

# *Le Verrier: The Celestial Mechanic*

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Urbain Jean Joseph Le Verrier, who was born 190 years ago, is best known for his role in the discovery of the planet Neptune. By applying the principles of Newtonian mechanics to the unusual motion of Uranus, he deduced the presence of a previously unknown planet whose gravitational pull accounted for the discrepancy. Using the same scientific methods, Le Verrier also analyzed peculiarities of Mercury's orbit, and postulated the existence of another planet that was never found.

Le Verrier was born on March 11, 1811, in St-Lô, Normandy, France. His father, a minor government official, sold the family home to finance Le Verrier's education at the École Polytechnique in Paris. Although Le Verrier started his career as a chemist in the laboratory of Gay-Lussac (1778–1850), in 1836 he was recruited to be an astronomy teacher at the École. He took up the study of celestial mechanics that had become a specialty of his countrymen, Lagrange (1736–1813) and Laplace (1749–1827). In the years 1845–46, Le Verrier concentrated on the irregularities of the motions of the planets Mercury and Uranus, with the encouragement of the Director of the Paris Observatory, François Arago (1786–1853).

Isaac Newton (1642–1727) had paved the way for the precise mathematical description of planetary motion with his development of the Laws of Motion and the Universal Law of Gravitation. However, the initial triumphs of these theories were restricted to the simple case of two-body motion; for example, a single planet travelling around the Sun, ignoring the

effects of all other bodies. For a body bound to the Sun, the orbital motion is a perfect ellipse, with specified major axis and eccentricity (out-of-roundness), the ellipse occupying a fixed orientation in space. The planet moves on this unchanging orbit almost like a bead on a wire, endlessly revolving on the same course. As soon as a third body is introduced to the system, the additional mutual attractions destroy this perfect picture; the orbit of the planet is no longer a perfect ellipse. (There do exist some mathematically simple solutions to the “three-body problem” but the conditions for their existence are so peculiar that they are never realized in Nature.) In general, the motion of three or more bodies moving under the influence of mutual gravitational attraction is mathematically predictable, but without apparent pattern — a classic example of chaos.

In cases where there is a single large attracting body, such as the Sun in the Solar system, we are rescued from this seemingly hopeless state of confusion by perturbation theory. If the masses of the minor bodies in the system are sufficiently small, over a short interval of time (which is still many, many revolutions of the planets around the Sun), it appears as though each planet is following its own, unchanging, elliptical orbit, regardless of the motions of the others. The influence of the Sun dominates the effects of the other bodies on each other; however, over time it will be seen that the size, shape, and orientation of the orbital ellipses slowly shift in response to the gentle tugs of the secondary bodies. Instead of a planet endlessly drawing out the same



A French postage stamp bearing the likeness of Urbain Le Verrier. (Issued 1958 February 15, Scott catalogue # 870)

ellipse repeatedly, the path of the planet traces out a complex curve that almost (but not quite) joins up after one revolution. (I am reminded of the multi-lobed curves produced by the child's toy known as the Spirograph. Do they still make those?)

Le Verrier's analysis of the orbit of Mercury discovered the planet's orbital precession; that is, the planet is a little further ahead after one revolution than the position predicted by simple Newtonian analysis. Even when the perturbative effects of all the other planets were accounted for, still there was a discrepancy of 40 seconds of arc per century (about one hundredth of a degree). Le Verrier's

study of Mercury lasted much of his life. Flushed by his success in predicting the existence and location of Neptune (described below), he deduced that there was another undiscovered planet causing the discrepancy in Mercury's motion. He became so confident of the existence of this planet he gave it the name Vulcan, after the blacksmith of the gods. This prediction fueled the search for an intra-Mercurian planet, which had already begun. There were several false alarms, and Le Verrier himself was convinced that the planet had been seen, but we now know that there is no such planet.

This part of Le Verrier's story does not end here, however, as the mystery of the precession of Mercury's orbit was eventually solved by Albert Einstein (1879–1955). Einstein's General Theory of Relativity is a radical departure from the Newtonian view of gravity and dynamics, but the differences are almost undetectable when applied to the motion of the solar system. Only in the case of Mercury, the planet subjected to the strongest gravitational field, are the relativistic effects significant (although still small). The precession noticed by Le Verrier is explained exactly by Einstein's theory. Today, Einstein's relativistic corrections are absolutely necessary to correctly interpret time and positional data of Earth satellites used in the Global Positioning System.

Le Verrier's work on the precession of Mercury gained him admission to the prestigious Paris Academy of Sciences in 1846. Arago urged him to study the motion of Uranus, which had only been followed for a half-century or so. This planet was not quite in the position predicted by Newtonian analysis of its motion. This time, Le Verrier's calculations paid off: he estimated the size and position of a planet needed to explain the motion of Uranus, and he wrote to Johann Galle (1812–1910) at the Berlin Observatory. Galle was the younger man, and had sent his doctoral dissertation to Le Verrier for comment; the Neptune prediction was only a passing comment in Le Verrier's reply. With the reluctant permission of the observatory director, Johann Encke (1791–1865), Galle began to search for the new planet on September 23, 1846, and found it at once, with the help of some newly printed star charts compiled by Carl Bremiker (1804–1877) and suggested by his doctoral student assistant Heinrich d'Arrest (1822–1875).

Unknown to Le Verrier, the Englishman John Couch Adams (1819–1892) had followed the same line of reasoning, but had difficulty having his prediction followed up by the British scientific establishment. Once the Le Verrier-Galle discovery was announced, supporters of Adams unsuccessfully attempted to have the priority of prediction

ascribed to Adams. There followed an acrimonious debate between English and French scientific camps that spilled into the popular press. John Herschel (1792–1871), whose father William had discovered Uranus, was instrumental in casting oil on the troubled scientific waters, and he eventually introduced Le Verrier and Adams at a scientific meeting in 1847, after which they became friends. Today, both Le Verrier and Adams are given equal credit for the achievement. Le Verrier received the Copley Medal of the Royal Society of London and became an officer of the Legion of Honour in France.

Le Verrier's subsequent career was somewhat chequered. He supported the 1848 Republican revolution, but quickly switched sides when Louis Napoleon restored the Empire. Le Verrier succeeded Arago as the Director of the Paris Observatory, but proved to be a demanding and unpopular boss, and was eventually removed from the position. He died in Paris on September 23, 1877, on the 31<sup>st</sup> anniversary (to the day) of the discovery of Neptune. ●

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'Tis the season to be Messier...

