stars. The division between the disciplines was increasingly fluid as personnel, practices, and resources passed back and forth between the one and the other.

Industrial Astronomy

Nineteenth-century astronomy was very far from being the solitary, individualist pursuit of popular imagination. For much of the previous century astronomy had increasingly been recognized as an essential adjunct to maritime supremacy and prowess. State-supported observatories were established in England, France, and the German lands not because of some abstract urge to further knowledge of the heavens but because that knowledge was recognized as having real strategic significance. Accurate maps of the stars were needed to be able to accurately position ships at sea. Astronomy was widely regarded by many—John Harrison and his clocks notwithstanding—as the real key to solving the problem of longitude. In England by the beginning of the century, astronomical endeavors were the subject of substantial state patronage. The British Admiralty, in particular, poured money into projects that were perceived as bolstering the navy's capacities to rule the waves. The primary function of the Royal Observatory at Greenwich, established by Charles II in 1675 with the aim of extending maritime power very much in mind—and other, Continental establishments—was not to make new astronomical discoveries, but to continually hone and refine knowledge of the exact position of known objects in the sky. It was a business that needed routine and careful management as much as innovation.

Partly as the result of the significant amounts of state largesse channeled through the British Admiralty into astronomy, the discipline was one that early attracted the reforming attentions of zealous Young Turks. The Board of Longitude, which under the aegis of the Admiralty oversaw the publication of the *Nautical Almanac* with its charts of astronomical data, was regarded by them as being in hock to the corrupt cronies of Sir Joseph Banks, who, through his long-standing presidency of the Royal Society, maintained a stranglehold over English science. The foundation of the Astronomical Society in 1820 was a direct challenge to Banks's authority—and one that he strenuously opposed. It was an effort to establish an alternative power base on the part of reforming astronomers. The Astronomical Society's reforming stalwarts wanted to have their say in the distribution of the Admiralty's coppers. They saw themselves as disciplined, meritocratic, and vocationally minded gentlemen who could rise to the challenge of putting English astronomy on a proper, businesslike footing. They saw their opponents as amateurish dilettantes, wedded to effete aristocratic interests. Leading members of the Astronomical Society—such as Francis Baily, John Herschel, and Sir James South—played a leading role in efforts to reform the Royal Society following Banks's death in 1820.

Business was the model for the Astronomical Society's cadres of reformers. Many of its founders had close links with the City. Francis and Arthur Baily, along with Benjamin Gompertz, were stockbrokers. Charles Babbage was the son of a wealthy banker. In their view, the foundation of astronomy—like the foundation of good business—was precise measurement and exact calculation: in a word, good bookkeeping. Astronomy, like business, both encouraged and required a habit of exactitude founded on discipline of self and of others. As such, the central function of astronomy was to produce more accurate tables of the skies. Rather than indulging in theoretical speculation, the new society's members were to take on the task of placing their discipline on a sound base of reliable calculation. The key to progress in astronomy as in financial speculation was the elimination of error, and that was best achieved by placing procedures on a proper and transparent footing. As Baily remarked of Babbage's projected calculating engine (and with both accountancy and astronomy in mind), "the great object of all tables is to save time and labour, and to prevent the occurrence of error in various computations."[1] Herschel concurred that good nautical computation "would consist in approximating as nearly as possible to that pursued in the observatory, and divesting it of those technicalities which are not only puzzling to learn, but which really act as obstacles to its improvement by placing it in the light of *a craft and a mystery*."[2]

That ideal was soon in the process of being realized at Greenwich's Royal Observatory, following the appointment of Cambridge senior wrangler George Bidell Airy as astronomer royal in 1835. Like many of the mill owners and Victorian factory managers with whom he had so much in common, Airy was very much a self-made man. Born in 1801, he entered Cambridge in 1819 and graduated as senior wrangler before being elected to a fellowship at Trinity College. His mathematical and astronomical interests aligned him at Cambridge with the Analytical Society's reforming clique—he was a student of the meliorist reforming don (and later bishop of Ely) George Peacock. After a stint in the Lucasian Chair of Mathematics, he was appointed in 1827 as Plumian Professor of Astronomy at the university and director of the recently reestablished university observatory. In a foretaste of things to come, he managed to persuade the university authorities to substantially increase the salary that came with the post. He repeated the trick when he was offered the post of astronomer royal. Unlike his predecessors, Airy did not intend to combine the post with a lucrative ecclesiastical living and demanded the extra cash to make up the difference. He ruled the roost at Greenwich for the next half-century, transforming it into the epitome of nineteenth-century observatories.

Airy imposed a "factory mentality" on the Royal Observatory. Work there was organized according to a strict hierarchy. At the top of the tree, of course, was Airy himself. Beneath him in the chain of command were his trusted lieutenants, Cambridge graduates who looked after the day-to-day management of the institution. Lower in the pecking order were the "obedient drudges"—the computers and observers who did the work. They were typically appointed in their midteens and trained exclusively to carry out particular specialized tasks or calculations. They were

[1]Quoted in W. Ashworth, "The Calculating Eye," 415.

[2]Quoted ibid., 431.

selected straight from school on the basis of competitive examination and typically left to become City clerks within ten years. Like contemporary mill owners and other enthusiasts for the factory system, Airy was well aware of the advantages of juvenile labor—it was easily trained, malleable, and above all, cheap. Under Airy's single-minded direction, Greenwich became a veritable production line of astronomical observations and calculations, churned out in published form on a regular and reliable basis. The observatory's brief, in Airy's view, was not "watching the appearances of the spots in the sun or the mountains in the moon, with which the dilettante astronomer is so much charmed . . . it is to the regular observation of the sun, moon, planets, and stars (selected according to a previously arranged system), when they pass the meridian, at whatever time of day or night that may happen, and in no other position; observations which require the most vigilant care in regard to the state of the instruments, and which imply such a mass of calculations afterwards, that the observation itself is in comparison a mere trifle."[3]

Other European observatory managers concurred with Airy's vision of how astronomy should be organized. Indeed, the superior managerial skills of Continental observatory directors was one of the factors English reformers held up as necessitating a thorough overhaul of native practices. The work of the German astronomer Friedrich Wilhelm Bessel was celebrated by Herschel as "the perfection of astronomical bookkeeping."[4] When the Göttingen-educated astronomer Johann Franz Encke (discoverer of the eponymous comet) became director of the Berlin Observatory in 1825, he initiated a thoroughgoing reform of the institution. With the support of the influential Alexander von Humboldt he lobbied successfully for more funds, better instruments, and a new building for his establishment. Under his direction the Berlin Observatory acquired an enviable reputation for the quality and accuracy of its star catalogues. Similarly, François Arago in France and Adolphe Quetelet in Brussels made their reputations as observatory directors largely on the basis of their managerial talents. Like Airy, both instituted regimes at their observatories that sought to replace the idiosyncrasies of individual observers with disciplined, instrumentalized, and routinized procedures. It was no coincidence that Quetelet's other claim to fame was as one of the founders of the science of "social physics." In his statistics, as in his astronomy, the aim was to eliminate variation and cultivate uniformity.

[3] G. B. Airy, "Greenwich Observatory," *Penny Cyclopaedia*, 1838, **11**: 442.

[4] Quoted in W. Ashworth, "The Calculating Eye," 429.

The controversy surrounding the disputed discovery of the planet Neptune in 1846 provides an instructive example of the priorities (and nonpriorities) of industrial astronomy. In late 1845, the diffident young Cambridge mathematician John Couch Adams approached Airy with the intriguing suggestion that, by calculating from hitherto unexplained observed perturbations in the orbit of the planet Uranus, he could predict the position of a new and previously unsuspected planet beyond Uranus's orbit. He had already shown his results to James Challis, Airy's successor as Plumian Professor and director of the Cambridge Observatory. Airy ignored Adams's suggestion that a search for the new planet in the predicted position might be a worthwhile proposition. In the meantime, the French astronomer Urbain Jean Joseph Leverrier had been carrying out his own calculations. Unlike Adams, he published his results and communicated his findings to a number of European observatories. On 25 September 1846, two days after receiving his communication, the Berlin astronomer J. G. Galle wrote to Leverrier, "The planet whose position you indicated really exists. The same day I received your letter I found a star of the eighth magnitude that was not recorded on the excellent Carta Hora XXI (drawn by Dr. Bremiker) . . . The observation of the following day confirmed that it was the planet sought."[5]

While Leverrier was lionized across Europe for his discovery, news leaked out in England that Adams had suggested the existence of this planet before Leverrier had, but that Airy and Challis had failed to act on his suggestion. The two men were pilloried in the press as a result. Airy was unrepentant, however. In his view, searching the skies for errant planets was no part of the Royal Observatory's remit. As he pointed out in another context to Greenwich's Board of Visitors, "the Observatory is not the place for new physical investigations. It is well adapted for following out any which, originating with private investigators, have been reduced to laws susceptible of verification by daily observation."[6] The observatory's primary function, he insisted, was the measurement and calculation of astronomical data for purposes of national utility. Intriguing as Adams's calculations might have been, it was not Airy's job to pursue them further. The regime at Greenwich was simply not designed to accommodate such haphazard undertakings. It was for Adams as a private individual to pursue his potential discovery with his own resources; it was not the business of state-sponsored industrial astronomy. Airy had been unimpressed,

[5]Quoted in *Dictionary of Scientific Biography*, s.v. "LeVerrier," 277.

[6]Quoted in A. Chapman, "Private Research and Public Duty," 122–23.

in any case, by the speculative nature of Adams's calculations. They took too much for granted for the hardheaded business astronomer. Too much speculation—in astronomy as in fiscal affairs—was something to be avoided. Like his friend William Whewell, Airy drew a distinction between the progressive sciences—those that were still engaged in the process of discovery—and the permanent sciences that were already fully worked out. In his view, only the permanent sciences (like his brand of astronomy) should be eligible for state support.

More expressive of Airy's views concerning the proper role of the Royal Observatory was his grand plan, developed during the late 1840s and early 1850s, to make Greenwich the central node in an international network of observatories. Using the rapidly developing new technology of electromagnetic telegraphy it would be possible, he argued, to send signals practically simultaneously between different observatories, marking the time at which prearranged observations of particular astronomical phenomena were carried out. The result would be vastly improved accuracy in measurements of those observatories' spatial location and hence in the astronomical data they produced. As the first step in this plan Airy, with the collaboration of Charles Vincent Walker, former secretary of the London Electrical Society, outlined a scheme to hook the Greenwich Observatory into the expanding national telegraph network with the aim of sending out a standardized telegraphic time signal throughout the nation. Airy argued to the Board of Visitors that the telegraph could be "employed to increase the general utility of the Observatory, by the extensive dissemination throughout the Kingdom of accurate time-signals, moved by an original clock at the Royal Observatory."[7] The vision was one where "we may soon expect to see every series of telegraph-wires forming part of a gigantic system of clockwork, by means of which, timepieces, separated from each other by hundreds of miles, may be made to keep exactly equal time, and the clocks of a whole continent move, beat for beat, together."[8]

Airy's and Walker's plan required unprecedented cooperation not only between Greenwich and Continental observatories but among a range of business interests as well. Telegraph and railway companies had to be convinced of the benefits that might accrue from the distribution of telegraphic time from the Royal Observatory. He had to persuade them

[7] Quoted in D. Howse, *Greewich Time and the Longitude*, 95.

[8] G. Wilson, *Electricity and the Electric Telegraph* (London, 1855), 59–60.

that his plan would turn Greenwich time into a universal commodity: "wherever we choose to stretch the telegraph-wires throughout the length and breadth of the land, we could set up a clock and read on its face the evidence of the care which the far distant astronomer bestowed on his observatory clock."[9] For Airy, beyond the virtue of embedding his observatory ever more firmly in the commercial life of the country, the ultimate payoff of the project was the production of an accountable network of observatories throughout Europe. As Walker explained to the *Times*, with the signaling system in place, "Mr. Airy at Greenwich, and M. Arago at Paris, will thus be able to fix a time when the eye of each shall be directed to the same star at the same time, and signal to each other as each wire [of the transit instrument] is passed."[10] In the United States, observatory managers such as William Cranch Bond at Harvard College Observatory and Truman Stafford at Chicago's Dearborn Observatory offered their commercial services in selling the true time to local jewelers and railway companies.

The establishment of the Greenwich time signal provides a fine example of the ambitions of industrial astronomy in action. Early nineteenth-century reformers, in England at least, regarded the state of astronomy as parlous. The science had been hijacked by a gaggle of effete, ineffective, and self-interested dilettantes who lacked the discipline to set astronomy on a proper footing and failed to appreciate its possibilities. Thus, astronomy's institutions required a thorough overhaul by hardheaded business astronomers who could impose the regulation the science needed. Observatories were to be regarded as factories dedicated to the production of numbers in industrial quantities. For fans of Adam Smith, it was self-evident that the best way of maximizing production in a factory was by a ruthless imposition of the division of labor. For astronomers such as Airy in England and Quetelet in Belgium, exactly the same lessons pertained to the conduct of observational astronomy. It was best carried out by hierarchically ordered and disciplined cadres of workers organized according to the division of labor. By midcentury, therefore, astronomy was a model of coordinated and collaborative science. In the interests of uniformity, observatory managers turned more and more to instrumentation and strict regimes of calculation and observation in order to minimize the impact of individual idiosyncrasies on their intellectual productions.

[9] Ibid., 63–64.

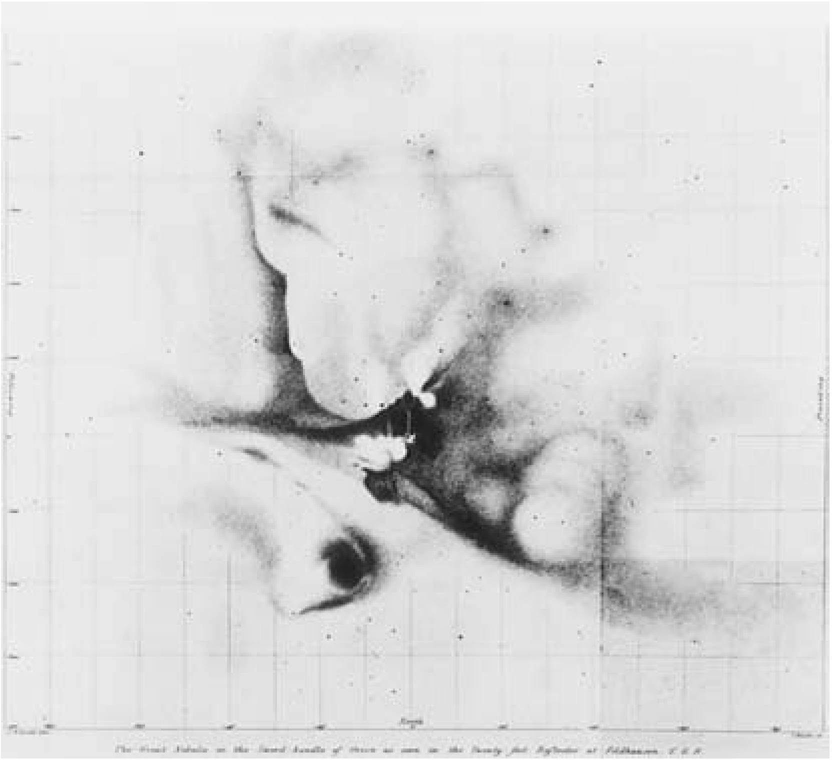
[10] Quoted in I. R. Morus, "The Nervous System of Britain," 466.

The Nebular Hypothesis

Other forms of astronomy that also fitted in well with Victorian ideals of progress developed during the first half of the nineteenth century. Following William Herschel's lead, astronomers scanned the sky with ever larger and more powerful telescopes. New astronomical discoveries—finding novelties in the night sky—were sources of considerable kudos. William Herschel, after all, had made his name and practically founded an astronomical dynasty with his spectacular discovery of Uranus. Telescopic astronomy gained additional significance during the first half of the nineteenth century as general perceptions of the Universe transformed. Eighteenth-century cosmologists typically regarded the cosmos as a timeless, changeless equilibrium. Their nineteenth-century inheritors more frequently visualized the Universe as being in a state of continuous progression. Telescopes that made it possible to gaze ever further into the cosmic vastness could therefore be regarded as doing far more than just providing a glimpse of the Universe's structure. They opened a window onto the Universe's past as well. Discussions on such topics had massive contemporary resonance. If the Universe was in a state of evolution, then maybe so was life on Earth. If progress in nature was a matter of natural law, then maybe social progress and emancipation rather than subservience to the status quo should be the norm as well.

One theory held particular resonance. The nebular hypothesis, as it was popularly dubbed, had an impressive pedigree. It was partially founded on William Herschel's compendious observations of nebulae—what seemed to be clouds of gaseous matter in space (figure 7.1). It carried the hallmark of Newtonian authenticity provided by the authority of the French physicist Pierre-Simon Laplace. As Herbert Spencer, one of the nebular hypothesis's many enthusiastic promoters, argued, "To have come of respectable ancestry is *prima facie* evidence of worth in a belief as in a person; while to be descended from discreditable stock is, in one case as in the other, an unfavourable index."[11] By that criterion, the nebular hypothesis came from distinguished stock indeed. Laplace had suggested in his *Exposition du Système du Monde*, at the close of the previous century, that nebulae might be regarded as the birthplaces of the stars and planets. In strict accordance with Newtonian mechanics, he envisaged a process whereby swirling clouds of cosmic gas gradually coalesced, first into clumps of matter around a slowly thickening central

[11] Quoted in S. Schaffer, "The Nebular Hypothesis and the Science of Progress," 132.



7.1 The Orion nebula as pictured by John Herschel.

mass, and finally into discrete satellites orbiting that glowing mass—just like the planets orbiting around the sun. To many, it seemed a persuasive scenario. Auguste Comte, the rising star of French philosophers, popularized and defended the idea as part of his developing creed of positive philosophy.

Nebulae came in all shapes and sizes. John Herschel in his popular volume *Treatise on Astronomy* for the best-selling Cabinet Cyclopaedia unreservedly credited his father for "the most complete analysis of the great variety of those objects which are generally classed under the head of Nebulae, but which have been separated by him into—1st, Clusters of stars, in which the stars are clearly distinguishable; and these, again, into globular and irregular clusters. 2d, Resolvable nebulae, or such as excite a suspicion that they consist of stars, and which any increase of the optical power of the telescope may be expected to resolve into distinct stars; 3d, Nebulae, properly so called, in which there is no appearance whatever of stars; which, again have been subdivided into subordinate classes, according to their brightness and size; 4th, Planetary nebulae; 5th, Stellar nebulae; and, 6th, Nebulous stars."[12] The "great power" of William Herschel's telescopes had revealed "an immense number of these objects, and shown them to be distributed over the heavens, not by any means uniformly, but, generally, speaking, with a marked preference to a broad zone crossing the milky way nearly at right angles."[13] About his father's speculations John Herschel was rather more circumspect. "The nebulae furnish," he remarked, "an inexhaustible field of speculation and conjecture." Most of them were made up of stars, he asserted, but "if it be true, as, to say the least, it seems extremely probable, that a phosphorescent or self-luminous matter also exists, disseminated through extensive regions of space . . . what we may naturally ask, is the nature and destination of this nebulous matter? Is it absorbed by the stars in whose neighbourhood it is found, to furnish, by its condensation, their supply of light and heat? or is it progressively concentrating itself by the effect of its own gravity into masses, and so laying the foundation of new sidereal systems or of insulated stars?"[14]

Some speculations concerning the Universe's origins could have distinctly subversive implications. The radical lecturer Thomas Simmons Mackintosh—a committed disciple of the utopian socialist Robert Owen—made quite a name for himself during the 1830s across Britain with his electrical theory of the universe. Lecturing in Owenite Halls of Science and Mechanics' Institutes the length and breadth of the country, Mackintosh put forward a view of the Universe that had electricity rather than gravity as its driving force—all "motion throughout the solar system is effected by the agency of electricity."[15] He took advantage of the reappearance of Halley's comet in 1835 to promote his theory, arguing that comets were "immense volumes of aeriform matter discharged from the sun by the agency of electricity"[16] and that they would eventually condense into planets. Electricity acted to prevent the planets from falling into the sun, but as that electricity dissipated, the eventual fate of the Solar System was inescapable: "The river flows because it is running

[12] J. Herschel, *Treatise on Astronomy* (London, 1833), 40.

[13] Ibid., 401.

[14] Ibid., 406–7.

[15] T. S. Mackintosh, "Electrical Theory of the Universe," *Mechanic's Magazine*, 1835–36, **24**: 228.

[16] Ibid., 11.

down; the clock moves because it is running down; the planetary system moves because it is running down; every system, every motion, every process, is progressing towards a point where it will terminate."[17] The relentless unfolding of natural law meant that the universe had a discrete beginning and end. There was no room for God in Mackintosh's cosmological picture and no room for Christian salvation either. The radical message behind his cosmology was that mankind needed to make its own salvation on earth while there was still time.

Even more dangerous in the eyes of many gentlemen of science, however, was the use made of the nebular hypothesis in the notorious *Vestiges of the Natural History of Creation*. Published anonymously in 1844, *Vestiges* was in fact the work of the Edinburgh publisher Robert Chambers. Born in 1802, the son of a hand-loom weaver, Chambers had by the 1830s made a name and some fortune for himself as a bookseller and publisher. Along with his brother William he ran *Chambers's Edinburgh Journal* from the early 1830s onwards, selling eighty thousand copies a week by the 1840s. Originally a Tory, Chambers was by now a firmly liberal Whig and the journal an expression of middle-class Whig values of improvement and progress. *Vestiges* was dangerous in the eyes of its opponents precisely because it was aimed at and written for exactly the kind of solid, respectable middle-class citizen who read *Chambers's Edinburgh Journal*. It could not be dismissed as easily as the patently radical rantings of an avowed socialist such as Mackintosh. The anonymous author (though many among the gentlemen of science suspected Chambers by the end of the 1840s) had done his homework as well. *Vestiges* made good use of the latest in natural philosophy to underpin its message.

Chambers's argument was simple. The history of the universe was the history of the gradual unfolding of natural law. He hammered the lesson home with examples ranging from the supposed development of stars and planets from nebular gas to the transmutation of species. For cautiously reformist gentlemen of science this was dangerous stuff. "The nebular hypothesis," *Vestiges* announced to its readers, "is, indeed, supported by so many ascertained features of the celestial scenery, and by so many calculations of exact science, that it is impossible for a candid mind to refrain from giving it a cordial reception, if not to repose full reliance upon it, even without seeking for it support of any other kind . . . seeing in our astral system many thousands of worlds in all stages of formation, from the most rudimental to that immediately preceding the present condition of those

[17] T. S. Mackintosh, *The Electrical Theory of the Universe* (Boston, 1846), 371.

we deem perfect; it is unavoidable to conclude that all the perfect have gone through the various stages which we see in the rudimental."[18] The conclusion was inescapable: "the whole of our firmament was at one time a diffused mass of nebulous matter, extending through the space which it still occupies. So also, of course, must have been the other astral systems. Indeed, we must presume the whole to have been originally in one connected mass, the astral systems being only the first division into parts, and solar systems the second." There was another conclusion as well: "that the formation of bodies in space is *still and at present in progress*."[19]

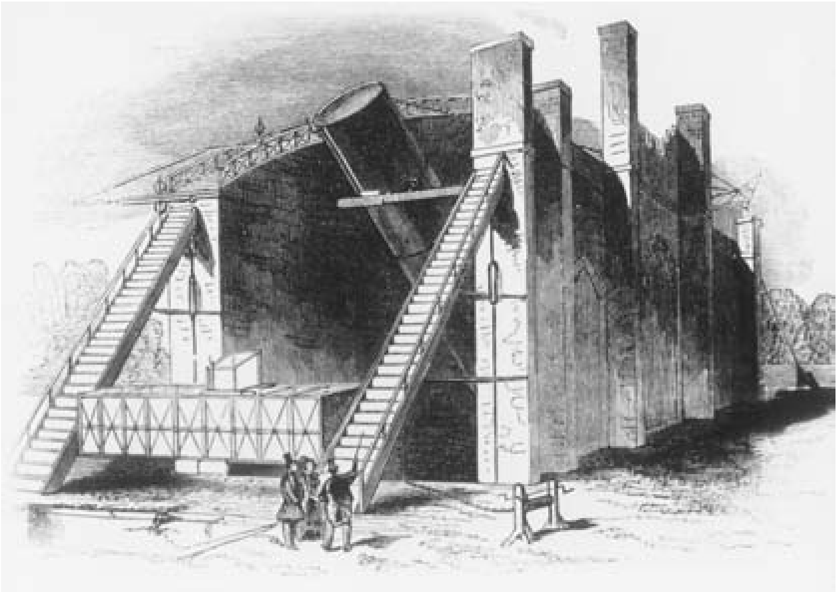
The importance of this appearance of continuous progress (and its implications for the progress of society) had also already been emphasized by John Pringle Nichol—another fan of the nebular hypothesis. "In the vast Heavens, as well as among phenomena around us, all things are in a state of change and PROGRESS,"[20] he proclaimed, making quite explicit the intimate connection between celestial physics and social dynamics. An avowed political radical, Nichol progressed himself during the 1830s from Scottish schoolmaster through popular lecturer and journalist on political economy and natural philosophy until in 1836 he was appointed professor of astronomy at Glasgow. In his popular and influential *Views of the Architecture of the Heavens* (1837) he was adamant that the nebular hypothesis demonstrated the existence of a progressive order in the universe that stretched from the formation of stars and planets to the actions of men on Earth. According to Nichol and his allies, the nebular hypothesis demonstrated the need for and indeed the inevitability of social reform. Society was subject to exactly the same kind of progressive forces that made the Solar System out of an inchoate cloud of stellar gas. Nichol's friend and political ally John Stuart Mill concurred and thought that Nichol's book would be the making of him.

For Mill, Nichol, and their associates, the nebular hypothesis was only one part—though an absolutely crucial part—of a wide-ranging and comprehensive science of progress. The science of progress incorporated Mill's logic, David Ricardo's political economy, George Combe's phrenology, and Jean-Baptiste Lamarck's theory of evolution by means of transmutation as well. Nichol was relentless in his campaign to underpin progressive change in society with the revelation of continuous progress in the heavens. Like Chambers, he emphasized that the nebular

[18] [R. Chambers], *Vestiges of the Natural History of Creation* (London, 1844), 19–20.

[19] Ibid., 20–21.

[20] J. P. Nichol, *Views of the Architecture of the Heavens* (Edinburgh, 1837), 206.



7.2 Lord Rosse's telescope.

hypothesis's main selling point was its very simplicity. Regardless of any cavils from the gentlemen of science, the hypothesis was so compelling as to be self-evident. Anyone with eyes to see and sufficiently powerful telescopes to look through could confirm the fact for themselves. The nebulae were there to be seen in the heavens and common sense did the rest. For those who could not gain access to large telescopes for themselves, Nichol's crowd-pleasing lectures were an equally compelling substitute. His shows were famous—to some notorious—for their "gorgeous style, gigantic diagrams and enthusiasm." Nichols was celebrated as "the prose laureate of the stars"[21] and traveled as far afield as New York to give his performances. To his opponents, however, his lectures seemed full of bombast rather than substance; the nebular hypothesis a misreading of the evidence of the heavens.

Working out just what the evidence of the heavens might be in this regard was one of the issues the aristocratic Lord Rosse hoped to resolve with the construction of his gargantuan telescope, the Leviathan of Parsonstown, at his family seat at Parsonstown in King's County (now County Offaly), Ireland (figure 7.2). Rosse was an enthusiastic

[21] Quoted in S. Schaffer, "The Nebular Hypothesis," 150.

astronomer with the leisure and resources to indulge his passion on a massive scale. Building on William Herschel's telescopic achievements, by the early 1840s Rosse had already constructed a thirty-six-inch reflecting telescope at Parsonstown and was about to embark on an even more audacious project. Between 1842 and 1845 work was under way on the Leviathan, which was to be seventy feet in length with a mirror six feet in diameter. The engineering achievement alone was widely celebrated as a symbol of progress. Rosse "had no skilled workmen to assist him. His implements, both animate and inanimate, had to be formed by himself. Peasants taken from the plough were educated by him into efficient mechanics and engineers."[22] Rosse mechanized the process, using steam-powered tools to polish the gigantic mirror. The final product was definitional of the aim of telescopic astronomy, and with it Rosse set out to scour the skies for nebulae and try whether his telescope's awesome power could resolve them. The more nebulae that could be resolved into constituent stars, the less plausible was the prospect of what Herschel had called "true nebulae" and therefore the nebular hypothesis.

Rosse's main ally was Thomas Romney Robinson, an Anglican divine and director of the Armagh Observatory in Ireland. He was a fervent opponent of Papism on the one hand and the materialist radicalism associated with the nebular hypothesis on the other. Their target was the Orion nebula that Nichol had pinpointed in *Views of the Architecture of the Heavens* as a likely candidate for true nebula status. Early in 1846, Rosse wrote to inform Nichol that the Leviathan had been successful in resolving the Orion nebula. It was, as Nichol ruefully remarked, no more than a "SAND HEAP of stars."[23] Robinson and Rosse had been working hard to discredit William Herschel's observations, on which the claims of the nebula's unresolvability—and hence the plausibility of the nebular hypothesis—rested (figure 7.1). Robinson in particular went out of his way to undermine Herschel's reputation, asserting that his nebular observations were worthless since Herschel was an incompetent telescope maker. Despite the Leviathan's reputation, however, its observations could not be decisive. Faced with the apparent resolvability of the Orion nebula, Nichol enthusiastically picked up on others of Rosse's observations—such as his reports on spiral nebulae—as new evidence of the existence of the kind of interstellar gaseous fluid required by the nebular hypothesis.

[22] A. Clerke, *A Popular History of Astronomy in the Nineteenth Century* (London, 1900), 115.

[23] Quoted in S. Schaffer, "The Leviathan of Parsonstown," 214.

Disputes concerning true nebularity dragged on for most of the rest of the century. No observations, not even ones with as powerful an instrument as Rosse's Leviathan, could ever be really decisive since so much rested on their interpretation. As the astronomer Otto Struve said to Rosse in 1868, "In my opinion if a nebula is resolvable it will offer the same appearance on any occasion when the images are sufficiently favourable. Thus admitted, your own observations show that, with regard to the central part of the nebula of Orion, this term ought not to be applied, for in different nights you see resolvability in different parts of the nebula."[24] Where Rosse saw stars, Struve and others saw constantly changing patterns of "nebulous matter" sometimes tangling into "separate knots." Rosse and his workers insisted that the superiority of their instrument should give them the final say. There was nothing about their observations that could force their opponents to capitulate, however. Too much was at stake as far as Nichol and his fellow proponents of the science of progress were concerned. Once in the public gaze, Rosse's observations ceased to be his property and could be read in a variety of ways quite conducive to the nebular hypothesis. New kinds of instruments and new technologies were competing with the Leviathan of Parsonstown as well for the status of being the ultimate arbiters on the matter.

The Sky's Laboratories

While Lord Rosse and his Leviathan might at first sight conform comfortably enough with the traditional image of the astronomer as lonely and heroic watcher of the skies, his operations in reality were quite different. The Leviathan was very much a product of industrial culture. Other innovations in astronomy during the middle parts of the nineteenth century also owed much to the physicist's laboratory and the mechanic's workshop. These decades saw the introduction of a number of new technologies into the practice of astronomy with the aim, at least in part, of making its processes less subject to the vagaries of the human observer and therefore more "objective." Establishing that objectivity was by no means a straightforward task. It was not at all obvious to contemporary commentators that the replacement of human illustrators with photographs as means of recording the appearance of the heavens, for example, was necessarily to make the representations more objective. They had to be persuaded. Turning the observatory into a physicist's

[24] Quoted ibid., 221.

laboratory was a business that involved the introduction of novel kinds of discipline and work organization as well as of new kinds of instruments. Astronomy's audiences needed to be persuaded as well that these novelties really would make their picture of the heavens more real.

Photographic pioneers were quick to suggest that astronomy was one science that might clearly benefit from their services—unsurprisingly given that some astronomers, notably John Herschel, played key roles in developing new photographic technologies. Herschel had been involved in experiments on the sensitivity of various chemical substances to light since the 1820s. He was a close associate of William Henry Fox Talbot, who had introduced the calotype method of photography. Herschel produced his first photographs in 1839 and was instrumental in introducing the term "photography" to describe the new technology. François Arago, the director of the Paris Observatory, was similarly instrumental in bringing the discoveries of the French inventor Louis Jacques Mandé Daguerre to the attention of the Académie des Sciences. He was also one of the first to suggest, shortly after Daguerre's announcement of his new photographic—or daguerreotype—process in 1839 that the new technique might have a useful role to play in astronomy. An early daguerreotype of the moon by Daguerre was probably taken at Arago's suggestion. Photography was touted as a means of making astronomical observations more objective—freeing them from the constraints of human subjectivity. They might also have the virtue of superior sensitivity. Chemicals that reacted to light that the human eye failed to register could capture images of stars and celestial phenomena that mere men might miss. This was one way in which photographs could help with the nebular hypothesis—they might provide evidence of that elusive nebular fluid that the naked eye might miss.

The possibilities of astronomical photography received a major boost when the Harvard astronomer William Cranch Bond exhibited daguerreotypes of the moon taken at the Great Exhibition in 1851. They were not the first of their kind, but they were notable for their clarity and their obvious affinity to naked eye impressions. They were celebrated as showing that photography really could replace and improve upon individual perceptions. Bond had produced the daguerreotypes with the help of Boston photographer J. A. Whipple. It was a process that required considerable experimentation to find the best chemicals for the exposure and a great deal of human ingenuity. Well into the 1850s George Phillips Bond (William Cranch Bond's son and successor as director of the Harvard Observatory) was still emphasizing the extent to which astronomers remained dependent on the skills of artists, engravers, and photographers to produce credible images of celestial objects. Such remarks underlined the difficulties to be overcome in using photography to turn astronomy into what George Bidell Airy called a "self-acting" science. Behind the scenes, photography remained very far from self-acting—it was dependent on its aficionados.

In Britain, one of those aficionados was Warren de la Rue, who for much of the nineteenth century was firmly established as the country's premier astronomical photographer. Born in London in 1815 and educated in Paris, de la Rue was the son of the founder of a stationery manufacturing firm. A member of the London Electrical Society, he was a keen enthusiast for natural philosophy, publishing on chemistry and electricity from the late 1830s. During the 1840s he turned his attention to astronomy and was soon an advocate of photography. In 1851 he produced his first photograph of the Moon, using the newly developed wet collodion process and pointing his camera through his own thirteen-inch reflecting telescope. Coming from a well-heeled manufacturing family had distinct advantages. De la Rue could afford his own private observatory. He had access to the resources (and the leisure) that remained essential for working with a still cumbersome and time-consuming new technology. Exposure times—even for a bright object like the Moon (one of the reasons de la Rue chose it as the object of his early experiments)—were a significant factor. De la Rue had to find ways of accurately tracking his target during the process.

De la Rue worked hard to improve the process, designing a driving clock that could move his telescope in tandem with the Moon. With the new technology—and a move to cleaner air outside London at what was then the picturesque village of Cranford (now a suburb of London)—he could produce images of impressive clarity. He also managed a stereoscopic (three-dimensional) portrait of the Moon that turned the eminent John Herschel into an instant fan. "I hasten to testify my admiration of this transcendent and wonderful effort," the astronomer enthused. "It is a step *in nature* but beyond *human* nature as if a giant with eyes some thousands of miles away looked at the moon through a binocular."[25] From the mid-1850s onwards he was also attracting Airy's attention, always on the lookout for ways of making the observer redundant. Airy argued that photography could introduce new standards of accuracy and objectivity from physics into astronomy: "it will supersede hand-drawing

[25]Quoted in H. Rothermel, "Images of the Sun," 144.

altogether, and even now the results obtained are much more accurate than anything hitherto done by mapping or hand-drawing."[26] Photography could eradicate the otherwise ineradicable "personal equation"—the idiosyncrasy that marked even the most alert and dedicated watcher's observations with an indelible individual taint. As such this import from physics could be an ideal addition to Airy's industrialized Greenwich regime.

Having been involved in studying sunspots during his self-imposed exile at the Cape of Good Hope, John Herschel, inspired by de la Rue's successes with lunar photography, was anxious for experiments with solar photography as well. In 1854 he prompted Edward Sabine—a fellow scientific reformer, campaigner for the "magnetic crusade" to map terrestrial magnetism, and influential member of the British Association for the Advancement of Science's Kew Observatory Committee—that it would be "an object of very considerable importance to secure at some observatory . . . daily photographic representations of the sun, with a view to keep up a consecutive and perfectly faithful record of the history of the spots."[27] De la Rue was soon recruited for the job and duly set up shop at Kew—where the British Association for the Advancement of Science maintained its observatory—with the aid of a £150 grant from the Royal Society. By 1858, de la Rue had perfected a working photoheliograph and instituted a successful regime "to determine all the data necessary for ascertaining the relative magnitudes and positions of the sun's spots."[28] The instrument's possibilities as a means of providing reliable representations of another solar phenomenon—the eclipse—were soon spotted. In 1860 plans were mooted to carry the photoheliograph to Spain to capture an eclipse of the sun there.

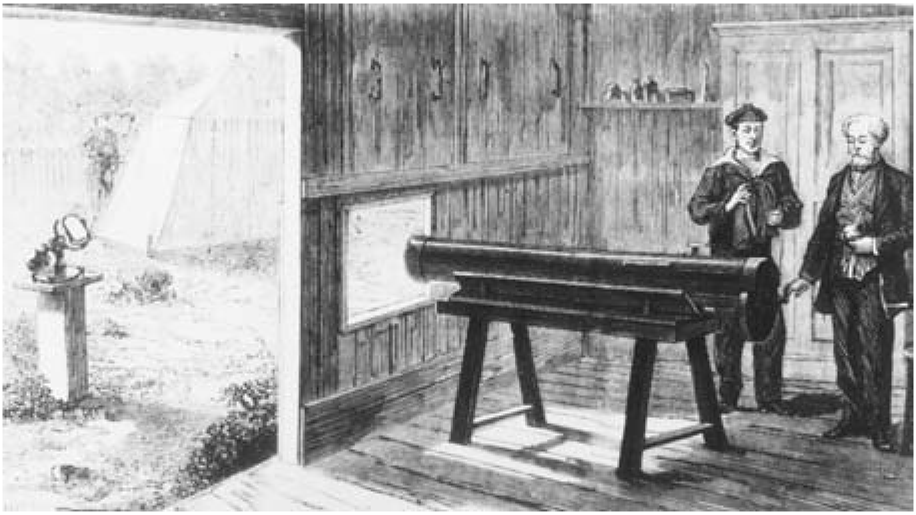
Pictures of solar eclipses were notoriously unreliable and hopes were high that photography might prove to be the answer. Illustrators and engravers during the 1830s and 1840s had developed an array of techniques in efforts to make sufficiently realistic representations of the elusive phenomenon. The comparative rarity of eclipses was one problem. Another was their short duration and the difficulty of looking at them for extended periods. Astronomers gave their draftsmen detailed instructions as to what they should look for and how they should try to depict their impressions. Finished drawings were out of the question. Observers made rapid sketches while an eclipse was in progress and tried to fill in the blanks from memory. The camera made such skills

[26] Quoted ibid., 145. [27] Quoted ibid., 152. [28] Quoted ibid., 153.

redundant, but introduced a whole range of new techniques instead. Photographing an eclipse was a labor-intensive process. Plates had to be carefully prepared beforehand. One assistant stood ready to hand plates to the photographer while another stood by to uncover and cover the telescope at the crucial moments. Another was ready to rush the exposed plates away to be developed immediately—the plates would spoil quickly if not dealt with on the spot. All this took place as a rule in some foreign clime far removed from the astronomer's home observatory.

Expeditions were essential to capture rare and transient astronomical phenomena like eclipses. Astronomers had to pack their bags and move lock, stock, and barrel to the appropriate spot on the Earth's surface where the phenomenon might best be observed. De la Rue's expedition to Spain in 1860 with the Kew photoheliograph is a good example. To deal with the expected difficulties of photographing the elusive phenomenon and the idiosyncrasies of the apparatus, de la Rue had a complete photographic observatory built for the occasion, divided into one part with a removable roof containing his heliograph and another equipped as a photographic room. The Admiralty, which was bankrolling the expedition, put up a ship to transport the astronomers and their traveling observatory en masse to Spain. The resulting photographs were a hit. Detailed preparations were similarly essential for the projected expedition to observe the Transit of Venus across the Sun's face in 1874—an event that had last taken place more than a century previously (figure 7.3). Airy and de la Rue were discussing plans for photographs as early as 1868. A model set up at Greenwich was used to train observers before they set out for the five observing stations in Egypt, Hawaii, New Zealand, and two South Pacific islands. The observing stations and their equipment were all identical, having been built at Greenwich before being shipped out to be reassembled on site. Despite all efforts, however, the expedition was a flop. The results turned out to be wildly inconsistent and nothing from the photographic parts of the enterprise ever saw print. It was an instructive lesson in the limits of instrumentalized standardization.

Spectroscopy was the other addition to the armory of astronomy during the second half of the nineteenth century. The new technique was the outcome of early nineteenth-century observations that the color of flames or of electric sparks between electrodes varied according to the makeup of the electrodes. The light when viewed through a prism gave a spectrum unique to each particular element. The brilliant German optical instrument maker Josef von Fraunhofer had noted that light from the Sun exhibited characteristic lines in its spectrum when viewed through a



7.3 Astronomers testing their equipment in preparation for observing the Transit of Venus.

prism. He had used these lines, which came to be known as Fraunhofer lines, to demonstrate the quality of his optical apparatus. Such a technology could, however, also be used by astronomers to identify the makeup of celestial bodies by studying the characteristics of their light. As James Clerk Maxwell noted, it was a striking vindication of the universality of physics: "when a molecule of hydrogen vibrates in the dog-star, the medium receives the impulses of these vibrations; and carrying them in its immense bosom for three years, delivers them in due course, regular order and full tale into the spectroscope of Mr Huggins at Tulse Hill."[29] The result, according to Mr Huggins himself—William Huggins, owner of a private observatory—was that "an astronomical observatory began, for the first time, to take on the appearance of a laboratory. Primary batteries, giving forth noxious gases, were arranged outside one of the windows; a large induction coil stood mounted on a stand on wheels so as to follow the positions of the eye end of the telescope, together with a battery of several Leyden jars; shelves with bunsen burners, vacuum tubes and bottles of chemicals, especially of specimens of pure metals, lined its walls."[30]

The German physicist Gustav Robert Kirchhoff took the lead in solar spectroscopy with experiments in the 1850s and 1860s. Kirchhoff

[29] J. C. Maxwell, *Scientific Papers of James Clerk Maxwell* (Cambridge, 1890), 2: 322.

[30] Quoted in S. Schaffer, "Where Experiments End," 268–69.

claimed that on the basis of detailed spectroscopic analysis of the Sun's light he and his coworkers could actually reproduce the solar atmosphere in their laboratory. Kirchhoff in 1861 used his spectral findings to promulgate a new theory of the Sun's composition. The Sun, according to his spectroscope, was made up of an incandescent, luminous fluid. Sunspots were cloudlike spots that floated high above its surface. Kirchhoff's model, and his assertion that the Sun's constitution could be reproduced under laboratory conditions, was strongly disputed by the French astronomer Hervé Faye, who argued that drawing such analogies between laboratory experiments and inaccessible celestial phenomena was tendentious at best. Kirchhoff's sunspot model was just as strongly disputed across the Channel in England. The dominant model there—formulated by William Herschel and strongly defended by his son—was that sunspots were holes through the Sun's atmosphere to the dark (and habitable) surface beneath. Unlike the Frenchman, however, British astronomers such as William Huggins and Norman Lockyer were more than happy to agree with Kirchhoff's claim that spectroscopy was the key to understanding the solar (and stellar) constitution.

There was little doubt in Lockyer's mind that spectroscopy was the key to unlocking the Sun's secrets. "There is an experiment by which it is perfectly easy for us to reproduce this artificially," he said of his claim that observed changes in the width of lines in the solar spectrum were the result of pressure changes in the Sun's atmosphere: "we can begin at the very outside of the Sun by means of hydrogen, and see the widening of the hydrogen lines as the Sun is approached; and then we can take the very Sun itself to pieces."[31] It was a powerful claim. One reason for spectroscopy's power as a tool for astronomers was the way it allowed them to make their observations public. Stellar phenomena invisible to the layperson could be reproduced in the laboratory—and more importantly in the lecture theater—and made accessible to all. Astronomers could tell stories that explicitly linked what was going on in the physics of a piece of terrestrial demonstration apparatus to what took place in the heart of the Sun, or the uncharted depths of interstellar space. Spectroscopy and solar physics could be marketed as tools that provided vital information about the age of the Sun and the lifespan of the Cosmos—topics that mattered to a generation obsessed with degeneration, evolution, and the heat death of the Universe.

[31] Quoted ibid., 283.

Victorian astronomers were well aware of the extent to which the importation of these new technologies transformed their discipline. David Gill, Britain's resident astronomer at the Cape Colony, represented them to a Royal Institution lecture audience as the acme of astronomy: "It is these after all that most appeal to you, it is for these that the astronomer labours, it is the prospect of them that lightens the long watches of the night."[32] While their products might be inspirational, the procedures and disciplines accompanying these new practices—carried over from the nineteenth century's growing laboratory culture—had their closest affinities to the industrialized astronomy of George Bidell Airy and his cohorts. As Airy's style of stargazing required the mobilization of ranks of ordered, disciplined observers and computers, astronomical physics needed the mass orchestration of new resources, skills, and workers as well. This was an astronomy that needed chemists, electricians, and photographic entrepreneurs as well as opticians and telescope makers. Ways had to be found of integrating these newcomers into older ways of doing things. Despite his enthusiasm, it was notable that even Airy balked at bringing too much of the new physics into the Royal Observatory, though he did establish an Astro-Photographic and Spectroscopic Department in 1874—it was a tool of spectacular discovery ill-suited to Greenwich's more utilitarian remit. In Britain at any rate, astronomical physics found its feet in smaller, often private observatories like those of de la Rue at Cranford and William Huggins at Tulse Hill, rather than under the aegis of state astronomy.

Other Worlds

One of the reasons the Victorian public, as well as astronomers, were so fascinated by the prospect of finding out more about the physical characteristics of celestial bodies was that it seemed to shed light on the possibility that those other worlds might be inhabited. The question of extraterrestrial life was both controversial and topical throughout the nineteenth century. It was not just an issue confined to the margins of cultural and intellectual life—some of Europe and America's most respected astronomers lined up to opine on the matter. Neither was this a new issue. By the beginning of the nineteenth century the question of extraterrestrial life and the possibility of a "plurality of worlds" had

[32]Quoted ibid., 267.

a long history. The infamous Giordano Bruno had been an enthusiastic proponent of the idea that life existed not only on the Moon and other planets, but on the stars as well. Johannes Kepler had been a little more circumspect but still believed that other planets were probably inhabited. Even the great Sir Isaac Newton expressed the view that if all parts of the Earth were inhabited, then there seemed no reason to suppose that God would have left the heavens uninhabited. Newton's remarks underlines the theological implications of discussions of the plurality of worlds—implications that were still there in the nineteenth century.

William Herschel—whose reputation as an astronomer remained high throughout the nineteenth century—was a particularly enthusiastic advocate of the plurality of inhabited worlds. He was adamant that the Moon must be occupied by inhabitants of one kind or another. He was confident as well that his increasingly powerful telescopes would eventually provide irrefutable proof on the matter. He even toyed with the idea that he had already seen such evidence. On one occasion he noted following some telescopic observations of the moon that "I believed to perceive something which I immediately took to be *growing substances*. I will not call them Trees as from their size they can hardly come under that denomination . . . My attention was chiefly directed to Mare humorum, and this I now believe to be a forest."[33] Some of his contemporaries thought that Herschel's preoccupation with lunar (and solar) life rendered him "fit for bedlam." He was not, however, the only Enlightenment astronomer to entertain the possibility of extraterrestrial life by any means. Laplace discussed the possibility in his *Mécanique Céleste*. The argument was supported by Jérôme Lalande, professor of astronomy at the Collège Royale, who argued that "the resemblance is so perfect between the earth and the other planets that if one admits that the earth was made to be inhabited, one cannot refuse to admit that the planets were made for the same purpose."[34]

The German astronomer Franz von Paula Gruithuisen was one of the early nineteenth century's most enthusiastic advocates of extraterrestrial life—as well as being one of the century's most prolific astronomical writers. In 1824, in his "Entdeckung vieler deutlichen Spuren der Mondebewohner, besonders eines collassalen Kunstgebäudes derselben" (Discovery of Many Distinct Traces of Lunar Inhabitants, Especially One

[33]Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 63.

[34]Quoted ibid., 79.

of Their Colossal Buildings) he argued that the colored tints he observed on the Moon's surface should be interpreted as evidence of vegetation. He claimed to have seen pathways through his telescope, demonstrating the existence of lunar animals roaming on the surface. He had also seen a variety of geometrically shaped features that he speculated might be artificially constructed roads and cities. One large, star-shaped structure in particular was labeled a temple. Some of his contemporaries regarded all of this as evidence that the professor of astronomy at the University of Munich had—like William Herschel—taken leave of his senses. The plurality of worlds was nevertheless part of the common discourse of astronomical debate in the German lands. Even those such as Carl Friedrich Gauss, Wilhelm Olbers, and Johann Joseph von Littrow, who regarded Gruithuisen's claims as patently absurd, were themselves sympathetic to the possibility that life existed on other worlds.

In Britain, William Herschel's stellar reputation, if nothing else, guaranteed discussions of the plurality of worlds a sympathetic hearing. John Herschel, as an assiduous defender of his father's achievements, was an advocate of pluralism as well, if a rather more circumspect one than his parent. The planets, according to John Herschel, were "spacious, elaborate and habitable worlds." The stars were "effulgent centres of life and light to myriads of unseen worlds."[35] Herschel's arguments in favor of this conviction were classic examples of British natural theological argument. "Now, for what purpose are we to suppose such magnificent bodies scattered through the abyss of space?" he queried. "Useful, it is true, they are to man as points of exact and permanent reference; but he must have studied astronomy with little purpose, who can suppose man to be the only object of his Creator's care, or who does not see in the vast and wonderful apparatus around us his provision for other races of animated beings."[36] John was not the only defender of the elder Herschel's reputation. W. H. Smyth, admiral in the British navy and astronomical enthusiast, asserted that the "inhabitants of every world will be formed of the material suited to that world, and also for that world, and it matters little whether they are six inches high, as in Lilliput . . . whether they crawl like beetles, or leap fifty yards high."[37] These were theological arguments—assertions that a recognition of the plurality of worlds was also a recognition of

[35] J. Herschel, *Treatise on Astronomy* (London, 1833), 2.

[36] Ibid., 380.

[37] W. H. Smyth, *Cycle of Celestial Objects* (London, 1844), 1: 92.

God's power and benevolence. The popular writer Jane Marcet in her best-selling *Conversations on Natural Philosophy* (1819) was an advocate of pluralism as well.

Not all British commentators concurred with this assessment. An equally best-selling popular writer, Mary Somerville, argued in her *Connexion of the Physical Sciences* (1834) that "the planets, though kindred with the earth in motion and structure, are totally unfit for the habitation of such a being as man."[38] Sir Charles Lyell deployed his geological expertise to cast doubt on the prospect of "the plurality of habitable worlds throughout space, however favourite a subject of conjecture and speculation."[39] Lyell's friend Charles Darwin, on the other hand, was a fan of pluralism, at least in his younger days. More dangerously for gentlemen of science, arguments in favor of the existence of extraterrestrial life lay at the center of the subversive *Vestiges of the Natural History of Creation*. The anonymous author (later revealed to be the publisher Robert Chambers) argued of the planets that "every one of these numberless globes is either a theatre of organic being, or in the way of becoming so . . . Where there is light there will be eyes, and these, in other spheres, will be the same in all respects as the eyes of tellurian animals, with only such differences as may be necessary to accord with minor peculiarities of condition and of situation."[40] Discussions of the possibility, at least, of the plurality of worlds was part of the common currency of astronomical debate in Britain as well as the German lands, and the balance of opinion seemed if anything to veer towards the positive.

In 1853, however, the English natural philosopher William Whewell delivered a devastating critique of the pluralist position in his anonymous pamphlet, *Essay on the Plurality of Worlds*. Whewell had previously been at least sympathetic to the possibility of extraterrestrial life, suggesting in 1833 that stars other than the Sun might also "have planets revolving about them; and these may, like our planet, be the seats of vegetable and animal and rational life."[41] By the 1850s, however, disgusted and shocked by the success of *Vestiges* and the impious uses to which it put the pluralist argument, the polymathic master of Trinity College, Cambridge—a devout Anglican and staunch Tory—had changed his mind. He now wanted

[38] M. Somerville, *Connexion of the Physical Sciences* (London, 1834), 264.

[39] Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 223.

[40] [R. Chambers], *Vestiges of the Natural History of Creation* (London, 1844), 161–64.

[41] W. Whewell, *Astronomy and General Physics* (London, 1833), 207.

to show that "dim as the light is which science throws upon creation, it gives us reason to believe that the placing of man upon the earth (including his creation) was a supernatural event, an exception to the laws of nature. The Vestiges has, for one of its main doctrines, that even this was a natural event, the result of a law by which man grew out of a monkey."[42] By this reading, any defense of pluralism was in danger of descending into an argument in favor of natural law and a denial of special creation. Whewell argued strenuously that "in the eyes of any one who accepts the Christian faith," the Earth could never be "regarded as being on a level with any other domiciles. It is the Stage of the great Drama of God's Mercy and Man's Salvation." The "assertions of Astronomers when they tell us that it is only one among millions of similar habitations"[43] demanded strenuous refutation.

Whewell's diatribe certainly raised eyebrows. As one reviewer commented, "We scarcely expected that in the middle of the nineteenth century, a serious attempt would be made to restore the exploded idea of man's supremacy over all other creatures in the universe; and still less that such an attempt would have been made by one whose mind was stored with scientific truths. Nevertheless a champion has actually appeared, who boldly dares to combat against all the rational inhabitants of other spheres; and though as yet he wears his vizor down, his dominant bearing, and the peculiar dexterity and power with which he wields his arms, indicate that this knight-errant of nursery notions can be none other than the Master of Trinity College, Cambridge."[44] The venerable Scottish natural philosopher, Sir David Brewster, pitched in with venom, dismissing Whewell's arguments as degrading astronomy and subverting true religion. In the unkindest cut of all, he even compared Whewell (unfavorably) to the author of the heretical *Vestiges*. The Rev. Baden Powell, Oxford's Savilian Professor of Geometry, was more circumspect. His view was that "by the light of inductive analogy, astronomical presumption, taking the truths of geology into account, seems to be in favour of progressive order, advancing from the inorganic to the organic, and from the insensible to the intellectual and moral in all parts of the material world."[45] He was unambiguous that the "material world" included other

[42] Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 275.

[43] [W. Whewell], *Essay on the Plurality of Worlds* (London, 1853), 44–45.

[44] Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 282.

[45] Baden Powell, *Essays on the Spirit of Inductive Philosophy, the Unity of Worlds, and the Philosophy of Creation* (London, 1855), 231.

planets orbiting around other suns as well. John Herschel's response in a letter to the besieged master of Trinity was dismissive: "So *this* then is the best of all possible worlds—the *ne plus ultra* between which and the 7th heaven there is nothing intermediate. Oh dear! Oh dear!"[46]

One of the most prolific and popular expositors of the argument for extraterrestrial life during the second half of the nineteenth century was Camille Flammarion. Born in Montigny-le-Roi in 1842, by the age of sixteen he had persuaded the eminent Leverrier, discoverer of Neptune and by then director of the Paris Observatory, to hire him as an apprentice. At the age of twenty, he published his first book, *La Pluralité des Mondes Habités*, an audacious and robust defence of pluralism that went through numerous editions (fifteen by 1870) and was translated into several languages. Unlike his patron Leverrier, who was a practitioner of Airy-style industrial astronomy, Flammarion was an enthusiast for astronomical physics and the possibilities it held of providing real information about the physical constitution of other worlds—and of their inhabitants. For Flammarion there was nothing about the Earth that marked it out as being particularly fit for life. There was nothing unique about humankind's habitation and everything to suggest that other worlds might prove at least as hospitable to life. Far from the Earth's being the world best established for the maintenance of life, a great number of other worlds were far superior in terms of inhabitability to our own humble planet.

If there really was life on other planets, it was a short step to ponder how communication might be established between the inhabitants of Earth and those of other worlds. Telegraphy and later telephony and wireless telegraphy established the possibility of communicating over vast distances. An increasing number of commentators from about the 1860s onwards speculated whether the vast interplanetary and interstellar chasms might be bridged in similar fashion. The Frenchman Charles Cros came up with the suggestion that electric light rays could be focused using parabolic mirrors so as to be strong enough to be detected by any inhabitants of Mars or Venus that might be looking at Earth through their telescopes. He proposed a code to establish communication. In 1891 Flammarion announced the bequest of 100,000 francs to the Académie des Sciences to establish a prize for the first person to communicate with the inhabitants of another planet and receive a reply within the next ten years. In England Francis Galton (Charles Darwin's cousin) suggested in the *Times* that signals from mirrors reflecting sunlight might

[46]Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 311.

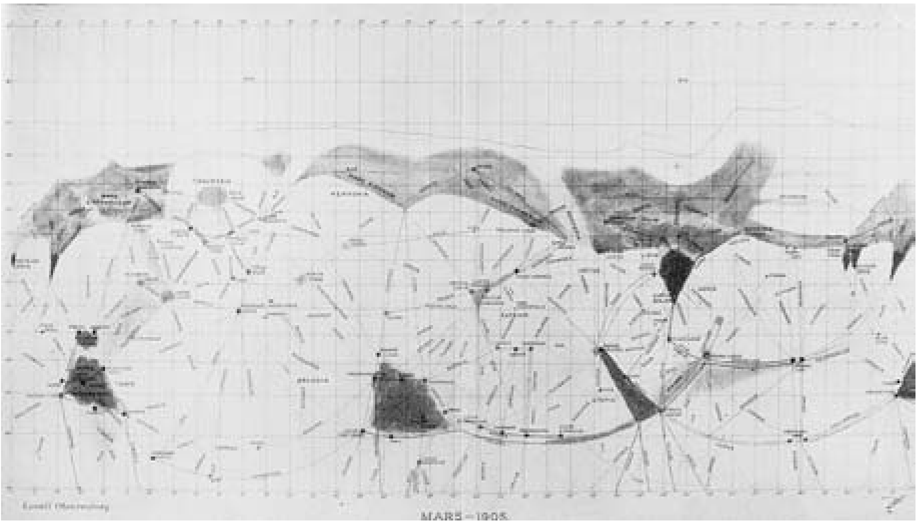
be detected by telescope-wielding Martians. In America the flamboyant inventor Nikola Tesla pronounced that "with an expenditure not exceeding two thousand horsepower, signals can be transmitted to a planet such as Mars with as much exactness and certitude as we now send messages by wire from New York to Philadelphia."[47]

One form of communication with life from other worlds was held to have already taken place. Analysis of meteorites—generally accepted to have an extraterrestrial origin—seemed to indicate that many contained carbon-based substances of organic origin. If these stones falling from the sky came from other worlds, then the organic remains they contained were clearly the remains of the indigenous life forms of those other worlds. The physicist Sir William Thomson, searching around for evidence to confute Darwinian evolution, quickly latched onto the possibilities. In his presidential address to the British Association for the Advancement of Science in 1871 he announced that "because we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own, we must regard as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space." Furthermore, the "hypothesis that life originated on this earth through moss-grown fragments of another world may seen wild and visionary; all I maintain is that it is not unscientific."[48] Evolutionists, sensing they were the target of Thomson's speculations, reacted scornfully. The prospect of life itself crossing interplanetary space was, however, very much in the air when H. G. Wells penned the *War of the Worlds* in 1898.

It was no coincidence either that Wells chose Mars as the subject of his fiction. The Planet of War hit the headlines in 1877 with the announcement by the Italian astronomer Giovanni Schiaparelli that he had discovered an extensive system of canals on the planet's surface. This was unambiguous proof that Mars was not only inhabited but inhabited by intelligent beings. Schiaparelli enjoyed a solid reputation as a cautious and reliable observer. He had studied with Encke in Berlin and Struve in Pulkowa before becoming director of the Brera Observatory in Milan in 1862. For more than two decades after his momentous discovery, astronomers across Europe and America lined up on one side or another of the disputed question: had Schiaparelli really seen canals or were they

[47] Quoted ibid., 398.

[48] W. Thomson, "Presidential Address," *Reports of the British Association for the Advancement of Science*, 1871, **41**: 269–70.



7.4 The canals of Mars as observed by Percival Lowell in 1905.

an optical illusion? The popular historian of astronomy Agnes Clerke, writing in 1885, was in no doubt, however, that the canals' existence had been fully substantiated. In 1894 the American astronomer Percival Lowell joined the fray. At his Lowell Observatory in Flagstaff, Arizona, Lowell confirmed that he too had seen the canals and put forward the theory that they were designed to carry meltwater from the planet's polar icecaps to the equator. Disputes concerning the canals' reality (and the evidence they afforded of Martian life) carried on well into the twentieth century and were grist for the mills of a generation of science fiction writers (figure 7.4).

Debates concerning the possibility of extraterrestrial life caught the Victorian public imagination for a variety of reasons. Such discussions intersected with a number of major cultural concerns. Extraterrestrial life had important theological consequences. To some it was evidence of God's munificence and the reliability of natural theological arguments. Others like Whewell came to regard the plurality of worlds as suggesting a dangerous dilution of Anglican doctrine. To many radical advocates such as Robert Chambers the plurality of inhabited worlds was, like the nebular hypothesis, proof of the universal operations of natural law and hence of the possibilities of human social (and spiritual) progress. In William Thomson's hands it became an anti-Darwinian bludgeon. Astronomers—particularly those advocates of astronomical physics—picked up on arguments concerning extraterrestrial life as providing a powerful new incentive and affirmation of the cultural relevance of their labors. Their endeavors could through such debates have important things to say about mounting late nineteenth-century concerns about humanity's place in the Universe. Extraterrestrials represented both fears and hopes concerning what humankind's own future in the coming new century might be. As Schiaparelli speculated about the Martian society that had built the canals, he concluded that the "institution of a collective socialism ought indeed to result from a parallel community of interests and of universal solidarity among the citizens . . . The interests of all are not distinguished from the other; the mathematical sciences, meteorology, physics, hydrography, and the art of construction are certainly developed to a high degree of perfection; international conflicts and wars are unknown; all the intellectual efforts which, among the insane inhabitants of a neighbouring world are consumed in mutually destroying each other, are unanimously directed against the common enemy, the difficulty which penurious nature opposes at each step."[49]

Conclusion

Astronomy had never really corresponded to its romantic image as a solitary science in which lonely watchers scanned the skies from their watchtowers. By the end of the nineteenth century it corresponded to that image even less. Astronomy was a labor- and time-intensive exercise that demanded the allocation of resources on an impressive scale. Successful observatories needed the managerial regimes of factory production. From the beginning of the century, astronomers were already the recipient of considerable state patronage throughout Europe. It seemed a prerequisite of imperial expansion. Astronomers' careful cataloguing of the skies could lead to ways of more accurately positioning ships at sea—solving the problem of longitude. Such knowledge could put a seafaring nation anxious for overseas expansion and nervous of the territorial ambitions of its neighbors at a distinct advantage. As well as their apparent utility, astronomers rode high on Newton's reputation. His *Principia* was celebrated for having placed the science of celestial motion on an apparently certain footing. Astronomers could predict the future movements of the planets with clockwork confidence. Their science had gathered for itself a reputation for mathematical exactitude that was the envy of other

[49] Quoted in M. Crowe, *The Extraterrestrial Life Debate*, 515.

natural philosophers. It was the model discipline against which others measured themselves.

Nineteenth-century astronomers fashioned themselves and their science so that they appealed to a broad swathe of constituencies. Astronomy remained an important adjunct of the state. Precision about the stars could deliver precision about political geography as well. Observatories became factorylike centers of calculation, machinelike in their reliability. The science of the stars could be made to matter for terrestrial politics too. Understanding the history of stellar evolution delivered important messages about the proprieties of contemporary social organization. This turned telescopes into potential weapons of insurrection that merited careful policing. Astronomers such as Lord Rosse at Parsonstown needed to be careful what use was made of their discoveries. Not just anybody could be allowed to speculate on the meaning of the heavens. The anonymous author of the *Vestiges of the Natural History of Creation* was ridiculed by gentlemen of science for his presumption in opining on matters beyond his ken. Only specialist astronomers had the nous to properly interpret the message of the stars. At the same time, moreover, large parts of astronomy were becoming adjuncts of physics. Men such as William Huggins argued that their work had brought celestial phenomena literally into the physical laboratory and the lecture theater. In this respect, while astronomers continued to provide physicists with important lessons in the management of large-scale institutions, physics by the end of the nineteenth century had become the dominant partner. Physics rather than astronomy was *the* nineteenth-century science.