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(*b*. Perinaldo, Imperia, Italy, 8 June 1625; *d*. Paris, France, 14 September 1712),

astronomy, geodesy.

The first of a family of astronomers who settled in France and were prominent in directing the activities of the French school of astronomy until the Revolution, Cassini was the son of Jacopo Cassini, a Tuscan, and Julia Crovesi. Raised by a maternal uncle, he studied at Vallebone and then at the Jesuit college in Genoa and at the abbey of San Fructuoso. He showed great intellectual curiosity and was especially interested in poetry, mathematics, and astronomy. He was attracted at first by astrological speculations, but reading Pico della Mirandola's pamphlet *Disputationes Joannis Pici Mirandolae adversus astrologiam divinatricem* persuaded him of the frivolity of that pseudoscience. Yet, paradoxically, the beginning of his scientific career benefited from the reputation he acquired for his knowledge of astrology. The Marquis Cornelio Malvasia, a rich amateur astronomer and senator of Bologna who calculated ephemerides for astrological purposes, invited him to come to work in his observatory at Panzano, near Bologna.

In accepting this position Cassini initiated the first part of his career, which lasted until his departure for france in February 1669. Thanks to the marquis's aid, he thus made use, from 1648, of several instruments that allowed him to begin his first researches. He was also able to complete his education under the tutelage of two excellent scientists, the Bolognese Jesuits Giovan Battista Riccioli—who was then finishing his great treatise, the *Almagestum novum* (1651)— and Francesco Maria Grimaldi, who later became famous for his discovery of the phenomenon of diffraction, published in his posthumous work *De lumine* (1665). Although one cannot exactly determine their influence on the young Cassini, it appears that they convinced him of the importance of precise and systematic observation and of the necessity of a parallel improvement in instruments and methods. They probably likewise contributed, less happily, to making him wary of the new theories—especially of Copernicus' system—and to reinforcing in him the conservative tendencies that he displayed throughout his life.

With his first works Cassini won the esteem of his fellow citizens to such an extent that in 1650 the senate of Bologna, on the recommendation of its patron, designated him to occupy the principal chair of astronomy at the university, which had been vacant since Bonaventura Cavalieri's death in 1647. Cassini was actively interested in planetary astronomy and in 1653 wrote to Pierre Gassendi requesting precise observations concerning the superior planets. In 1652–1653 the passage of a comet attracted his attention. In the account of his observations he accepted that the earth is at the center of the universe, that the moon possesses an atmosphere, and that the comets, which are situated beyond Saturn, are formed as a result of emanations originating from the earth and the planets. But he affirmed later that comparison with other observations soon led him to reject the latter theory, of Aristotelian inspiration, and to adopt that of Apollonius of Myndos; thus he now considered the comets as heavenly bodies analogous to the planets but describing trajectories of very great eccentricity.

A happy circumstance permitted him to reveal his practical abilities. Since the determination of certain essential astronomical data is tied to the movement of the sun (solstices, obliquity of the ecliptic, and so forth) and thus requires the daily observation of the height of that body at the time of its passage to the meridian, astronomers for a long time had tried to increase the precision of these observations by employing high structures—churches in particular— as supports for large sundials, called meridians. Such was the case at the church of San Petronio of Bologna, where an important meridian had been constructed in 1575 by a predecessor of Cassini in the chair of astronomy at the university, Egnatio Danti. Unfortunately, structural modifications necessitated by the enlargement of the church had recently rendered this meridian unusable by blocking the orifice through which the solar rays entered. In 1653, Cassini, wishing to employ such an instrument, sketched a plan for a new and larger meridian but one that would be difficult to build. His calculations were precise; the construction succeeded perfectly; and its success made Cassini a brilliant reputation.

During the following years Cassini made with this meridian numerous observations on the obliquity of the ecliptic, on the exact position of the solstices and the equinoxes, on the speed of the sun's apparent motion and the variation of its diameter, and even on atmospheric refraction; for all these phenomena he provided increasingly more precise measurements. His principal observations, published in *Specimen observationum Bononiensium*… (1656), are dedicated to Queen Christina of Sweden, then in exile in Italy. In later publications he drew upon other of the measurements he made by means of the meridian of San Petronio.

Activities of a more technical nature, however, were to oblige Cassini to abandon astronomical research to some extent. As an official expert delegated by the Bolognese authorities, he participated in 1657 in the settlement, directed by Pope Alexander VII, of a dispute between the cities of Bologna and Ferrara concerning the course of the Reno River. On this occasion he composed several memoirs on the flooding of the Po River and on the means of avoiding it; moreover, he also carried out experiments in applied hydraulics. In the course of the following years he was charged with various further missions and important technical functions. In 1663 he was named superintendent of fortifications and in 1665 inspector for Perugia.

In 1663 Cassini defended the views of the papal authorities before the grand duke of Tuscany at the time of the controversies regarding the regularization of the waters of the Chiana River. He returned to Tuscany in 1665 for the same purpose, with the title of superintendent of the waters of the ecclesiastical states. Requested by the pope to take holy orders, he declined to do so and endeavored to reconcile the exercise of his functions at the papal court with his teaching at the University of Bologna. He was resolved not to give up his purely scientific activity, and he accordingly took advantage of his numerous trips to participate in certain meetings of the Accademia del Cimento in Florence, to make observations on insects, and to carry out experiments on blood transfusion at Bologna.

Astronomy, however, remained his preoccupation. In 1659 he presented a model of the planetary system that was in accord with the hypothesis of Tycho Brahe; in 1661 he developed a method, inspired by Kepler's work, of mapping successive phases of solar eclipses; and in 1662 he published new tables of the sun, based on his observations at San Petronio. He also elaborated the first major theory of atmospheric refraction founded on the sine law. Although his model of the atmosphere was incorrect, the tables that he made in 1662 were later successfully employed in the construction of the ephemerides, before being corrected in accordance with the observations made by Jean Richer in Cayenne in 1672. In 1664 Cassini published an observation of a solar eclipse made at Ferrara. The study of comets, however, continued to hold his special interest. In 1664–1665 he observed one of them in the presence of Queen Christina and formulated on this occasion a new theory (in agreement with the Tychonian system) in which the orbit of the comet is a great circle whose center is situated in the direction of Sirius and whose perigee is beyond the orbit of Saturn.

A new and fertile direction now opened up for Cassini's observations. Through his friendship with the famous Roman lensmakers Giuseppe Campani and Eustachio Divini, Cassini, beginning in 1664, was able to obtain from them powerful celestial telescopes of great focal length. He used these instruments—very delicate and extremely accurate for the time— with great skill, and made within several years a remarkable series of observations on the planetary surfaces, which led him to important discoveries. In July 1664 he detected the shadow of certain satellites on Jupiter's surface and was thus able to study the revolution of the satellites and to demonstrate that of the planet; the period that he attributed to the latter, $9^h 56^m$, is close to the presently accepted value. At the same time, he described the whole group of the planet's bands, as well as its spots, and observed its flattening. This discovery involved him in polemics which, far from diminishing his activity, incited him to pursue his research and his observations. At the beginning of 1666 he observed the spots on Mars and investigated the rotation of that planet, whose period hecalculated at $24^h 40^m$ (three minutes less than the value presently accepted). He made the same observations regarding Venus in 1667, but in a less precise form.

Cassini likewise worked on establishing tables of movements of the satellites of Jupiter, a task that Galileo had undertaken primarily in order to obtain a solution to the problem of the determination of longitudes. While Galileo was unable fully to develop these tables owing to a lack of sufficiently precise and complete observations, and while his direct successor, Vincenzo Renieri, similarly failed, Cassini succeeded in this enterprise and published in 1668 his *Ephemerides Bononienses mediceorem siderum*. These ephemerides were employed for several decades by astronomers and navigators, until they were replaced by the more precise tables that Cassini published in Paris in 1693; in particular, they were used by Olaus Römer in his demonstration, in 1675, that light has a finite speed.

The fame that these tables, as well as his important discoveries concerning the planets, brought to Cassini was to change his destiny and to open up for him a new and brilliant career at Paris, at the recently founded Académic Royale des Sciences. Desiring to enhance the prestige of the Academy, Colbert endeavored to attract to France several famous for eign scientists. Thus, after having recruited Christian Huygens before the Academy actually opened, in 1667, he offered Cassini membership as a regular correspondent.

Cassini accepted, and in 1668 Colbert proposed that he come to Paris for a limited period, under attractive financial conditions, to help set up the observatory, the construction of which had just begun. Several persons took part in this negotiation, including the astronomer Adrien Auzout; the terms settled upon were an annual pension of 9,000 livres (Huygens himself received only 6,000 livres), free lodging, and a travel allowance of 1,000 écus. After a second, diplomatic discussion, the senate of Bologna and the pope authorized Cassini at the end of 1668 to accept the invitation, while maintaining both the various titles he had acquired in Italy and their corresponding emoluments. In fact, his departure from Bologna on 25 February 1669 marked not the beginning of a long foreign mission but the end of his Italian career.

Cassini arrived in Paris on 4 April and was very cordially received by the king five days later. He immediately began to participate in the activities of the Academy, taking an active role in the enterprises already under way. Since he had a particular interest in the construction of the observatory, he strove in vain to modify the plans, which had been conceived by Claude Perrault and approved by the Academy. Cassini thought to remain in France for only the brief time arranged and then to resume his previous duties and way of life; therefore he at first made little effort to accustom himself to French life. Moreover, he spoke French only haltingly; and his rather authoritarian character and privileged situation, due to the favor of the Crown, provoked considerable hostility from the moment of his arrival.

He gradually got used to speaking French, however. He was delighted by the living and working conditions provided for him. The ambition to organize and direct the important research program of the Academy fortified his resolve. With all this, Cassini succeeded in overcoming much of the opposition he had encountered and in winning essential collaboration. In September 1671 he moved into the apartment prepared especially for him in the new observatory, where work was now beginning. Although this establishment had in theory been placed under the collective respon sibility of the astronomers of the Academy, Cassini assumed the effective direction of it. He then decided to settle in France, and on 14 July 1673 he obtained the benefits of French citizenship. In 1674 he married Geneviève de Laistre, the daughter of the lieutenant general of the *comté* of Clermont, whose dowry of valuable landholdings included the château of Thury in the Oise, which became the family's summer residence. From this marriage Cassini had two sons; the younger, Jacques, succeeded him as astronomer and geodesist under the name of Cassini II.

The important work that Cassini accomplished in France encompassed quite diverse aspects. Some were related to the continuation of his Italian projects and to the exploitation of the new paths that he had opened; others pointed toward new directions brought to light by discussions among the Academicians and by the possibilities offered by the new observatory.

While remaining faithful to certain traditional methods (he had a gnomon constructed in the great hall of the observatory), Cassini strove to follow the rapid progress of technology and to utilize recent inventions and improvements: lenses of high focal length, the micrometer, and the attachment of eyepieces to measuring instruments. A large of ficial subsidy allowed the purchase of new instruments which were thus employed for observations regularly made at the observatory as well as in preparing the ephemerides, in improving the celestial map, and in various researches: they were further used in the course of the numerous geographic, geodesic, and astronomical expeditions carried out under the patronage of the observatory. These instruments included quadrants, octants, equatorials, telescopes, and azimuth compasses and such original contrivances as a main mast and a wooden tower 120 feet high erected on top of the observatory to permit the use of the most powerful lenses.

Cassini continued the observational work begun in Italy using a lens made by Campani with a focal length of seventeen feet that he had brought from Italy, as well as others even more powerful (up to a focal length of 136 feet), commissioned from either Campani or Divini, or from French lensmakers. In September 1671 he discovered a second satellite of Saturn, Iapetus (VIII), and explained that the variations in its brightness were due to its always turning the same face toward Saturn. In 1672 he observed a third satellite, Rhea (V), and on 21 March 1684, two others, Tethys (III) and Dione (V). Moreover, his remarkable abilities as an observer allowed him to discern a band on the surface of the planet and to discover, in 1675, that its ring is subdivided into two parts, separated by a narrow band (Cassini's division). He suggested that the two parts are constituted by the aggregation of a very great number of corpuscles, each of which is invisible and behaves like a tiny satellite; this hypothesis has been verified by spectroscopy. Between 1671 and 1679 he observed the features of the lunar surface and sketched an atlas that enabled him to draw a large map of the moon, which he presented to the Academy in 1679. In 1683 he observed, following Kepler, the zodiacal light and had the merit of considering this phenomenon as being of a cosmic, not a meteorological, order. It is true, however, that he linked it in part to a completely false theory of the solar structure.

In 1680 the appearance of a particularly spectacular comet led Cassini back to one of his favorite subjects. Yet while Newton drew decisive arguments from this occasion for his gravitational theory, Cassini saw in it the confirmation of the cogency of his method of studying cometary trajectories and of his theory limiting these trajectories to a band of the celestial vault, the cometary zodiac.

The tables of the eclipses of the satellites of Jupiter that Cassini had published in 1666 were utilized for the determination of longitudes in the course of numerous worldwide expeditions undertaken by French astronomers (in Denmark, the coast of France, Cayenne, Egypt, the Cape Verde Islands, and the Antilles, among other places). As initiator of the new method, Cassini made the observations at Paris to serve as controls and coordinated the results on a large planisphere. Beyond its geographical implications, Richer's expedition to Cayenne in 1672–1673 had several astronomical objectives, of which the most important was the determination of the parallax of Mars during its opposition of 1672; it was accomplished through the simultaneous observations made by Richer at Cayenne and by Cassini and Jean Picard in Paris. The result obtained, 25´, enabled them to fix the parallax of the sun at 9.5´ (instead of 8.8´) and to calculate for the first time with a reasonable approximation the mean earth-sun distance and the dimensions of the planetary orbits. The members of this expedition were also able to study atmospheric refraction near the equator and to correct the tables previously published by Cassini. Finally, Richer observed that the length of a pendulum with a frequency of once a second is less at Cayenne than at Paris, an unexpected fact whose interpretation provoked ardent polemics for two thirds of a century. Whereas Richer thought this phenomenon could be explained by the flattening of the earth and while Huygens— quickly followed by Newton but through a different approach—arrived at this same conclusion, Cassini believed in the sphericity of the earth and attempted to explain the phenomenon by temperature differences. Settlement of the debate required better measurements of arcs of meridian than those taken by Picard between Paris and Amiens from 1668 to 1670. In 1683 Cassini obtained an agreement from Colbert and the king to extend the earlier measurement (an arc of approximately 1°21´) to an arc of 8°30´ between the northern and southern frontiers of France. Assisted by several collaborators, he immediately undertook to extend the meridian of Paris toward the south, while Philippe de la Hire carried out the same operation toward the north. But in 1684 the death of Colbert and the difficult situation of the public treasury interrupted these activities at a time when Cassini had reached only the vicinity of Bourges. It was not until 1700 that the king decided to resume the project. With the aid of several collaborators, including his son Jacques and his nephew Giacomo Filippo Maraldi, Cassini measured the arc of meridian from Paris to Perpignan and, in addition, conducted various associated geodesic and astronomical operations, which he reported on to the Academy. The result of this last great expedition directed by Cassini led him to adopt the hypothesis of the lengthening of the terrestrial spheroid, which was viewed favorably by the Cartesians. His direct successors, moreover, were to defend this hypothesis with a certain obstinacy.

The traditionalist character shown by Cassini's position in this controversy is characteristic of the majority of his theoretical conceptions. While it seems that in 1675 he narrowly preceded Römer in formulating the hypothesis of the finite speed of light to explain certain irregularities in the apparent movements of Jupiter's satellites, he soon rejected this explanation and, as a resolute Cartesian, combated Römer's theory, which had the support of Huygens. Likewise Cassini was a determined opponent of the theory of universal gravitation. Moreover, while he seems to have renounced Tycho Brahe's planetary system, his Copernicanism remained very limited, especially as he proposed to replace the Keplerian ellipses by curves of the fourth degree (ovals of Cassini), a locus of points of which the product of the distances to two fixed points is constant.

At the beginning of the eighteenth century, Cassini's activities declined rapidly, and his son Jacques gradually replaced him in his various functions. His last two years were saddened by the total loss of his sight.

Judgments on Cassini's work vary greatly. While many historians, following Jean-Baptiste Delambre, accuse him of having found his best ideas in the writings of his predecessors and of having oriented French astronomy in an authoritarian and retrograde direction, others insist on the importance of his work as observer and organizer of the research at the Observatory. Although Cassini's control did restrict the Observatory's studies and although he did fight against most of the new theories, his behavior does not seem as uniformly tyrannical and baleful as Delambre described it. He was not a theoretician; he was, however, a gifted observer and his indisputable discoveries are sufficient to win him a high position among the astronomers of the pre-Newtonian generation.

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