Preface

The name of Urbain Jean Joseph Le Verrier is well known today as that of one of the immortals of astronomy. It was he who discovered a planet, "with the tip of a pen, without any instruments other than the strength of his calculations alone," as his colleague, François Arago, memorably exclaimed.

The planet was even referred to as "Le Verrier" for a short time though it is now, of course, known as Neptune. The story of its discovery is one of the best known, and most dramatic, in the history of astronomy.

The drama played out over the year 1845–1846 – a remarkable year, in and out of astronomy. Lord Rosse at Birr, Ireland, first made out the spiral arms of the nebula M51 in Canes Venatici at almost the very moment the Irish potato crop failed and brought famine and devastation to his tenants; the year England dedicated itself to laissez-faire economics on the basis of the principles of Adam Smith; the year of the Mexican-American War, opposed by a young congressman from Illinois named Abraham Lincoln; the year that US production of whale oil peaked; the year of the Oregon Trail; the year of Henry David Thoreau's experiment in "living deliberately" at Walden Pond.

It was also a year in which the ledger sheet of the motions of the last major planet in the Solar System to be discovered, Uranus, was finally put in order. Soon after its unexpected discovery by William Herschel in March 1781, astronomers who calculated the orbit of Uranus and worked out its motions found that it was straying from its predicted path. The foundling on the outermost porch of the Solar System proved to be an obstinate and defiant child: it refused to do as the astronomers bade it. In the early 1800s, it was moving too fast, while after 1822 it began to move too slowly.

Prediscovery observations turned up in astronomers' log books, including one dating back to 1690 by the Astronomer Royal at Greenwich, John Flamsteed, made while he was preparing a star catalog. These "ancient observations" should have made it easier to compute the orbit. Instead it was found that an orbit could be computed that satisfied either the old observations or the new, but not both. When, in 1820, the French mathematical astronomer Alexis Bouvard tackled the problem, he decided to throw out the old observations. Even this slander to the reputation of the

old observers did not suffice; the planet continued to stray – by 1832, when George Biddell Airy of the Cambridge University Observatory drew up a report to the British Association for the Advancement of Science, the discrepancy of Uranus's motion in longitude from Bouvard's orbit had amounted to 30 s of arc, an unacceptably large discrepancy by the precise standards of positional astronomy. Thereafter, things only proceeded to get worse.

The idea that an exterior planet was probably pulling Uranus off course occurred to a number of astronomers, including Alexis Bouvard himself (according to a statement by his nephew, Eugène, also an astronomer); the English amateur Rev. T.J. Hussey, who wrote to Airy in 1834 on the matter but received a discouraging reply; and Friedrich Wilhelm Bessel, mathematical astronomer extraordinaire at the Königsberg Observatory in Prussia. Bessel even took the step of assigning the problem of computing the orbit of the unknown planet to an assistant, Friedrich Wilhelm Flemming, but Flemming died soon afterward, and Bessel's health was also failing, and he died in March 1846.

Meanwhile, in England, Airy's report to the British Association had come to the attention of a 22-year-old undergraduate at St John's College, Cambridge: John Couch Adams. Adams was a remarkable man. Raised in rural Cornwall, he distinguished himself from an early age in mathematics and earned a place at Cambridge where he took all the mathematical honors in sight. On 3 July 1841, he jotted this memorandum in his notebook:

"Formed a design, in the beginning of this week, of investigating, as soon as possible, after taking my degree, the irregularities of the motion of Uranus, which are not yet accounted for, in order to find whether they may be attributed to the action of an undiscovered planet beyond it."

Adams's interest was entirely self-initiated. Still a student (and a very conscientious one at that), he did not have time to work in earnest on the problem until after his graduation in 1843. He had set himself an extraordinarily difficult problem. Effectively, it was an inverse problem in perturbations: it is always much more difficult to work out a cause from the effects than the effects from a cause. As the Irish astronomy writer Agnes M. Clerke later put it: "The difficulty of determining the perturbations produced by a given planet is small compared with the difficulty of finding a planet by its resulting perturbations. Laplace might have quailed before it; yet it was now grappled with as a first essay in celestial mechanics."

After his graduation, Adams remained on as a fellow at St. John's, but was still charged with many routine duties. Receiving from Airy (through an intermediary, Cambridge University Observatory astronomer James Challis) Greenwich Observatory data on the motion of Uranus and working mainly during the vacations, by September 1845 (using simplifying assumptions) he had wangled a tentative orbit and had produced a theoretical position for the planet which, as it turned out, put it within a degree and a half from where it was actually lurking at the time.

Adams, of course, is an extremely sympathetic figure. He was a brilliant mathematician, though prone to be perfectionistic; he was also, almost fatally, a faint and forgettable personality; one of his fellow students only remembered him as "a rather small man, who walked quickly, and wore a faded coat of dark green." The story is

well known about how he was failed by his superiors and how the British consequently failed to discover Neptune. To some extent, no doubt, his own naivete (and perhaps tendencies to Asperger's syndrome) played a role in this failure. He did not know how to promote his research and, on returning from vacation in Cornwall to Cambridge in October 1845, attempted an (unannounced) visit to Airy's residence at which he was not received. He only had time to drop a thumbnail sketch of his calculations in Airy's letter box. Unorthodox as Adams's method of publication was, Airy, who was the busiest civil servant in the land, did not lack interest and tried to follow up – on 5 November 1845, he wrote to Adams about the "radius vector" problem. An exterior planet would, after all, produce both tangential and radial displacements from the unperturbed orbit. So, Airy was asking whether the same theory that corrected the error in Uranus's longitude also corrected that in the radius vector. The question was a good one, and it also happened to be one to which Airy himself attached the greatest importance (he even called it the *experimentum crucis*). But Adams never replied. (We now know that he started to do so; a draft, dated 13 November 1845, has turned up in the Adams papers in the Cornwall Record office in Truro, which begins: "Sir—I must apologize for having called at the observatory the other day at so unreasonable an hour, the reason was that I had only arrived in town that morning & it was necessary for me to be in Cambridge the same day, so that I had no other opportunity. The paper I then left contained merely a statement of the results of my calculation...." But Adams breaks off before getting around to answering Airy's question. He is known to have disliked writing letters. On the other hand, perhaps he did not quite know how to answer.)

Whatever the reason for it, the lapse proved critical. Airy, nothing if not regular in his habits, would later recount: "I waited with much anxiety Mr. Adams' answer to my query. Had it been in the affirmative, I should at once have exerted all the influence which I might possess… to procure the publication of Mr. Adams' theory." Not hearing from Adams, however, as Airy afterward explained to the Cambridge geologist Adam Sedgwick (Airy to Sedgwick, 4 December 1846), "not only left the matter in an unsatisfactory state … but also entirely stopped me from writing again."

And so, as of November 1845, the trail of the British planet investigation went cold even as an impressive series of results began to trickle in from France. In the *Comptes rendus* of the French Academy for 10 November 1845, which did not arrive in England until December, Le Verrier published a paper summarizing an investigation (instigated, he says, at the request of Arago) on the perturbations of Uranus produced by Jupiter and Saturn. Airy later said of this impressive paper: "I shall only say that, while the correctness of the former theories, as far as they went, was generally established, many small terms were added; that the accuracy of the calculations was established by duplicate investigations, following different courses, and executed with extraordinary labour; that the corrections to the elements, produced by treating the former observations with these corrected perturbations, were obtained; and that the correction to the ephemeris for the present time, produced by the introduction of the new perturbations and the new elements, was investigated, and found to be incapable of explaining the observed irregularity of Uranus. Perhaps it may be truly said that the theory of Uranus was now, for the first time, placed on

a satisfactory foundation." Here, indeed, was a substantial piece of work and, moreover, *published* work. The contrast (in Airy's mind at least) between Le Verrier's accomplished labor and the rather shadowy promissory investigation being pursued by Adams could hardly have been greater.

Nothing more took place until the following June. On 1 June 1846, Le Verrier appeared before the public again with a summary of calculations in the *Comptes rendus* in which he offered a sketch of a theory of an exterior perturbing planet and gave the position where it ought to lie in the heavens. That position, near the Aquarius/Capricorn border was, as Airy noted toward the end of the month when the publication reached England, uncannily close to the one which Adams had casually dropped in Airy's letter box the previous autumn. About to leave for Europe, Airy took pains to entrust to Challis, who had the large Northumberland refractor of the Cambridge University Observatory at his disposal, a stealthy search to find the planet. Airy himself laid out the parameters of how the search should proceed. Challis cannot be said to have been enthusiastic, but he was conscientious, and at the end of the month, somewhat ploddingly, he embarked on a 2-month survey of the stars in the region indicated, looking for the planet. The search would notoriously miscarry.

In the English-speaking world – to which this translation of James Lequeux's masterful biography of Le Verrier is addressed – Adams has always been the young man let down by his superiors, the underdog whose brilliance was unrecognized. Le Verrier, though there has never been any doubt as to his great ability, enters the narrative as a rather cold and remote figure. It is usual to picture him as an established scientist, in contrast with the young and inexperienced Adams, the assumption being that he commanded the full support of his superiors as well as all the resources of the French scientific establishment. We must remember, however, that Le Verrier, born in the provincial town of Saint-Lô in 1811, had originally been trained as a chemist and was a protégé of the famed chemist J.L. Gay-Lussac; he had switched to mathematical astronomy in 1837 when Gay-Lussac, having to choose between him and Victor Regnault, a chemist of equal promise, for a single vacant position, neatly solved the dilemma by offering Le Verrier a position of equal rank in astronomy. Malleable to circumstance, he had achieved in 2 years, through a level of concentration and intelligence that still seem little less than marvelous, sufficient mastery over the arcana of celestial mechanics to begin to contribute important and original research. When Arago proposed that he tackle Uranus, he was still only 34.

Apart from the fact that Le Verrier was acting as a professional on an assigned project, rather than as a self-directed student like Adams, he too worked without assistance. The papers that caught Airy's attention were the tip of the iceberg; they were mere summaries. In fact, Le Verrier's "Uranus" file in the Paris Observatory Library, which culminates with the discovery of a planet, contains hundreds of pages, full of tables and intricate calculations, only a small part of which has ever been published and not studied thoroughly since Felix Tisserand did so at the end of the nineteenth century. Having held this sheaf of paper in my hands and shuffled through the pages, I can hardly begin to convey the sense of awe they inspire. Adams's papers are also impressive, but more scattered. Needless to say, no one can

fully appreciate the intelligence required to achieve what Le Verrier and Adams accomplished who has not carefully studied the manuscripts in which they laid out their subtle calculations.

The idea that Le Verrier enjoyed the cooperation of his French colleagues whereas Adams was failed by Airy and Challis is also a myth. Le Verrier himself was not employed at the Paris Observatory at the time; he had a position with the Bureau of longitudes, but even before he embarked on the Uranus problem, his relations with some of his French colleagues were already seriously strained. Despite Arago's undoubted personal brilliance, he was the exception: as a whole, the Paris Observatory was then highly dysfunctional, under the thumb of the Bureau, and possessed of old, unproductive, self-satisfied astronomers patrolling the skies with an array of doddering instruments. It is rumored that a brief search for Le Verrier's planet was mounted in Paris, though the details are vague; if it was, it seems that Le Verrier himself was never made aware of it. Regardless, the French search was soon given up as hopeless. Indeed, Le Verrier was compelled to seek assistance from abroad. After Airy received the 1 June 1846 *Comptes rendus* paper, he submitted to Le Verrier the very same question he had put to Adams about the radius vector. Le Verrier responded decisively and affirmatively and also appealed to Airy to take up the cudgel for his planet by mounting a search for it from one of the well-equipped observatories in England. He even offered to send Airy refinements in his calculated position in due course. Now, however, it was Airy's turn to become unaccountably silent: he would not, in fact, communicate with his French colleague again until after the planet's discovery, a circumstance that, once Adams's so far secret efforts and the extent of the British search became known after the planet's actual discovery, would ultimately prove a matter of considerable embarrassment to Airy and come close, as Airy himself admitted, to provoking a war with France.

Le Verrier was kept completely in the dark about developments in England. If there was anything nefarious about Airy's actions, it was no doubt, as the historian of astronomy Robert W. Smith has pointed out, merely a matter of wanting the planet's discovery to redound to the honor of Cambridge – Airy, Challis, Adams, and Sir John Herschel were all Cantabridgeans. They acted in loyalty to the old school tie. Challis might have been successful if he had possessed an up-to-date star chart of the region where Adams and Le Verrier put the planet. He did not; therefore, he had to go ploddingly through the stars, with the diligence of the maker of a star chart. Adams's investigation, dormant apparently since the previous November, was also reanimated; he began revising his calculations and also produced for Challis a set of ephemerides to guide his search. The first date of the ephemeris is 20 July. It is a duplicate calculation: the first set is based on the assumption that a "lost" planet recorded by Louis Wartmann of the Geneva Observatory in 1831 might have been the sought-for planet; the other calculation is based on Le Verrier's theory. The existence of this paper (in the Challis papers at Cambridge University Library) shows that Adams himself was aware of what Le Verrier had done, and though Challis undoubtedly grasped that both men had put the planet within the search area defined by Airy, the ephemerides he was using were explicitly for Le Verrier's planet, ironically as calculated by Adams. Starting his search on 29 July,

Challis actually recorded the planet twice, on 4 and 12 August. However, he failed to compare his observations.

The rest of the story is well known. While Challis continued his dogged search and Adams continued, at times with an air of desperation, to tinker with his calculations, Le Verrier published another paper – on 31 August – suggesting that the planet might most easily be disclosed by its disk. Other searchers in England were beginning to catch the scent: notably, William Lassell, who had built a 24-in. equatorial reflector and who seems to have heard of the putative planet from his friend the Rev. W.R. Dawes but who was "indisposed" at the moment of opportunity with a sprained ankle. Le Verrier, meanwhile, established communication with Johann Gottfried Galle, an assistant at the Berlin Observatory. Galle was enthusiastic and managed to get the permission of the director Encke for the search (the latter being in a perhaps more congenial mood than usual as he was headed home for a celebration of his birthday). Assisted by a graduate student, Heinrich Louis d'Arrest, who remembered that a star chart of the region had recently turned up and found it in a cubbyhole outside Encke's office, Galle detected the planet after an hour's search around midnight on 23/24 September 1846. The memorable exclamation of d'Arrest ranks among the most thrilling words ever uttered: "That star is not on the map!" The "star" was Le Verrier's planet, and was found within a degree of where Le Verrier's calculations had put it.

There followed, of course, the international priority dispute, which has been well summarized in James Lequeux's biography and elsewhere. Laurel wreaths of credit for the co-prediction would eventually be settled on both Le Verrier's and Adams's heads, through a carefully worked-out international compromise not unlike the Congress of Vienna that determined the balance of European powers after the Napoleonic Wars. Each was hailed as a codiscoverer. The animus that existed between England and France at the time has long since been forgotten, and the discovery was certainly great enough – the "zenith of Newtonian mechanics" – to cover more than one man in glory (or ignominy, in the case of Airy and Challis). But the great event had very different consequences for each of the two men, based on their very different personalities. Adams remained bashful, retiring, modest, prone to blushing. He took like a fish to water to the quiet life of an eccentric Cambridge don and spent most of his career unwinding the complicated motions of the Moon. Le Verrier, on the other hand, with steely determination, tremendous organizational abilities, and an almost pathological need to impose order on everything and everyone he came in touch with, used his great fame as the discoverer of Neptune to begin a very public, productive, but often acrimonious career as the director of the Paris Observatory. In the end, despite facing opposition that would have broken most men, and being pulled down by his own disgruntled staff (though he was subsequently reinstated), he would leave the mark of his strong personality on every aspect of French science. Among his achievements was not only mastery of the motions of the planets but the introduction of telegraphy to timekeeping and longitude determinations, as well as pioneering work in meteorology.

Though the discoverer of Neptune is presented here in his full glory, the less familiar post-Neptunian giant of French science appears here for the first time, at

least to the English-speaking world. For Le Verrier lived another 31 years to the day after the celebrated discovery of Neptune. His later career, rich with accomplishment, has been comparatively little studied. James Lequeux's long-overdue biography at long last restores some sense of balance.

James Lequeux's book is not only authoritative, and likely to remain so for the far foreseeable future, it is also well timed, as 2011 marked both the bicentennial of Le Verrier's birth and the celebration of Neptune's first complete orbit of the Sun since its discovery. Four times, in 2010–2011, Neptune returned to the same field of stars where, on 23/24 September 1846, Galle spotted it and d'Arrest exclaimed: "That star is not on the map!" We will have to wait another 165 Earth years for it to do so again.

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http://www.springer.com/978-1-4614-5564-6

Le Verrier—Magnificent and Detestable Astronomer

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2013, XVI, 337 p., Hardcover
ISBN: 978-1-4614-5564-6