Biographical Encyclopedia of Astronomers

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Leibniz, Gottfried Wilhelm

Born Leipzig, (Germany), 1 July 1646

Died Hanover, (Germany), 14 November 1716

Gottfried Leibniz was one of the most universal scholars Europe has produced: a mathematician, a philosopher, and a logician of the first order, as well as a considerable physicist, historian, jurist, and diplomat. His father, Friedrich Leibniz, was a professor of moral philosophy at the University of Leipzig. His mother, Catherina, Friedrich's third wife, was the daughter of a prominent jurist and a very pious woman who took care of Gottfried and his two half-siblings once her husband died in 1652. Leibniz was a very precocious child who spent many an hour in his father's library and taught himself Latin by reading Livy. His formal education took place at the University of Leipzig, where he earned a law degree in 1665. In 1672, Leibniz went to Paris, where he stayed until 1676. The Parisian period was crucial to his intellectual development, for there he was exposed to Cartesianism and became acquainted with the leading thinkers of his time, including Nicolas Malebranche and Christiaan Huygens. By the end of his stay in Paris, Leibniz had invented calculus, although he postponed its publication until 1684. This invention later became the source of a very acrimonious dispute with Isaac Newton, who, although he had invented his own version in the mid-1660s, did not publish it until 1693. Though the evidence suggests that Leibniz and Newton invented calculus independently, it was Leibniz who produced the principal notation that is still in use and who had the greatest impact on the discipline through the work of his immediate followers, such as Guillaume de l'Hospital.

At the end of 1676, Leibniz became librarian to the Duke of Brunswick at Hanover, a post he held for the rest of his life. He traveled for some time in Italy to collect material for his history of the House of Brunswick, which, however, was never published. Perhaps because of this failure, and perhaps in part because of personal dislike, when George Louis, the Duke of Brunswick, became King of England as George I in 1714, he did not take Leibniz along to London as a court historian, in spite of Leibniz's pleas. Leibniz was compelled to remain in Hanover, where he died almost in disgrace.

Leibniz's astronomical contributions are to be found in his efforts at explaining planetary motions. Like Huygens, he never accepted Newtonian gravitation because of its apparent mechanical inexplicability Quite reasonably, Leibniz became convinced that, according to the Newtonians, gravity is a primitive property of matter, that is, a property not further explainable in material terms. Although Newton, at least publicly, professed agnosticism on whether gravity is primitive to matter or not, some of his followers, such as Roger Cotes, seem to have been ready to think of universal gravitation as primitive in the sense of being essential to matter, and others, such as Samuel Clarke, publicly held that gravitation is a primitive feature of matter ultimately caused by continuous divine intervention. Leibniz considered these views to be poor science and worse, theology. As a result, although he clearly understood Newton's

revolutionary achievement in connecting mechanics and astronomy in the Principia, he tended to downplay its physical significance. Even if Newton had shown the exact mathematical relation between centripetal forces and Johannes Kepler's area law, he had not given any explanation of them. In this respect, Newton had provided a clever mathematical model but not a physical explanation of the motions of the planets. René Descartes's vortices, by contrast, provided a physical explanation of the motion of the planets, but a mathematically incorrect one, since, for example, Kepler's area law cannot be derived from it. Leibniz saw himself as providing a vortical theory that is also mathematically correct.

Leibniz's attempt is the *Tentamen De Motuum Coelestium Causis*, published in 1689 and, contrary to his claims, composed after he had seen Newton's *Principia*. In it, he argued that since all bodies tend to move uniformly and to recede along the tangent when moving in a curve, planets must be constrained and moved by an ethereal matter because their motion is not uniform; they move faster when closer to the Sun—and curved. Leibniz then supposed that this subtle matter moves around the Sun with harmonic motion, at a speed that

is inversely proportional to the distances, or radii, from the Sun. Each planet floats in this fluid and is endowed with two motions: a transradial one in which it is carried by and moves exactly like the fluid (harmonically), and a radial motion, which Leibniz called "paracentric," in which it moves along the radius from layer to layer of the fluid. The paracentric motion itself is the result of two radial impulses: a gravitational one, the mechanism of which Leibniz did not explain, and a centrifugal one arising from the planet's transradial motion and measured by the square of the transradial velocity divided by the distance from the center. The transradial harmonic motion provides Kepler's area law, while the positing of a Keplerian elliptical orbit traversed with such a harmonic motion produces the inverse-square law of gravitation

Although, at the end of the *Tentamen*, Leibniz had to admit that, despite the fact that his mechanical model of planetary motion involved a centripetal impulse toward the Sun, he had not provided an explanation of gravity. In letters, notes, and personal reworkings of the Tentamen, he considered various mechanical models, apparently favoring two. One involved a fluid propagating from the center in accordance with the inverse-square law, in analogy with light. The fluid penetrated bodies through their pores, and since there was less receding fluid in them than elsewhere, they were pushed back toward the center in proportion to the number of their pores. The other was a modification of Huygens's model for terrestrial gravity based on fluid matter moving in all directions on spherical surfaces around the Earth Leibniz assumed the equality of vis viva in each circle of fluid, suggesting that it could explain the stability of the fluid system, and managed to infer Kepler's third law and the inverse-square law.

The *Tentamen* was vehemently criticized by Newton and his followers, who argued that it bristled with errors. John Keill, giving public voice to Newton's views, called it "the most absurd piece of philosophy ever written." However, some of Newton's mathematical criticisms were ill taken, and some of the physical ones did not fare much better. For example, the claim that a vortical theory of attraction entails that bodies are pushed to the axis of the vortex and not to the center was based on Leibniz's mostly rhetorical praise of the alleged vortex theory of gravitation by Descartes, and not on Leibniz's actual unpublished models which, like Huygens's, overcome the problem Similarly, E. J. Aiton has argued that Newton's critique of

Leibniz's notion of centrifugal force as not being equal and opposed to gravitational force missed the point that Leibniz was working within a framework that owed more to Huygens than to him.

Still, Leibniz's theory did have very serious problems, some of which were pointed out early on. In spite of Leibniz's attempts, Huygens, whose rejection of nonmechanical gravitation was as firm as his, could not see the need for the harmonic vortex. He asked Leibniz why the harmonic vortex is necessary given Newton's system, in which "the movement of the planets is explained by the heaviness towards the Sun and the vis centrifuge, which are in balance." *Vis centrifuge* aside, Huygens's question was about the apparent redundancy of Leibniz's theory: Why did Leibniz want the harmonic vortex in addition to that which produces gravity? Leibniz replied that one reason was that the harmonic vortex explains why all the planets move roughly in the same plane and in the same direction, while a theory like Newton's cannot

Huygens and James Gregory also noted that Leibniz's system fails to produce a satisfactory account of the motion of comets because they would be impeded by the Leibnizian vortices. Leibniz answered that the vortex does not significantly impede the motion of comets passing through it, although it does conserve the motion of planets within it. But even if one were to accept Leibniz's answer, his theory suffers from other problems. For one thing, how the fluid in harmonic motion can offer no resistance to radial motion while pushing the planet transradially is unclear. Nor is it clear how the harmonic vortex and the gravitational vortex postulated in an attempt to explain gravitational impulses can avoid interacting. More seriously, the harmonic vortex transports the planet, which therefore moves in accordance with Kepler's law of the areas, but it is the gravitational vortex that rotates in accordance with Kepler's third law; in the end, Leibniz could not account for Kepler's three laws together.

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