INTRODUCTION

PHYSICAL ASTRONOMY

THE infinite varieties of motion in the heavens, and on the earth, obey a few laws, so universal in their application, that they regulate the curve traced by an atom which seems to be the sport of the winds, with as much certainty as the orbits of the planets. These laws, on which the order of nature depends, remained unknown till the sixteenth century, when Galileo,[1] by investigating the circumstances of falling bodies, laid the foundation of the science of mechanics, which Newton,[2] by the discovery of gravitation, afterwards extended from the earth to the farthest limits of our system.

This original property of matter, by means of which we ascertain the past and anticipate the future, is the link which connects our planet with remote worlds, and enables us to determine distances, and estimate magnitudes, that might seem to be placed beyond the reach of human faculties. To discern and deduce from ordinary and apparently trivial occurrences the universal laws of nature, as Galileo and Newton have done, is a mark of the highest intellectual power.

Simple as the law of gravitation is, its application to the motions of the bodies of the solar system is a problem of great difficulty, but so important and interesting, that the solution of it has engaged the attention and exercised the talents of the most distinguished mathematicians; among whom Laplace[3] holds a distinguished place by the brilliancy of his discoveries, as well as from having been the first to trace the influence of this property of matter from the elliptical motions of the planets, to its most remote effects on their mutual perturbations. Such was the object contemplated by him in his splendid work on the Mechanism of the Heavens;[4] a work which may be considered as a great problem of dynamics, wherein it is required to deduce all the phenomena of the solar system from the abstract laws of motion, and to confirm the truth of those laws, by comparing theory with observation.

Tables of the motions of the planets, by which their places may be determined at any instant for thousands of years, are computed from the analytical formulae of Laplace. In a research so profound and complicated, the most abstruse analysis is required, the higher branches of mathematical science are employed from the first, and approximations are made to the most intricate series. Easier methods, and more convergent series, may probably be discovered in process of time, which will supersede those now in use; but the work of Laplace, regarded as embodying the results of not only his own researches, but those of so many of his illustrious predecessors and contemporaries, must ever remain, as he himself expressed it to the writer of these pages, a monument to the genius of the age in which it appeared.

Although physical astronomy is now the most perfect of sciences, a wide range is still left for the industry of future astronomers. The whole system of comets is a subject involved in mystery; they obey, indeed, the general law of gravitation, but many generations must be swept from the earth before their paths can be traced through the regions of space, or the periods of their return can be determined. A new and extensive field of investigation has lately been opened in the discovery of thousands of double stars, or, to speak more strictly, of systems of double stars, since many of them revolve round centres in various and long periods. Who can venture to predict when their theories shall be known, or what laws may be revealed by the knowledge of their motions?—but, perhaps, *Veniet tempus, in quo ista quae nunc latent, in lucem dies extrahat et longioris aevi diligentia: ad inquisitionem tantorum aetas una non sufficit. Veniet tempus, quo posteri nostri tam aperta nos nescisse mirentur.*[5]

It must, however, be acknowledged that many circumstances seem to be placed beyond our reach. The planets are so remote, that observation discloses but little of their structure; and although their similarity to the earth, in the appearance of their surfaces, and in their annual and diurnal revolutions producing the vicissitudes of seasons, and of day and night, may lead us to fancy that they are peopled with inhabitants like ourselves; yet, were it even permitted to form an analogy from the single instance of the earth, the only one known to us, certain it is that the physical nature of the inhabitants of the planets, if such there be, must differ essentially from ours, to enable them to endure every gradation of temperature, from the intensity of heat in Mercury, to the extreme cold that probably reigns in Uranus. Of the use of Comets in the economy of nature it is impossible to form an idea; still less of the Nebulae, or cloudy appearances that are scattered through the immensity of space; but instead of being surprised that much is unknown, we have reason to be astonished that the successful daring of man has developed so much.

In the following pages it is not intended to limit the account of the *Mécanique Céleste* to a detail of results, but rather to endeavour to explain the methods by which these results are deduced from one general equation of the motion of matter. To accomplish this, without having recourse to the higher branches of mathematics, is impossible; many subjects, indeed, admit of geometrical demonstration; but as the object of this work is rather to give the spirit of Laplace's method than to pursue a regular system of demonstration, it would be a deviation from the unity of his plan to adopt it in the present case.

Diagrams are not employed in Laplace's works, being unnecessary to those versed in analysis; some, however, will be occasionally introduced for the convenience of the reader.

Notes

[1] Galilei, Galileo, 1564-1642, Galilei was born in Pisa in 1564, the son of Vincenzo Galilei, well known for his studies of music, and Giulia Ammannati. He studied at Pisa, where he later held the chair in mathematics from 1589 - 1592. He was then appointed to the chair of mathematics at the University of Padua, where he remained until 1610. During these years he carried out studies and experiments in mechanics, and also built a thermoscope. He devised and constructed a geometrical and military compass, and wrote a handbook which describes how to use this instrument. In 1594 he obtained the patent for a machine to raise water levels. He invented the microscope, and built a telescope with which he made celestial observations, the most spectacular of which was his discovery of the satellites of Jupiter. In 1610 he was nominated the foremost Mathematician of the University of Pisa and given the title of mathematician to the Grand Duke of Tuscany. He studied Saturn and observed the phases of Venus. In 1611 he went to Rome. He became a member of the Accademia dei Lincei and observed the sunspots. In 1612 he began to encounter serious

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opposition to his theory of the motion of the earth that he taught after Copernicus. In 1614, Father Tommaso Caccini denounced the opinions of Galileo on the motion of the Earth from the pulpit of Santa Maria Novella, judging them to be erroneous. Galileo therefore went to Rome, where he defended himself against charges that had been made against him but, in 1616, he was admonished by Cardinal Bellarmino and told that he could not defend Copernican astronomy because it went against the doctrine of the Church. In 1622 he wrote the *Saggiatore* (*The Assayer*) which was approved and published in 1623. In 1630 he returned to Rome to obtain the right to publish his *Dialogue on the two chief world systems* which was eventually published in Florence in 1632. In October of 1632 he was summoned by the Holy Office to Rome. The tribunal passed a sentence condemning him and compelled Galileo to solemnly abjure his theory. He was sent to exile in Siena and finally, in December of 1633, he was allowed to retire to his villa in Arcetri, the Gioiello. His health condition was steadily declining, - by 1638 he was completely blind, and also by now bereft of the support of his daughter, Sister Maria Celeste, who died in 1634. Galileo died in Arcetri on 8 January 1642. I*nstitute and Museum of the History of Science of Florence, Italy.*

[2] See note 1, *Preliminary Dissertation.*

[3] See note 18, *Preliminary Dissertation.*

[4] Laplace, Pierre Simon, marquis de, *Traité de mécanique céleste*, Paris, Chez J.B.M. Duprat, an VII [1798]-1823 [i.e. 1825].

[5] *The time will come in which the diligence of a longer age draws into the daylight those things which are now concealed. For the enquiry into so many things one lifetime is not sufficient. There will come a time in which our ancestors are astonished that we did not know such obvious things.* Translated by Ian Johnston, Malaspina University-College.