The System of the World — A Classic of Science

Astronomy

THE SYSTEM OF THE WORLD, by M. le Marquis de Laplace [published 1796], translated from the French, and elucidated with explanatory notes, by the Rev. Henry H. Harte. Dublin: MDCCCXXX (1830).

Laplace's hypothesis of the structure of the universe is one of the great summations in the history of science. It was published in two forms: in the universal language of mathematics as "Mechanique Celeste," and, for others than mathematicians to read, as "L'Exposition du Systeme du Monde." The relationship between our sun's solar system, our galaxy of stars which makes up the "milky way," and the various types of nebulae still affords one of the most fertile fields of research to astronomers, who are building larger and larger telescopes to get more data on our remotest neighboring universes.

THE preceding summary of the history of Astronomy presents three distinct periods, which referring to the phenomena, to the laws which govern them, and to the forces on which these laws depend, point out the career of this science during its progress, and which consequently ought to be pursued in the cultivation of other sciences. The first period embraces the observations made by Astronomers antecedently to Copernicus, on the appearances of the celestial motions, and the hypotheses which were devised to explain those appearances, and to subject them to computation. In the second period, Copernicus deduced from these apperances, the motions of the Earth on its axis and about the Sun, and Kepler discovered the laws of the planetary motions. Finally in the third period, Newton, assuming the existence of these laws, established the principle of universal gravitation; and subsequent Geometers, by applying analysis to this principle, have derived from it all the observed phenomena, and the various inequalities in the motion of the planets, the satellites, and the comets. Astronomy thus becomes the solution of a great problem of mechanics, the constant arbitraries of which are the elements of the heavenly motions. It has all the certainty which can result from the immense number and variety of phenomena, which it rigorously explains, and from the simplicity of the principle which serves to explain them. Far from being apprehensive that the discovery of a new star will falsify this principle, we may be antecedently certain that its motion will be conformable to it; indeed this is what we ourselves have experienced with respect to Uranus and the four telescopic stars recently discovered, and every new comet which appears, furnishes us with an additional proof.

Such is unquestionably the constitution of the solar system. The immense globe of the Sun, the focus of these motions, revolves upon its axis in twenty-five days and a half. Its surface is covered with an ocean of luminous matter. Beyond it the planets, with their satellites, move, in orbits nearly circular, and in planes little inclined to the ecliptic. Innumerable comets, after having approached the Sun, recede to distances, which evince that his empire extends beyond the known limits of the planetary system. This luminary not only acts by its attraction upon all these globes, and compels them to move around him, but imparts to them both light and heat; his benign influence gives birth to the animals and plants which cover the surface of the Earth, and analogy induces us to believe, that he produces similar effects on the planets for, it is not natural to suppose that matter, of which we see the fecundity develope itself in such various ways, should be sterile upon a planet so large as Jupiter, which, like the Earth, has its days, its nights, and its years, and on which observation discovers changes that indicate very active forces. Man, formed for the temperature which he enjoys upon the Earth, could not, according to all appearance, live upon the other planets; but ought there not to be a diversity of organization suited to the various temperatures of the globes of this universe? If the difference of elements and climates alone causes such variety in the productions of the Earth, how infinitely diversified must be the productions of the planets and their satellites? The most active imagination cannot form any just idea of them, but still their existence is, at least, extremely probable.

However arbitrary the elements of the system of the planets may be, there exists between them some very remarkable relations, which may throw light on their origin. Considering it with attention, we are astonished to see all the planets move round the Sun from west to east, and nearly in the same plane, all the satellites moving round their respective planets in the same direction, and nearly in the same plane with the planets. Lastly, the Sun, the planets, and those satellites in which a motion of rotation have been observed, turn on their own axes, in the same direction, and nearly in the same plane as their motion of projection.

The satellites exhibit in this respect a remarkable peculiarity. Their motion of rotation is exactly equal to their motion of revolution; so that they always present the same hemisphere to their primary. At least, this has been observed for the Moon, for the four satellites of Jupiter, and for the last satellite of Saturn, the only satellites whose rotation has been hitherto recognized

Phenomena so extraordinary, are not the effect of irregular causes. By subjecting their probability to computation, it is found that there is more than two thousand to one against the hypothesis that they are the effect of chance, which is a probability much greater than that on which most of the events of history, respecting which there does not exist a doubt, depends. We ought therefore to be assured with the same confidence, that a primitive cause has directed the planetary motions.

Another phenomenon of the solar system equally remarkable, is the small excentricity of the orbits of the planets and their satellites, while those of comets are very much extended. The orbits of this system present no intermediate shades between a great and small excentricity. We are here again compelled to acknowledge the effect of a regular cause; chance alone could not have given a form nearly circular to the orbits of all the planets. It is therefore necessary that the cause which determined the motions of these bodies, rendered them also nearly circular. This cause then must also have influenced the great excentricity of the orbits of comets, and their motion in every direction; for, con-

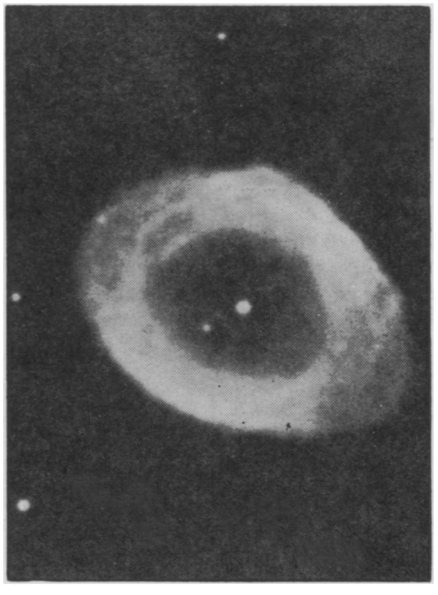
sidering the orbits of retrograde comets, as being inclined more than one hundred degrees to the ecliptic, we find that the mean inclination of the orbits of all the observed comets, approaches near to one hundred degrees, which would be the case if the bodies had been projected at random.

What is this primitive cause? In the concluding note of this work I will suggest an hypothesis which appears to me to result with a great degree of probability, from the preceding phenomena, which however I present with that diffidence, which ought always to attach to whatever is not the result of observation and computation.

Whatever be the true cause, it is certain that the elements of the planetary system are so arranged as to enjoy the greatest possible stability, unless it is deranged by the intervention of foreign causes. From the sole circumstance that the motions of the planets and satellites are performed in orbits nearly circular, in the same direction, and in planes which are inconsiderably inclined to each other, the system will always oscillate about a mean state, from which it will deviate but by very small quantities. The mean motions of rotation and of revolution of these different bodies are uniform, and their mean distances from the foci of the principal forces which actuate them are constant; all the secular inequalities are periodic.

The most considerable are those which affect the motions of the Moon, with respect to its perigee, to its nodes and the Sun; they amount to several circumferences, but after a great number of centuries they are reestablished. In this long interval all the parts of the lunar surface would be successively presented to the earth, if the attraction of the terrestrial spheroid, which causes the rotation of the Moon to participate in these great equalities, did not continually bring back the same hemisphere of this satellite to us, and thus render the other hemisphere for ever invisible. It is thus that the primitive attraction of the three first satellites of Jupiter originally established, and maintains the relation which is observed between their mean motions, and which consists in this, that the mean longitude of the first satellite minus three times that of the second, plus twice that of the third is equal to two right angles. In consequence of the celestial attractions the duration of the revolution of each planet is always very nearly the same. The change of inclination of its orbit to that of its equator being confined within narrow limits, only produces slight changes in the seasons. It seems that nature has arranged every thing in the heavens, to secure the continuation of the planetary system, by views similar to those which she appears to follow so admirably on the earth, for the preservation of individuals and the perpetuity of the species. It is principally to the attraction of the great bodies which are placed in the centre of the system of the planets, and the system of the satellites, that the stability of these systems is due, which the mutual action of all the bodies of the system, and extraneous attractions tend to derange. If the action of Jupiter ceased; his satellites, which now appear to move with such admirable

A planetary nebula. Laplace believed this type of object half way between a cloud of tenuous matter and a solar system like ours. The stuff making up the ring, according to his hypothesis, will condense into solid planets.



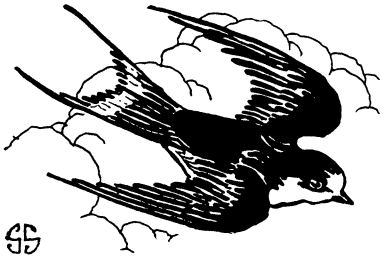
regularity, would be immediately disturbed, and each would describe about the Sun a very excentric ellipse; others would recede indefinitely in hyperbolic orbits. Thus an attentive inspection of the solar system evinces the necessity of some paramount central force, in order to maintain the entire system together, and secure the regularity of its motions. . . .

IT appears that far from being distributed at distances which are nearly equal, the stars are disposed in groups, some of which contain thousands of these objects. Our Sun, and the most brilliant stars, probably constitute part of one of those groups, which, seen from the earth, appear to surround the earth, and form the milky way. The great number of stars, which are seen in the field of a powerful telescope, directed towards this way, evinces its immense distance, which is a thousand times greater than the distance of Syrius from the earth, so that it is probable that rays emanating from these stars have employed several centuries to reach the earth. To a spectator at an immense distance from the milky way, it would present the appearance of an uninterrupted band of white light, having a very inconsiderable diameter, for the irradiation which subsists even in our best constructed telescopes, would not cover the interval between the stars. It is therefore probable, that amongst the nebulæ several consist of groups of a great number of stars, which, viewed from their interior, appear similar to the milky way. If now we reflect on the profusion of stars and nebulæ distributed through the heavenly regions, and on the immense intervals between them, the imagination, struck with astonishment at the magnitude of the universe, will find it difficult to assign any limits to it.

Herschel, while observing the nebulæ by means of his powerful telescopes, traced the progress of their condensation, not on one only, as their progress does not become sensible until after the lapse of ages, but on the whole of them, as in a vast forest we trace the growth of trees, in the individuals of different ages which it contains. He first observed the nebulous matter diffused in several masses, through various parts of the heavens, of which it occupied a great extent. In some of these masses he observed that this matter was fully condensed about one or more nuclei, a little more brillant. In other nebulæ, these nuclei shine brighter, relatively to the nebulosity which environs them. As the atmosphere of each nucleus separates itself by an ulterior condensation, there results several nebulæ constituted of brilliant nulcei very near to each other, and each surrounded by its respective atmosphere; sometimes the nebulous matter being condensed in a uniform manner, produces the nebulæ which are termed *planetary*. Finally, a greater degree of condensation transforms all these nebulæ into stars. The nebulæ, classed in a philosophic manner, indicate, with a great degree of probability, their future tranformation into stars, and the anterior state of the nebulosity of existing stars. Thus, by tracing the (*Turn to page* 302)

NATURE RAMBLINGS

By Frank Thone



Swift Wings

ONE of the favorite sentimental songs of our mothers—and of the younger generation among our grandmothers—was "When the Swallows Homeward Fly." As music that song was mighty good (ask Dad; he knows), but as ornithology it can have no standing at all.

For it envisaged, sadly, as all the good old songs liked to do, these swift-winged birds flying away to some unknown home in the South, leaving the northern skies as desolate and empty as a disappointed lover's heart. But as a matter of fact when the swallows fly southward in autumn they are going away from home. Their home is here, among our own chimneys and cliffs, and when the swallows homeward fly they are coming back to us. And that is what they are doing now.

The swallow, with his cousin the swift, does not come north quite so promptly and in defiance of chances of late snowstorms as do the robins and redwinged blackbirds. He is an early comer, but a safe one, and when you see him circling in the air it is safe to call spring an established fact.

Swallows and swifts are not identical, though they are usually lumped into one by the average citizen. They look a good deal alike, and their habits in flight are very similar, so that only the most meticulous of scientists would find fault with this popular confusion in nomenclature. As a matter of fact, one of the most notable of early American ornithologists called the chimney swift a swallow.

Both swallows and swifts are "wing feeders," catching their insect prey on the fly. That explains their swoopings and circlings and occasional eccentric dartings. They do fly for fun a part of the time, but a great part of their energetic wing work is involved in the serious business of getting a living.

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King Sargon—*Cont'd*

heads and will make one of the most beautiful examples of Assyrian art. And the Assyrians, in my opinion, have surpassed even the Greeks in their representations of animals. This cannot be said of the human figures, because there they followed too closely their own artistic conventions.

The "quarry" was carefully excavated, and we were able to save for science several important slabs. One of these represents two small horses and three attendants, all perfectly preserved. We excavated in a large, well-paved courtyard, and there we had the prize find: six large slabs of stone, two and one-half by three and one-half meters (about eight by eleven and a half feet), each one representing two immense figures of eunuchs bearing gifts to King Sargon. Four of these six slabs, and the most interesting ones at that, had never been seen by anyone since Assyrian days. A number of small objects also were salvaged, among which the most notable are a group of clay labels that had been used in closing cloth bags. Against the clay seals could still be seen the impression of the cloth, and imbedded in the clay was still the cord which had been used in tying them. Most of these labels were impressed with Assyrian seals; but one of them had an inscription in early Aramaic, and another in the still unreadable Hittite characters.

The published plans of the palace were improved upon, at least for the portion of it that could be excavated during the first campaign. Last, perhaps, in scientific interest, but first for its popular appeal, was the discovery and transportation of a huge Assyrian bull, weighing about thirty-five tons. He is one of those hybrid figures, with the head and beard of a man, the wings of an eagle, and the body of a bull, that used to watch the gates of the palace to ward off evil spirits. He lies now, well protected in strong cases, under the north stand of the football field at the University of Chicago. When the new building of the Oriental Institute shall have been completed, he will resume his duties, interrupted for twenty-seven centuries. Though six thousand miles from his original location and among strange people, he will have at least one consolation: the new building will never be permitted to fall over his head, for scientific interest will outlive the whole Assyrian Empire.

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World System—*Cont'd*

progress of condensation of the nebulous matter, we descend to the consideration of the Sun, formerly surrounded by an immense atmosphere, to which consideration we can also arrive, from an examination of the phenomena of the solar system, as we shall see in our last note. Such a marked coincidence, arrived at by such different means, renders the existence of this anterior state of the Sun extremely probable.

Connecting the formation of comets with that of nebulæ, they may be considered as small nebulæ, wandering from one solar system to another, and formed by the condensation of the nebulous matter which is so profusely distributed throughout the universe. The comets will be thus, relatively to our system, what the meteoric stones appear to be relatively to the earth, to which they do not appear to have originally belonged. When these stars first become visible, they present an appearance perfectly similar to the nebulæ; so much so, that they are frequently mistaken for them, and it is only by their motion, or by our knowing all the nebulæ contained in our part of the heavens, that we are able to distinguish one from the other. This hypothesis explains, in a satisfactory manner, the increase of the heads and tails of the comets, according as they approach the sun, and the extreme rarity of their tails; motions of the comets, which are performed in every direction, and the great eccentricity of their orbits.

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