PROLOGUE

CHAPTER 1

In an Immense Universe

Quota pars operis tanti
nobis committitur?
—SENECA

IN AN immense universe a little globe revolves around a star; it is the third in the row—Mercury, Venus, Earth—of the planetary family. It is of a solid core covered over most of its surface with liquid, and it has a gaseous envelope. Living creatures fill the liquid; other living creatures fly in the gas; and still others creep and walk upon the ground on the bottom of the gaseous ocean. Man, a being of erect stature, thinks himself the prince of creation. He felt like this long before he, by his own efforts, came to know how to fly on wings of metal around the globe. He felt godlike long before he could talk to his fellow-man on the other side of the globe. Today he can see the microcosm in a drop and the elements in the stars. He knows the laws governing the living cell with its chromosomes, and the laws governing the macrocosm of the sun, moon, planets, and stars. He assumes that gravitation keeps the planetary system together, man and beast on their planet, the sea within its borders. For millions and millions of years, he maintains, the planets have rolled along on the same paths, and their moons around them, and man in these eons has arisen from a one-cell infusorium all the long way up the ladder to his status of Homo sapiens.

Is man's knowledge now nearly complete? Are only a few more steps necessary to conquer the universe: to extract the energy of the atom—since these pages were written this has already been done—to cure cancer, to control genetics, to communicate with other planets and learn if they have living creatures, too?

Here begins Homo ignoramus. He does not know what life is or how it came to be and whether it originated from inorganic matter. He does not know whether other planets of this sun or of other suns have life on them, and if they have, whether the forms of life there are like those around us, ourselves included. He does not know how this solar system came into being, although he has built up a few hypotheses about it. He knows only that the solar system was constructed billions of years ago. He does not know what this mysterious force of gravitation is that holds him and his fellow man on the other side of the planet with their feet on the ground, although he regards the phenomenon itself as "the law of laws." He does not know what the earth looks like five miles under his feet. He does not know how mountains came into existence or what caused the emergence of the continents, although he builds hypotheses about these, nor does he know from where oil came—again hypotheses. He does not know why, only a short time ago, a thick glacial sheet pressed upon most of Europe and North America, as he believes it did; nor how palms could grow above the polar circle, nor how it came about that the same fauna fill the inner lakes of the Old and the New World. He does not know where the salt in the sea came from.

Although man knows that he has lived on this planet for millions of years, he finds a recorded history of only a few thousand years. And even these few thousand years are not sufficiently well known.

Why did the Bronze Age precede the Iron Age even though iron is more widely distributed over the world and its manufacture is simpler than that of the alloy of copper and tin? By what mechanical means were structures of immense blocks built on the high mountains of the Andes?

What caused the legend of the Flood to originate in all the countries of the world? Is there any adequate meaning to the term "antediluvian"? From what experiences grew the eschatological pictures of the end of the world?

In this work, of which the present book is the first part, some of these questions will be answered, but only at the cost of giving up certain notions now regarded as sacred laws in science—the millions of years of the present constitution of the solar system and the harmonious revolution of the earth—with all their implications as regards the theory of evolution.

The Celestial Harmony

The sun rises in the east and sets in the west. The day consists of twenty-four hours. The year consists of 365 days, 5 hours, and 49 minutes. The moon circles around the earth, changing its phases—crescent, full, decrescent. The terrestrial axis points in the direction of the polar star. After winter comes spring, then summer and fall. These are common facts. Are they invariable laws? Must it be so forever? Was it so always?

The sun has nine planets. Mercury has no satellites; Venus has no satellites; the earth has a moon; Mars has two small trabants, mere pieces of rock, and one of them completes its month before Mars ends its day; Jupiter has eleven moons and eleven different kinds of months to count; Saturn has nine moons, Uranus has five moons,[1] Neptune one, Pluto none.[2] Was it always so? Will it be so forever?

The sun rotates in an easterly direction. All planets revolve in their orbits in the same direction (counterclockwise if seen from the north) around the sun. Most of their moons revolve counterclockwise (in direct motion), but there are a few that revolve in the opposite direction (in retrograde motion).

No orbit is an exact circle; there is no regularity in the eccentrical shapes of the planetary orbits; each elliptical curve verges in a different direction.

It is not known for certain, but it is assumed that Mercury permanently shows the same face to the sun, as our moon does with respect

[1] The fifth satellite of Uranus was discovered in 1948.

[2] Due to the great distance of Neptune and Pluto from the earth, smaller satellites around these planets may have remained undiscovered.

Note: While this book was on the press another satellite of Neptune was discovered by G. P. Kuiper.

to the earth. Information obtained by different methods of observation of Venus is contradictory; it is not known whether Venus rotates so slowly that its day equals its year, or so rapidly that the night side is never sufficiently cooled. Mars rotates in 24 hours, 37 minutes, 22.6 seconds (mean period), a period comparable to the terrestrial day. Jupiter, which in volume is thirteen hundred times larger than the earth, completes a rotation in the short space of 9 hours and 50 minutes. What causes this variability? It is not a law that a planet must rotate or have days and nights; still less that its day and night must return every twenty-four hours.

If Pluto rotates from east to west,[3] it has the sun rising in the west. Uranus has the sun rising and setting neither in the east nor in the west. So it is not a law that a planet of the solar system must rotate from west to east and that the sun must rise in the east.

The equator of the earth is inclined to the plane of its ecliptic at an angle of 23½°; this causes the change of seasons during the annual revolution around the sun. The axes of other planets point in the directions of seemingly deliberate choice. It is not a general law for all planets that winter must follow fall and summer the spring.

The axis of Uranus is placed almost in the plane of its orbit; for about twenty years one of its polar regions is the hottest place on the planet. Then night gradually descends and twenty years later the other pole enters the tropics for an equal length of time.[4]

The moon has no atmosphere. It is not known whether Mercury has any atmosphere. Venus is covered with dense clouds, but not of water vapor. Mars has a transparent atmosphere, but almost without oxygen or water vapor, and its composition is unknown. Jupiter and Saturn have gaseous envelopes; it is not known whether they have solid cores. It is not a general law that a planet must have atmosphere or water.

Mars is 0.15 of the volume of the earth; the next planet, Jupiter, is about 8,750 times as large as Mars. There is no regularity of, or relation between, the size of the planets and their position in the system.

On Mars are seen "canals" and polar caps; on the moon, craters; the

[3] G. Gamow, *Biography of the Earth* (1941), p. 24.

[4] The equator of Uranus is inclined at an angle of 82° to the plane of its orbit.

earth has reflecting oceans; Venus has brilliant clouds; Jupiter has belts and a red spot; Saturn has rings.

The celestial harmony is composed of bodies different in size, different in form, different in the velocity of rotation, with differently directed axes of rotation, with different directions of rotation, with differently composed atmospheres or without atmospheres, with a varying number of moons or without moons, and with satellites revolving in either direction.

It appears then to be by chance that the earth has a moon, that we have day and night and that their combined length is equal to twenty-four hours, that we have a sequence of seasons, that we have oceans and water, atmosphere and oxygen, and probably also that our planet is placed between Venus at our left and Mars at our right.

The Origin of the Planetary System

All theories of the origin of the planetary system and the motive forces that sustain the motion of its members go back to the gravitational theory and the celestial mechanics of Newton. The sun attracts the planets, and if it were not for a second force, they would fall into the sun; but each planet is impelled by a motive force to proceed in a direction away from the sun, and as a result, an orbit is formed. Similarly, a satellite or a moon is subject to a force that drives it away from its primary, but the attraction of the primary bends the path on which the satellite would have proceeded if there had been no attraction between the bodies, and out of these forces a satellite orbit is traced. The inertia or persistence of motion implanted in planets and satellites was postulated by Newton, but he did not explain how or when the initial pull or push occurred.[1]

The theory of the origin of the planetary system which dominated the entire nineteenth century was proposed by Swedenborg, the theologian, and Kant, the philosopher. It was put into scientific terms by Laplace,[2] although not explored by him quantitatively, and in brief is as follows:

[1] Isaac Newton, *Principia* (Mathematical Principles) (1686), Bk. III.

[2] P. S. Laplace, *Exposition du système du monde* (1796).

Hundreds of millions of years ago the sun was nebulous and very large and had a form approaching that of a disc. This disc was as wide as the whole orbit of the farthest of the planets. It rotated around its center. Owing to the process of compression caused by gravitation, a globular sun shaped itself in the center of the disc. Because of the rotating motion of the whole nebula, a centrifugal force was in action; parts of matter more on the periphery resisted the retracting action directed toward the center and broke up into rings which balled into globes—these were the planets in the process of shaping. In other words, as a result of the shrinkage of the rotating sun, matter broke away and portions of this solar material developed into planets. The plane in which the planets revolve is the equatorial plane of the sun.

This theory is now regarded as unsatisfactory. Three objections stand out above others. First, the velocity of the axial rotation of the sun at the time the planetary system was built could not have been sufficient to enable bands of matter to break away; but even if they had broken away, they would not have balled into globes. Second, the Laplace theory does not explain why the planets have larger angular velocity of daily rotation and yearly revolution than the sun could have imparted to them. Third, what made some of the satellites revolve retrogradely, or in a direction opposite to that of most of the members of the solar system?

"It appears to be clearly established that, whatever structure we assign to a primitive sun, a planetary system cannot come into being merely as the result of the sun's rotation. If a sun, rotating alone in space, is not able of itself to produce its family of planets and satellites, it becomes necessary to invoke the presence and assistance of some second body. This brings us at once to the tidal theory." [3]

The tidal theory, which, in its earlier stage, was called the planetesimal theory,[4] assumes that a star passed close to the sun. An immense tide of matter arose from the sun in the direction of the passing star and was torn from the body of the sun but remained in its

[3] Sir James H. Jeans, *Astronomy and Cosmogony* (1929), p. 409.

[4] The planetesimal hypothesis was developed by T. C. Chamberlin and F. R. Moulton.

domain, being the material out of which the planets were built. In the planetesimal theory the mass that was torn out broke into small parts which solidified in space; some were driven out of the solar system, and some fell back into the sun, but the rest moved around it because of its gravitational pull. Sweeping in elongated orbits around the sun, they conglomerated, rounded out their orbits as a result of mutual collisions, and grew to form planets and satellites around the planets.

The tidal theory [5] does not allow the matter torn from the sun to disperse first and reunite later; the tide broke into a few portions that rather quickly changed from gaseous to fluid, and then to the solid state. In support of this theory it was indicated that such a tide, when broken into a number of "drops," would probably build the largest "drops" out of its middle portion, and small "drops" from its beginning (near the sun) and its end (most remote from the sun). Actually, Mercury, nearest to the sun, is a small planet. Venus is larger; earth is a little larger than Venus; Jupiter is three hundred and twenty times as large as the earth (in mass); Saturn is somewhat smaller than Jupiter; Uranus and Neptune, though large planets, are not as large as Jupiter and Saturn. Pluto is quite as small as Mercury.

The first difficulty of the tidal hypothesis lies in the very point adduced in its support, the mass of the planets. Between the earth and Jupiter there revolves a small planet, Mars, a tenth part of the earth in mass, where, according to the scheme, a planet ten to fifty times as large as the earth should be expected. Again, Neptune is larger and not smaller than Uranus.

Another difficulty is the allegedly rare chance of an encounter between two stars. One of the authors of the tidal theory gave this estimate of its probability: [6]

"At a rough estimate we may suppose that a given star's chance of forming a planetary system is one in 5,000,000,000,000,000,000 years." But since the life span of a star is much shorter than this figure, "only about one star in 100,000 can have formed a planetary system in the whole of its life." In the galactic system of one hundred million stars,

[5] The tidal theory was developed by J. H. Jeans and H. Jeffreys.

[6] Jeans, *Astronomy and Cosmogony*, p. 409.

planetary systems "form at the rate of about one per five billion years. . . . our own system, with an age of the order of two billion years, is probably the youngest system in the whole galactic system of stars."

The nebular and tidal theories alike regard the planets as derivatives of the sun, and the satellites as derivatives of the planets.

The problem of the origin of the moon can be regarded as disturbing to the tidal theory. Being smaller than the earth, the moon completed earlier the process of cooling and shrinking, and the lunar volcanoes had already ceased to be active. It is calculated that the moon possesses a lighter specific weight than the earth. It is assumed that the moon was produced from the superficial layers of the earth's body, which are rich in light silicon, whereas the core of the earth, the main portion of its body, is made of heavy metals, particularly iron. But this assumption postulates the origin of the moon as not simultaneous with the origin of the earth; the earth, being formed out of a mass ejected from the sun, had to undergo a process of leveling, which placed the heavy metals in the core and silicon at the periphery, before the moon parted from the earth by a new tidal distortion. This would mean two consecutive tidal distortions in a system where the chance of even one is held extremely rare. If the passing of one star near another happens among one hundred million stars once in five billion years, two occurrences like this for one and the same star seem quite incredible. Therefore, as no better explanation is available, the satellites are supposed to have been torn from the planets by the sun's attraction on their first perihelion passage, when, sweeping along on stretched orbits, the planets came close to the sun.

The circling of the satellites around the planets also confronts existing cosmological theories with difficulties. Laplace built his theory of the origin of the solar system on the assumption that all planets and satellites revolve in the same direction. He wrote that the axial rotation of the sun and the orbital revolutions and axial rotations of the six planets, the moon, the satellites, and the rings of Saturn present forty-three movements, all in the same direction. "One finds by the analysis of the probabilities that there are more than four thousand billion chances to one that this arrangement is not the result of chance; this probability is considerably higher than that of the reality of historical events with regard to which no one would venture a doubt."[7] He deduced that a common and primal cause directed the movements of the planets and satellites.

Since the time of Laplace, new members of the solar system have been discovered. Now we know that though the majority of the satellites revolve in the same direction as the planets revolve and the sun rotates, the moons of Uranus revolve in a plane almost perpendicular to the orbital plane of their planet, and three of the eleven moons of Jupiter, one of the nine moons of Saturn, and the one moon of Neptune revolve retrogradely. These facts contradict the main argument of the Laplace theory: a rotating nebula could not produce satellites revolving in two directions.

In the tidal theory the direction of the planets' movements depended on the star that passed: it passed in the plane in which the planets now revolve and in a direction which determined their circling from west to east. But why should the satellites of Uranus revolve perpendicularly to that plane and some moons of Jupiter and Saturn in reverse directions? This the tidal theory fails to explain.

According to all existing theories, the angular velocity of the revolution of a satellite must be slower than the velocity of rotation of its parent. But the inner satellite of Mars revolves more rapidly than Mars rotates.

Some of the difficulties that confront the nebular and tidal theories also confront another theory that has been proposed in recent years.[8] According to it, the sun is supposed to have been a member of a double star system. A passing star crushed the companion of the sun, and out of its debris planets were formed. In further development of this hypothesis, it is maintained that the larger planets were built out of the debris, and the smaller ones, the so-called "terrestrial" planets, were formed from the larger ones by a process of cleavage.

The birth of smaller, solid planets out of the larger, gaseous ones is conjectured in order to explain the difference in the relation of

[7] Laplace, *Théorie analytique des probabilités* (3rd ed., 1820), p. lxi; cf. H. Faye, *Sur l'Origine du monde* (1884), pp. 131-132.

[8] By Lyttleton and, independently, by Russell.

weight to volume in the larger and smaller planets; but this theory is unable to explain the difference in the specific weights of the smaller planets and their satellites. By a process of cleavage, the moon was born of the earth; but since the specific weight of the moon is greater than that of the larger planets and smaller than that of the earth, it would seem to be more in accord with the theory that the earth was born of the moon, despite its smallness. This confuses the argument.

The origin of the planets and their satellites remains unsolved. The theories not only contradict one another, but each of them bears within itself its own contradictions. "If the sun had been unattended by planets, its origin and evolution would have presented no difficulty." [9]

The Origin of the Comets

The nebular and tidal theories endeavor to explain the origin of the solar system but do not include the comets in their schemes. Comets are more numerous than planets. More than sixty comets are known to belong definitely to the solar system. These are the comets of short periods (less than eighty years); they revolve in stretched ellipses and all but one do not go beyond the line marked by the orbit of Neptune. It is estimated that, besides the comets of short periods, several hundred thousand comets visit the solar system; however, it is not known for certain that they return periodically. They are seen presently at an approximate rate of five hundred in a century, and are said to have an average period of tens of thousands of years.

A few theories of the origin of comets have been proposed, but aside from one attempt to see in them planetesimals that did not receive a side pull sufficiently strong to bring them into circular orbits,[1] no scheme has been developed that explains the origin of the solar system in its entirety, with its planets and comets; yet no cosmic theory can persist which limits itself to the problem of either planets or comets exclusively.

[9] Jeans, *Astronomy and Cosmogony*, p. 395.

[1] An attempt to explain the comets, in the frame of the planetesimal theory, as scattered debris of a great wreck, was made by T. C. Chamberlin, *The Two Solar Families* (1928).

One theory sees in the comets errant cosmic bodies arriving from interstellar space. After approaching the sun, they turn away on an open (parabolic) curve. But if they happen to pass close to one of the larger planets, they may be compelled to change their open curves to ellipses and become comets of short period.[2] This is the theory of capture: comets of long periods or of no period are dislodged from their paths to become short-period comets. What the origin of the long-period comets is remains an unanswered question.

The short-period comets apparently have some relation to the larger planets. About fifty comets move between the sun and the orbit of Jupiter; their periods are under nine years. Four comets reach the orbit of Saturn; two comets revolve inside the circle described by Uranus; and nine comets, with an average period of seventy-one years, move within the orbit of Neptune. These comprise the system of the short-period comets as it is known at present. To the last group belongs the Halley comet, which, among the comets of short periods, has the longest period of revolution—about seventy-six years. Then there is a great gap, after which there are comets that require thousands of years before they return to the sun, if they return at all.

The distribution of the short-period comets suggested the idea that they were "captured" by the large planets. This theory has for its support the direct observation that comets are disturbed on their path by the planets.

Another theory of the comets supposes their origin to have been in the sun, but in a manner unlike that conceived of in the tidal theory of the origin of planets. Mighty whirls on the surface of the sun sweep ignited gases into great protuberances; these are observed daily. Matter is driven off from the sun and returns to the sun. It is calculated

[2] That planets are able to change the path of a comet is not only known from observation but has even been calculated in advance. In 1758 Clairaut predicted the retardation of Halley's comet, on its first return foretold by Halley, for a period of 618 days, because it had to pass near Jupiter and Saturn. It was retarded for almost the computed length of time. Similarly, the orbits of other comets were occasionally distorted. Lexell's comet was disturbed by Jupiter in 1767 and in 1770 by the earth, D'Arest's comet was disturbed in 1860, Wolf's comet in 1875 and 1922. By an encounter with Jupiter in 1886, Brook's comet changed its period from 29 years to 7 years; the period of Jupiter was not altered by more than two or three minutes, and probably less.

that if the velocity of the ejection were to exceed 384 miles per second, the speed of motion in a parabola, the matter would not return to the sun but would become a long-range comet. Then the path of the ejected mass might become perturbed as a result of its passage near one of the larger planets, and the comet would become one of a short period.

Birth of a comet in this manner has never been observed, and the probability that matter in explosion may reach a speed of 384 miles per second is highly questionable. It was therefore supposed alternatively that millions of years ago, when the activity of their gaseous masses was more dynamic, the large planets expelled comets from their bodies. The speed required for the ejected mass to overcome the gravitational pull of the ejecting body is less in the case of the planets than in the case of the sun, owing to their smaller gravitational pull. It is calculated that a mass hurled from Jupiter at a speed of about 38 miles per second, or at only a little more than a third of this velocity in the case of Neptune, would become expelled.

This variant of the theory neglects the question of the origin of the long-period comets. However, an explanation was offered, according to which the large planets throw the comets that pass close to them from their short orbits into elongated ones, or even expel them entirely from the solar system.

When passing close to the sun, comets emit tails. It is assumed that the material of the tail does not return to the comet's head but is dispersed in space; consequently, the comets as luminous bodies must have a limited life. If Halley's comet has pursued its present orbit since late pre-Cambrian times, it must "have grown and lost eight million tails, which seems improbable." [3] If comets are wasted, their number in the solar system must permanently diminish, and no comet of short period could have preserved its tail since geological times.

But as there are many luminous comets of short period, they must have been produced or acquired at some time when other members of the system, the planets and the satellites, were already in their places. A theory has been offered that once the solar system moved through a nebula and obtained its comets there.

[3] H. N. Russell, *The Solar System and Its Origin* (1935), p. 40.

Did the sun emit planets by shrinkage or by tide, and comets by explosion? Did the comets come from interstellar space and were they captured into the solar system by larger planets? Did the larger planets produce the smaller planets by cleavage, or did they expel the short-period comets from their bodies?

It is admitted that we cannot know the truth about the origin of the planetary and cometary systems billions of years ago. "The problem of the origin and development of the solar system suffers from the label 'speculative.' It is frequently said that as we were not there when the system was formed, we cannot legitimately arrive at any idea of how it was formed." [4] The most we can do, it is believed, is to investigate one planet, the one under our feet, in order to learn its past; and then, by the deductive method, to apply the results to other members of the solar system.

[4] Harold Jeffreys, "The Origin of the Solar System" in *Internal Constitution of the Earth*, B. Gutenberg, ed. (1939).