Biographical Encyclopedia of Astronomers

Euler, Leonhard

Born Basel, Switzerland, 15 April 1707.

Died Saint Petersburg, Russia, 18 September 1783.

Leonhard Euler made major contributions to celestial mechanics and spherical astronomy, as well as to mathematics and physics.

Leonhard's father, Paulus Euler, was a Protestant minister and married Margaretha Brucker in 1706. The family moved to the village of Riehen, near Basel, where Euler spent his childhood. In 1720 he joined the Department of Arts of the University of Basel, where he received his *prima laurea* (bachelor's degree) in 1722. One year later, Euler received his master's degree in philosophy, which was on comparing the world systems and theories of gravitation of René Descartes and Isaac Newton. In 1723, he joined the Department of Theology, but devoted most of his time to mathematics Euler was given the opportunity to attend private lectures by Johann Bernoulli, who recognized Euler's extraordinary potential in mathematics. At the age of 18, Euler began his own investigations into mechanics and mathematics. He left Basel in 1727 to accept an invitation from the newly organized Saint Petersburg Academy of Sciences. There he became professor of physics in 1731 and succeeded Daniel Bernoulli.

At the young Russian academy, Euler was surrounded by first-rank scientists, such as Jakob Hermann, Bernoulli, Christian Goldbach, and the astronomer and geographer Joseph Delisle, who introduced him to the current problems in theoretical, observational, and practical astronomy. In 1733, Euler married Katharina Gsell, and in 1734, Johann Albrecht was born, the first of their 13 children.

Following an invitation from Frederick the Great of Prussia, Euler moved to Berlin with his family in 1741. He was appointed director of the mathematical class of the academy and deputy to the academy's president, Pierre de Maupertuis. After Maupertuis's death in 1759, Euler continued to preside over the academy, although without the title of president. During this period, he considerably broadened the scope of his investigations and, competing with Jean d'Alembert, Alexis Clairault, and D. Bernoulli, laid theoretical foundations of mathematical physics and astronomy

Conflicts with King Frederick caused Euler to leave Berlin in 1766 and return to the Saint Petersburg Academy, with which he had maintained regular working contacts. Together with his son Johann Albrecht, Euler was a member of the commission in charge of the academy's management in 1766. Illnesses in 1738 and 1766 had damaged his eyesight, and by 1771 he was completely blind. Yet his blindness did not lessen his scientific activity.

Euler was a member of the academies of sciences of Saint Petersburg (1731), Berlin (1746), and Paris (1755), and was a fellow of the Royal Society of London (1746). He died of a brain hemorrhage

Euler's astronomical works address three fields of research: celestial mechanics, spherical astronomy and astronomical geodesy, and geo- and astrophysics ("cosmical physics"). His main interests, however, were focused on celestial mechanics.

Euler developed the theory of the motions of two bodies in his *Mechanica*, published in 1736, which he considered not only as

An introduction to celestial mechanics, but also the foundation of all mechanics. The novelty of this book lies in its use of analysis rather than geometry to mathematically describe the free and constrained motions of point-like masses in empty space as well as in resisting media. Euler studied the motion of a particle around a central body when subjected to a central force (Keplerian motion). An important application concerns the determination of the orbits of planets and comets. Stimulated by the appearance of two great comets in 1742 and 1744 (C/1742 C1 and C/1743 X1), Euler developed new methods to determine the (elliptical) orbits of planets and the (parabolic) orbits of comets

Euler wrote several treatises on the mutual perturbations of celestial bodies due to the inverse-square law of gravitation (perturbation theory), usually assuming the accelerations or perturbative forces as given and developing their effects on the orbital elements. He tried to solve the general problem of perturbation analytically, in particular the general problem of three bodies. He found solutions for special cases, which he called "restricted three-body problems." Euler applied these theories to four main astronomical problems that could be solved (at least approximately) by such theories: (1) the theory of the motion of the planets around the Sun, in particular the inequalities in the respective motions of Jupiter and Saturn (Great Inequality), (2) the motion of the barycenter of the Earth-Moon system around the Sun, considering gravitational interactions of the planets, (3) the motion of the Moon around the Earth, and (4) the rotation and figure of the Earth (lunisolar precession and nutation). For the latter two problems, both the Earth and Moon had to be treated as extended rigid bodies. Euler's best-known discovery is the famous equations describing the rotational motion of rigid bodies, which first appeared (with respect to an inertial frame of reference) in 1752. He completed the theory of the motion of rigid bodies in 1765. The "Eulerian equations" with respect to a body-fixed coordinate system also first appeared in 1765. He found special solutions to these equations, in particular in the absence of external torques (Eulerian free nutation). These studies on rigid bodies evidently stimulated Euler in 1759 to develop the theory of the two- and three-body problem applied to rigid bodies.

For Euler, empty space was not an acceptable idea. He postulated instead the existence of an omnipresent, extremely thin and subtle continuous "matter," characterized by extremely high elasticity and extremely low density. This medium is Euler's ether, and he derived gravity from ethereal pressure Euler also used this model to explain secular effects in the motions of the Moon (secular acceleration) and the planets (long-time variations of the orbital elements, e.g., gradual shrinking of orbits) caused by ethereal resistance. But this model was insufficient to explain all inequalities, particularly the motion of the Moon's apogee. In this case, Euler questioned the validity of the inverse-square law and formulated and used (in several of his treatises) the law of attraction in a more general way. When Clairault proved the correctness of the inverse-square law in the case of the Moon's apsidal motion in 1750, this matter was definitively settled.

The earliest published astronomical tables incorporating perturbations deduced analytically from the inverse-square law of gravitation appear to have been Euler's *Novae et correctae tabulae ad loca lunae computanda* and *Tabulae astronomicae solis & lunae*, published in 1745 and 1746, respectively.

Euler developed the formulae of spherical trigonometry and used them for transformations of celestial coordinates, probably inspired by his own studies on the theory of rotation of celestial bodies. He contributed to the reduction of astronomical observations Euler developed new methods for determining and calculating effects such as precession, nutation, aberrations, parallaxes, and refractions, which must be considered when processing astromometric observations of the positions of celestial bodies. Moreover, Euler was aware that his solar, lunar, and planetary theories could only be modeled with sufficient accuracy by using correctly reduced observations. Some of his papers are therefore devoted to determining astronomical constants associated with these effects. Euler developed a new and general processing method for estimating the solar parallax by transits of Venus and determined a value very close to the present-day value.

Euler wrote several papers on the physical constitution of celestial bodies (mainly on comets) as well as on celestial and terrestrial phenomena related to the Earth's atmosphere or its magnetic field. Most prominent is his theory on the physical cause of comet tails, of the northern lights, and of the zodiacal light, which he tried to explain by one and the same physical process.

Euler's memoir published in 1752 may be regarded as one of the first studies on photometric astrophysics. He developed a theory of the intensities of illuminations from celestial bodies for stars, planets, and satellites. Euler then tried to determine the distances and physical constitutions of these bodies from their apparent brilliances and found that "the material of the Sun has to be totally different from any burnable matter on Earth, and that it must be in such a state of heating as no body on Earth could ever be."

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