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Devoted to the Science of Religion, the Religion of Science, and the Extension of the Religious Parliament Idea

FOUNDED BY EDWARD C. HEGELER

MAY, 1930

VOLUME XLIV NUMBER 888

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THE PHILOSOPHICAL REVIEW

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MODERN ASTRONOMY AND THE NEW COSMOS

BY J. V. NASH

UNTIL the beginning of the sixteenth century, the Ptolemaic system, positing a static earth round which the sun and planets revolved, dominated the mind of man. Then came the revolutionary discovery of Copernicus, who pried the earth loose from its moorings and sent it whirling through space, revolving on its own axis, in its orbit about the sun. The realization that the so-called fixed stars are distant suns followed as a natural sequence; this was one of the great conceptions of Bruno.

Finally, we grew accustomed to speaking of the *universe*, of which our solar system, as we believed, formed an important part. But now it has been revealed that not only is our sun a comparatively insignificant member of our own universe, but that the latter itself is a minor unit in a great galaxy of universes. The cosmos, in short, is not a universe but a pluriverse.

It was not until the end of the eighteenth century that Laplace, a French scientist, worked out his famous Nebular hypothesis, which held that the solar system was born of a whirling cloud of gaseous matter. This theory, attractive and plausible as it was in many respects, failed to survive modern scientific tests; it has now been superseded very widely by the Planetesimal hypothesis.

The testing of the Laplacian theory which definitely proved its untenability, and the subsequent development of the Planetesimal hypothesis, were the work of two Chicago scientists, Dr. Thomas C. Chamberlin, the eminent geologist and naturalist, and Dr. F. R. Moulton, well known as an astronomer and mathematical physicist. Chamberlin and Moulton were ideally fitted by training in two different fields to collaborate in solving the great problem of planetary genesis.

Dr. Moulton, the younger and now the surviving member of the partnership, explains the Planetesimal hypothesis as follows:

"About once in a period of a thousand times a million times a million (1,000 x 1,000,000 x 1,000,000) years, our sun will, on the average, approach near another sun. Enormous tides will be formed and a certain amount of material will be shot out, and in this way a spiral nebula will be developed. It will contain nuclei and vast quantities of scattered material. The nuclei in their circulation round the central sun will sweep up the scattered material and grow into planets.

"One such nucleus gradually grew into our present earth. The earth originally probably was too small to hold an atmosphere or water on its surface. As it grew in size, by sweeping up the scattered material in its path, its gravitation increased and eventually it became surrounded by an atmosphere and largely covered with water. The process of growth produces circularity, and so those planets that have grown the most should have the most nearly circular orbits, as Jupiter, Saturn, and the others do.

"The earth is still growing by the accretion of particles of matter. It is highly probable that in earlier times there were possibly thousands of pounds of meteoric material falling every day on every square mile of the earth's surface."

Such, in brief, is the substance of the Planetesimal hypothesis, which now seems destined to hold the field indefinitely. Conceived in its first tentative form about 1900, it has steadily made its way into general acceptance in the United States. In England, about 1919, its underlying principles were adopted by Jeans and Jeffreys as the basis of their "tidal theory," which has gained wide currency abroad.

Nevertheless, the Laplacian hypothesis will always command respect as a landmark in scientific progress. It was a truly great achievement when given to the world in 1796, and the fact that it held the field for over a century is in itself a remarkable tribute to its plausibility. It was a beautiful theory, appealing strongly to the imagination. Dr. Moulton himself speaks kindly of it. He believes that it rendered a priceless service by accustoming mankind to the idea of a natural evolution of the earth, involving a time element of millions of years in place of the six thousand years of Biblical chronology. The Planetesimal hypothesis pushes back the ultimate

origin of the earth—and, incidentally, of the life thereon—to an immensely greater distance still. A hundred years ago the world was not ready for such daring conceptions as are involved in the Planetesimal hypothesis.

Dr. Moulton believes that life began on the earth at least two billions of years ago. "Life did not begin," he says, "until our earth had reached approximately its present size, and this was probably two billion—two thousand million—years ago. It is likely that life began first on the seashore, where the air and the soil and the water unite.

"The water dissolved from the rocks various elements, such as sodium, potassium, calcium, iron, and so forth, and carried them in solution into the sea. On the seashore there was an infinite variety of concentration of these various elements. There was also the rhythmic succession of day and night, and the pulsing tides and the lapping waves, which gave a variety so great that it is impossible now to match it artificially.

"Somehow, in a manner unknown, the first steps in the great life sequence upon the earth were taken. Of course, the first forms of life were very low. The smallest micro-organism which we have to-day may be comparatively high in the scale, containing at least 100,000 molecules. Most of the life history of the earth was past before the vertebrates came on.

"During all that period the sun has radiated light and heat upon the earth almost exactly at its present rate, and during all that time the earth has never been visited by any great cataclysm which destroyed all life."

But the earth, important as it is to mankind, is merely one member, and not a particularly significant one, of a large planetary family circling about the sun. Besides the eight principal planets,[1] there are about a thousand smaller ones. The eight major planets are divided into two groups. The four nearest to the sun are called the terrestrial or earthlike planets, and are similar in many ways to the earth. Mercury is less than one-half the size of the earth, and is too small to hold an atmosphere. Mars is one-third smaller than the earth, and has only a very thin atmosphere. Venus is almost exactly

[1] The discovery, early in 1930, at the Flagstaff Observatory, of a transneptunian planet increases this planetary group to nine. Professor Chamberlin had forecast the discovery of planetary bodies beyond Neptune. See *The Two Solar Families: The Sun's Children*, pp. 154-156.

the same size as the earth; it is, indeed, often called the earth's twin. It is about 25,000,000 miles nearer the sun, and has so dense an atmosphere that its surface is entirely obscured; hence we are not acquainted with the markings on it.

The question of life on Mars has for long baffled investigation. Mars is about 50,000,000 miles farther from the sun than is the earth; its temperature, according to Dr. Moulton, is on the average about that of the poles on the earth, although during the Martian summer the temperature in the equatorial belt probably rises above freezing.

Some observers have reported curious markings on the surface of Mars, which they thought to be artificial canals constructed for the purpose of irrigating the arid surface of the planet from the melting ice-caps in the Martian polar regions. These ice-caps are clearly visible through our large telescopes. The "canals" of Mars were first reported by Schiaparelli, the Italian astronomer, in the 1870's. In recent years the late Percival Lowell at Flagstaff Observatory, in Arizona, has drawn elaborate maps showing an intricate network of these "canals." Other experts maintain that these markings are an optical illusion; at any rate, no actual photographs of them have ever been secured.

In view of the scarcity of atmosphere and of water, together with the very low temperature and the small size of the planet, Mars does not seem very attractive as a place of residence. In this it differs notably from Venus, where, because of the greater proximity to the sun, the average temperature is, as Dr. Moulton believes, about 150 degrees. In the course of millions of years, however, the planet will slowly cool, so that when the earth becomes too cold to support life in comfort and its natural resources are exhausted Venus may offer a refuge for mankind, if man can in the meantime perfect a means of crossing the gulf of space which separates the two planets. The British scientist, J. B. S. Haldane, has published some fascinating speculations on the subject of the colonization of Venus from the earth.

The other group of planets consists of four globes of tremendous size in comparison with the earth. Jupiter is a thousand times larger. Saturn, Uranus, and Neptune, the outermost planet, complete the group. All four are probably entirely gaseous in composition and, owing to their immense distance from the sun, they receive a negligible amount of light and heat. The quantity of heat

received by Jupiter, for instance, is only one-tenth of that at the North Pole of the earth.

In the space between Mars, the most outlying of the terrestrial planets, and Jupiter, the nearest of the giants, about a thousand planetoids, or little planets, have their orbits. They are of varying sizes, some not more than twenty-five miles in diameter and scarcely visible through the most powerful telescopes, while others attain a diameter of between 200 and 500 miles.

All of the principal planets, except Uranus and Neptune, have been familiar to man since the earliest times, for they are brilliant objects in the sky. Uranus, however, is just beyond the reach of the unaided eye; it was discovered by William Herschel in 1781, and was for a time known by his surname. The orbit of Uranus was soon calculated and the movements of the planet noted for a considerable number of years. This led to one of the most astonishing and dramatic discoveries in the history of astronomy. One of the most impressive characteristics of the universe, as Dr. Moulton likes to emphasize, is its orderliness. Astronomers, therefore, were puzzled because the movements of Uranus, as observed from year to year, did not agree with the mathematical predictions. In the course of time the variation became intolerable to scientists. It was just as perplexing as if every time one added up a given column of figures, and knew that no error had been made, a different total resulted.

Finally, it was suggested that the irregularities in the motion of Uranus might be caused by the disturbing effect of an undiscovered planet. But how should one know where to look for this elusive, unknown planet, invisible to the unaided eye, in the immensity of space? It would first be necessary to work out, by higher mathematics, the supposed orbit of a planet which human eye had never seen, basing the calculations on the accumulated effects of its attraction upon Uranus over a period of sixty years. A young English scientist named Adams and a young Frenchman named LeVerrier, working independently and by different methods, determined the spot where the mysterious planet should be, in the depths of space three billions of miles away. Then a young German named Galle pointed a telescope at the spot indicated by LeVerrier and found the planet now known as Neptune, in almost the exact location where it was believed, on theoretical evidence, to be. This was one of the most memorable discoveries in the history of science.

Strange, erratic members of our solar system are the comets—attenuated gaseous bodies, with brilliantly glowing heads and fanlike

THE GREAT SPIRAL NEBULA IN TRIANGULUM.
(Yerkes Observatory)

tails often extending for a distance of 100,000,000 miles into space. The tail always points away from the sun, regardless of whether the comet is coming or going. In receding from the sun, a comet's

appearance suggests the headlight of a locomotive on a misty night.

Comets have singular, elongated orbits. They approach the sun from regions far beyond the orbit of Neptune, dash around the solar disc, and retreat again into the outlying regions of space. Occasionally a comet head is disintegrated by collision with a planet or by too closely approaching the sun.

The distances which comets traverse are so enormous that in some cases the periods of their visits to the vicinity of the earth are separated by more than a human lifetime. In 1680, Newton calculated the orbit of a great comet visible at that time and found its periodicity to be 600 years. Its next visit to this part of space is therefore still several centuries distant.

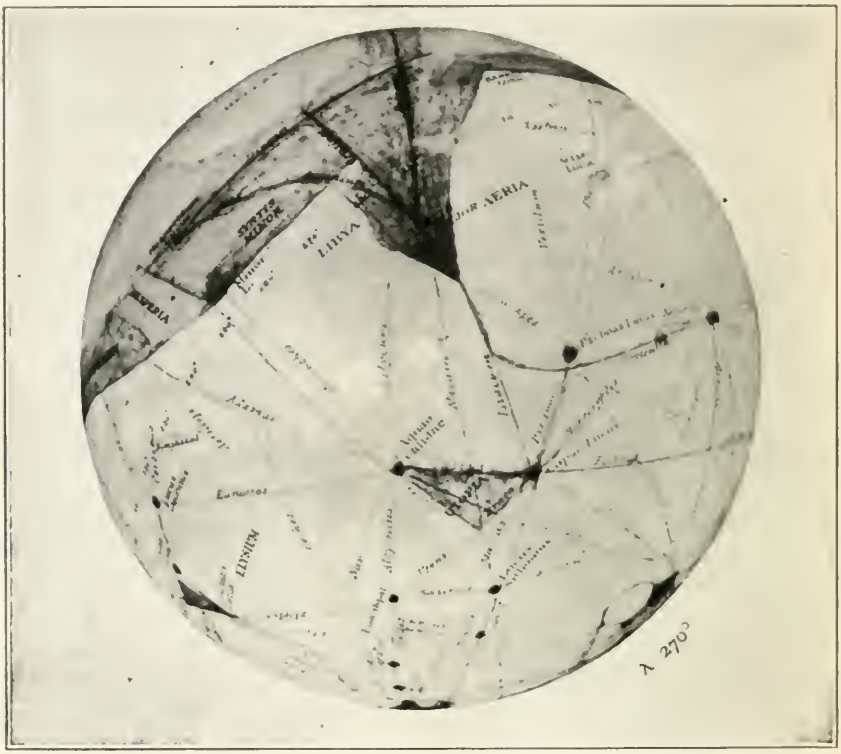
Halley's comet was named for the man who, after the comet's visit in 1682, first worked out its orbit, proving that it was the same comet as those which had aroused excitement in 1607, 1531, 1456, and so on back to 1066, the year in which William the Conqueror landed in England. He predicted its next return in 1759. In other words, its visits are approximately seventy-five years apart. Its next visit was in 1835. Mark Twain, born in that year, had a whimsical belief that he would leave the earth when the comet called again; and as it happened, the comet found him on his deathbed when it blazed into the sky in the spring of 1910. The new-born baby of 1835 had become a white-haired old man of seventy-five years.

The best and most recent explanation of the origin of comets—two complex for discussion here—is that given by the late Dr. T. C. Chamberlin in his last book, *The Two Solar Families: The Sun's Children.*

From the earthly point of view, the sun is first among the heavenly bodies. It is, always has been, and always will be, the ultimate source of all life—vegetable, animal, and human—on the earth. It pours out upon our planet every day the light and heat without which any kind of life would be impossible.

The amount of energy which is thrown into space by the sun is so immense as to be far beyond ordinary comprehension. It has been calculated that the energy radiated per square yard from the sun's surface is equivalent to 70,000 horse power. This represents an amount of heat which would melt a globe of ice as large as the earth in two hours and forty minutes. The earth is constantly re-

ceiving energy from the sun at the rate of 160 horse power per inhabitant; yet less than one two-billionth of the energy thrown out by the sun is intercepted by the earth.



MAP OF MARS, BY LOWELL, SHOWING "CANALS."

(Many leading astronomers question the existence of the "canals." Actual photographs do not disclose these strange markings.)

Again, it is not generally realized that the sun is the cause of all our wind and rain. The sun warms the air over the equatorial regions of the earth more than that over the higher latitudes; the resulting currents that are set up produce our winds. The sun's heat evaporates the water of the ocean and raises it into the air a half-mile or more, the winds carry a part of this water vapor in

over the land, where it falls as rain or snow, and in descending again to the ocean it plunges down steep grades and energy is released, which is increasingly being harnessed by man and converted into electric power. The amount of work that the sun does in raising water which falls again as rain may be realized when it is shown that in the eastern half of the United States, where the annual rainfall is about 35 inches, 2,000,000 tons of water fall on each square mile from a height of half a mile or more.

The titanic storms that rage on the surface of the sun are among the most extraordinary of celestial phenomena. They occur with greater intensity and frequency about every eleven years. The spots produced by sun storms range in diameter from the limits of visibility up to more than a hundred thousand miles across. In these storms huge masses of vaprous heated substances, sometimes hundreds of times larger than our earth, are driven hither and thither, with a speed ranging into hundreds of miles a minute. They are sometimes thrown aloft to a height above the sun's surface twice as great as the distance from the earth to the moon; in other words, to a distance of half a million miles. If the earth were lashed by one of these terrific whips of flame, life would be annihilated.

Looked at from the sun, our earth, at a distance of nearly 93,000,000 miles, would appear as a tiny speck. The size of the sun in comparison with the earth may be illustrated by imagining the earth placed at its center and the moon revolving round it as at present. We should find that the moon's orbit would be not only wholly within the sun, but hardly more than half way from the sun's center.

Of the moon, little need be said here. As the heavenly body nearest the earth, it has from the earliest times been a source of lively curiosity to man. Many superstitions have grown up about it; the word *lunatic,* meaning literally "moon-struck," is a reminiscence of one of these superstitions. Others had to do with the supposed effect of the moon on vegetation and crops. The moon was the basis of the first calendar; it gave mankind the *month.*

Many primitive races regarded the moon, like the sun, as a divinity; the moon deity, especially, occupied an important place in their mythologies. The marks on the face of the moon, clearly visible without a glass on a bright night, gave rise to the legend of "the man in the moon." Widely separated tribes, from the Eskimos of the Arctic to the South Sea Islanders, have their stories about

"the man in the moon." An eclipse of the moon was regarded with consternation as an evil portent.

The moon is a dead world, airless and waterless, wandering in its orbit about the earth, and turning on its axis in the same period that it revolves round our planet, so that the same side is forever facing us. Its face is deeply pitted and scarred. There are mountain ranges on the moon, and some 30,000 so-called craters have been mapped. The great lunar crater Theophilus is 64 miles in diameter and 19,000 feet deep. In its center rises a peak 11,00 feet above the plain on which it rests.

Though the moon is devoid of life, it figures largely in human sentiment. When at its full, glowing softly with a tender radiance on summer nights, it has inspired poets and lovers alike. Romance and literature would be poorer without the moon.

Conditions on the moon are widely different from those on earth. A lunar day, for instance, lasts about fifteen of our days, and a lunar night is of the same duration. The surface is heated to probably above the boiling point during the long day, while in the lunar night it falls to at least 100 degrees below zero. A human body on the moon would weigh only about one-sixth as much as on the earth.

But our entire solar system is itself only a relatively insignificant unit in the cosmos. The starry heavens, the contemplation of which so deeply stirred the mind of the philosopher Kant, offer on a cloudless night the most glorious of spectacles. The vast dome of the sky is, as it were, spangled with brilliant jewels—diamonds, emeralds, sapphires, topazes, turquoises, and rubies. Some of them are arranged in curious and intricate patterns, such as the Big Dipper in Ursus Major, the semi-circle in Corona Borealis, the diamond in Delphinus, the cross in Cygnus, and so on.

Each of the innumerable stars is an immense sun, many almost inconceivably larger than our own. Betelgeuse, for instance, measured by the interferometer, has been found to be twenty-seven million times as great in volume as our sun, which itself is a million times larger than the earth. The star known as Red Antares is even larger than Betelgeuze. It is conceivable that these other suns may have families of planets circling round them; but in any case, they would be invisible with the most powerful telescopes.

The story of stellar evolution is told in the colors of the stars,

which range from a dull red, through yellow and bluish-white and back again to red. Our own sun is in the yellow stage; it is well along in life, but still far from old. Doubtless there are many black,

VENUS, AS SEEN BY E. E. BARNARD, LICK OBSERVATORY.
(Note resemblance to new moon.)

burnt-out suns drifting dead and cold in the abysses of space. Occasionally such a dead sun will collide with another sun, either living or dead, and the terrific impact will turn the colliding bodies into an incandescent state, to begin another life cycle. From time to time astronomers witness a conflagration suddenly blaze up where no star was observed before. The new star may have been born thousands of years ago, and its light, traversing the gulfs of space at the rate of 186,000 miles a second, is just reaching us.[2]

About 5,000 stars are visible with the unaided eye. But powerful telescopes reveal myriads more. At least 500,000,000 stars are

[2] Some stars are of such almost incredible density that a cupful of their material, according to a recent statement by Professor Frost, would weigh many tons.

now known to astronomers. A photograph of some parts of the sky, as seen through a large telescope, will show innumerable points of light packed so closely together that they form an almost solid mass; yet each of the little dots is actually millions times millions of miles distant from its nearest neighbor.

To form an idea of the distance between the stars, let us imagine a sphere with the earth as its center, the sphere having a radius of 200,000 times 100,000,000 miles in all directions. There would be no star within that sphere except our own sun.

One of the latest triumphs of astronomy is the mapping of the position of our solar system. "Our sun," says Dr. Moulton, "lies deep in a galaxy shaped like a lens or a watch. This galaxy consists of at least a thousand million suns comparable to our own. About half of them are in most respects very much like our own sun, but some of them radiate thousands of times as much light, and and some of them are millions of times as great in volume.

"The thickness of this galaxy is the distance that light travels in twenty or thirty thousand years. Its distance through, from edge to edge, is approximately ten times this distance, or that which light travels in 200,000 or 300,000 years.

"Outside of our galaxy are other galaxies in enormous numbers. Only recently have we been able to measure the distance to them. The nearest, which has been known as the Andromeda Nebula, was found by Hubble to be distant about 1,000,000 light years. Most of them are much farther from us than the Andromeda Nebula. We photograph some that are so far away that light has been on its way to us millions of years, and we see them as they were at that long ago epoch.

"It may be that these galazies in great numbers together form a super-galaxy, just as myriads of stars together constitute our galaxy, and it is quite possible that many super-galaxies make up a larger cosmic unit which may be called a super-galaxy of the second order. Even then we probably have not reached the limit, for super-galaxies of higher and higher orders may exist without end."

Dr. Moulton, when discussing astronomy, warms up to his subject in a contagious way. "I used to think, when a boy," he said reminiscently, "that the days of adventure and discovery were over, and I felt sorry for it, as there seemed to be nothing left for the explorer to do. But when I became an astronomer I found that

Columbus never had such an adventure as a person gets when he explores the depths of the universe. Now I am glad that I did not live any earlier, because of the marvelous riches that science has brought to us in our own day, which make life really worth living.

"With our powerful telescopes," he continued, "we sweep the heavens, and millions of stars are revealed to us which the naked

VIEWS OF MARS, BY BARNARD, AT LICK OBSERVATORY.

eye never sees. Many stars, indeed, are so distant that they can be detected only by long exposure of delicate photographic plates.

"Every star, of course, is a sun. We have called the stars fixed, just as we used to speak of *the eternal hills;* but only poets now speak of the eternal hills, for we know that to-morrow, geologically speaking, they will disappear. So the stars are moving, but they are moving so slowly from our point of view that it takes a long time to detect the movement even with the most powerful telescopes. But we know from their distribution, from the forces operating on them, and from the underlying laws controlling them, that they are moving around among each other like bees in a swarm, or people on State Street on a busy afternoon.

"If we watch these suns for only two hundred years, we find that they seem to be moving in straight lines, but if we could watch them for 20,000 or perhaps 200,000 years, we should observe a curvature in their paths. Our sun moves, with respect to other

stars, about 400,000,000 miles per year. The distance of the stars from us is so vast that it is best expressed in light-years, which

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means the time that it takes their light, traveling at nearly 200,000 miles per second, to reach the earth. Many of the stars are millions of light-years distant.

"One naturally recoils from these bewildering figures. The thing seems unreal because it is unfamiliar. But to those of us who

are familiar with it and are mathematicians the difficulties are not serious. There are more mental difficulties in comprehending an atom than there are in these great stellar galaxies. I might say that there is as much mystery in the radio. Is it not hard to conceive of the marvellous amplification by the audion of those feeble impulses that go through the ether?"

We know not only the distances, the sizes, and the ages of the stars, but also of what elements they are composed. A great philosopher once declared that the latter was one of the few things which mankind would never know.

"Every kind of substance," Dr. Moulton pointed out, in explaining the operation of spectrum analysis, "gives forth a certain kind of light. Iron, sodium, calcium, and so on, each gives its own special light. If there is a certain character of light that travels twenty feet in the laboratory, it will be the same if it comes millions of miles from the sun. So from the character of light that comes from the sun, as registered by the lines in the spectrum, we can determine what is in the sun. We know that there are iron, nickel, and cobalt in the sun, and in fact most of the common elements. The gas called *helium,* now known to exist on the earth and produced commercially, was first discovered in the sun. The sun and the earth are composed of the same things, though perhaps not in the same proportions. That is not so startling, however, for all the elements are made of electrons, and it may be that all the elements we have are all that can exist."

Our solar system, the earth, and man himself are reduced to insignificance, from a quantitative standpoint, when we go with an astronomer like Dr. Moulton on a mental exploration trip through the vast reaches of the universe, passing on the way myriads of flaming suns which could swallow our own, and glimpse far beyond our own universe the boundaries of other universes of whose existence a few years ago we were unaware. But then one thinks of the human intelligence which measures these distant suns and charts the depths of cosmic space. The study of astronomy humbles man, but paradoxically it gives one a new sense of human dignity and worth.