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The Address of the President - The Cosmology of the Universe

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THE ADDRESS OF THE PRESIDENT

THE COSMOLOGY OF THE UNIVERSE

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Astronomy is the original science. Its scope comprehends all the physical sciences — geology, physics, chemistry — and even the natural sciences. All borrow from it, and in turn contribute to astronomical knowledge. Moreover, from the very beginning, the study of astronomy has been inseparably connected with philosophy and religious speculation. For its theme — its age-long objective — has been a true world concept. I quote: "Back of every religion, and of every philosophy or science, worthy of the name, lies a world-view, a concept in which are included all localities and all beings supposed in that religion or philosophy or science to exist. In proportion to its clearness and completeness it, in every case, groups and mentally pictures these localities and beings in certain relations to each other, and thus also in their total unity as a universe. The science which critically investigates and expounds the world-view of any people or of any system of doctrine is called cosmology."

Every race has had its cosmology, the current interpretation of which has in many cases gone far afield through the teaching of various leaders in scholarship. Almost daily new facts and new relations have been revealed by investigators, so that any deduction or concept needs for its best statement continual modification. One needs only to call to mind the metamorphosis of world concepts from the days of the ancient Babylonians to the deductions of the theory of relativity, to support this statement. The history of the struggle to gain a true concept of the solar system is familiar to all and will be passed with this single mention.

Today the attention of the astronomer is absorbed in a similar attempt to solve the cosmogony of the stellar universe. Of course we have long ago passed the Egyptian and Ptolemaic and have penetrated far into the Copernican age of siderial astronomy. Since the days of Halley, Wright, Kant, and La Place this concept has undergone continuous modification. In a masterful discussion of "The Structure of the Universe," Dr. Simon Newcomb says:

"From the philosophic standpoint a discussion of the subject which is of such weight that in the history of thought it must be assigned a place above all others is that of Kant in his *Kritik*. Here we find two opposing propositions — the thesis that the universe occupies only a finite space and is of finite duration; the antithesis that it is infinite both as regards extent in space and duration of time. Both of these opposing propositions are shown to admit of demonstration with equal force, not directly, but by methods of *reductio ad absurdum*."

I cannot agree fully with the *reductio ad absurdum* method of proof, especially in astronomical science, admittedly true for certain lines of logic. But who is to determine when a proposition regarding the nature and extent of the cosmos has been reduced to absurdity? In my opinion this depends upon the experience of the one who judges the argument. What is absurd in the scientific world today becomes a method for investigation of new truths tomorrow.

In 1720 Halley argued that "the light would diminish more rapidly than the distance between the stars increased and therefore space would not be equally illuminated if the stars were infinite in number." He further suggested that light from the stars at a great distance would not reach the earth. It would seem that Halley had in mind an infinite universe. The main argument that is constantly being used against an unlimited universe is that space would be equally and brilliantly illuminated if the stars were infinite in number. Practically all the older methods of dealing with the extent and form of the universe were based upon the principle of equal distribution of the stars (uniform density of matter) and their apparent luminosity. About the only observational data upon which to base this principle was the observed stellar density and the ratio of the number of stars of any given apparent magnitude to the number of stars in the next lower magnitude, together with the pitifully small number of stars whose distances had been determined by direct trigonometric methods.

From such inductive studies, astronomers, notably Wolf of Germany, Eddington of England, and Newcomb of America, have postulated a fairly accordant concept of the extent and structure of our stellar universe, the general characteristics of which are (1) that the stars are limited in number and not uniform in distribution; (2) that the "Milky Way" or "Great Galaxy" constitutes the major part of our system and is about thirty thousand light years in its longest diameter and something like

one-sixth this distance in thickness; (3) that the solar system is not far from the center of the galactic system. According to this postulate our system is comparatively simple in structure and extremely finite in dimensions. The classes of objects visible in our telescope and generally considered as constituting the universe consist of (1) stars with their attendant system of planets, including the double and multiple systems; (2) star clusters of two main types — globular and loose clusters; (3) nebulae, of which there are four types — (a) bright, diffuse, undifferentiated masses of enormous size and wholly gaseous in character, (b) dark nebulae of remarkable form and size and associated in practically every case with bright nebulae, (c) planetary nebulae including the ring form. These are very few in number and practically all in the "Milky Way." They give a gaseous spectrum and have high radial velocities. (d) The spirals, with their peculiar space distribution, clustering about the poles of the "Milky Way." Their numbers run into the hundreds of thousands if not millions. Their spectrum resembles that of the denser clusters and bright star clouds in our galaxy. Their space velocities are enormous.

Astronomical research is as noted for its methods as it is for its results. We have seen on the instrumental side the most astounding development recorded by any science; from the sextant of Tyco Brahe through the telescope of Galileo to the one-hundred-inch Hooker; from the spectroscope of Huggins to the spectroheliograph of Hale; from the micrometer of Hershell to the interferometer of Michelson. On the theoretical side the list of notable names is too long to mention more than the extreme limits, commencing possibly with Olbers and expanding into a great galaxy of present-day men. Indeed, very recently there has been developed a new branch of science known as Statistical Astronomy. As Theoretical Astronomy attacked the problems of the solar system, so statistical astronomy bids more than fair to solve the question of the extent and form of our siderial universe. Kapteyn in Europe and Russell in America are probably the pioneers of this new astronomy. Within the last ten years Dr. Russell has demonstrated a remarkable progression of absolute magnitude with spectral type and suggested the strong possibility of the existence of so-called giant and dwarf stars. Dr. Walter S. Adams of the Mount Wilson observatory has discovered a similar relation between the relative intensities of certain sets of spectral lines in stars of known distances and their absolute magnitude. We have here then a method which will determine the

distances of the stars by means of their spectra and apparent magnitude, though depending fundamentally on direct measurements for its scale. Dr. H. H. Turner of the Greenwich observatory, commenting upon the accordance of the trigonometric parallaxes as measured by Dr. S. A. Mitchell at the Leander McCormick observatory with the spectroscopic parallaxes as determined by Dr. W. S. Adams at Mount Wilson, said: "It gives good assurance that Dr. Adams' working curves for inferring parallaxes which were necessarily formed by a series of approximations (trial and error), are approaching final shape, if indeed they have not already attained it, and I will venture to add a word of admiration for the great advance in our knowledge of the distance of the stars rendered conspicuous by this most beautiful accordance of the two methods."

With these methods and the ever-increasing mass of data made possible by our modern observatories, we have a system of measuring distance beyond the most daring dream of celestial mechanics. Dr. H. D. Curtis, director of the Allegheny observatory has examined about five thousand separate parallax results from which he has selected one thousand six hundred strictly modern values for one thousand one hundred stars, and plotted their absolute magnitude against spectral type, the results of which investigation will be shown on the screen. Through his extensive study of stellar clusters Dr. Shapley, director of the Harvard College Observatory, has shown remarkable correlations between the members of star clusters and like members in the solar neighborhood, which has extended our knowledge of the star clusters and groups of stars to unbelievable limits.

For example, in a series of papers entitled "Studies Based on the Colors and Magnitudes in Stellar Clusters" he finds that a wide range of color is present in star clusters, but that change of color with brightness is hardly perceptible, that magnitudes of the blue stars seem to indicate the remoteness of the star clusters and also that they are of great dimensions. He further deduces that cluster stars are very probably giants in luminosity and accordingly the distance of the groups must be of the order of fifteen thousand light years. The wide dispersion in magnitude of both blue and red stars indicates a similarly great distance for the neighboring galactic clouds. He suggests that the extent of the stellar clouds in the line of sight is relatively very great. In fact, the depth may be as great as or greater than the distance of the nearer boundary.

In the bulletin of the National Research Council, May, 1921, the same author says: "We know some of these important correlations with greater certainty in the star clusters than in the solar neighborhood. We now have the spectra of many individual stars, the colors and spectral type of variables and something also of the absolute luminosity of the brightest stars of the clusters from the appearance of the spectra. Is it surprising therefore that we venture to determine the distance of this cluster "Messier 13" and similar systems with more confidence than was possible when none of these facts was known or even seriously considered in cosmic speculation?"

In a report on "The Physical Members of the Pleiades Group," L. O. Bulletin No. 333, Mr. Robert Trumbler who has given extensive study to this cluster through the application of these modern criteria, says: "With respect to the distribution of the stars among the different spectral types, the relation between luminosity, spectral type and color, the proportion of double stars, etc., this cluster resembles our stellar system on the average, with the exception however that yellow and red giants are completely missing in the Pleiades and that the stellar density is about ten times greater than in the immediate neighborhood of our sun."

As a result of these statistical studies we find that the stars differ greatly in absolute luminosity and absolute magnitude. By absolute magnitude is meant the apparent magnitude of the stars if they were all placed at the same distance, that is, at a distance corresponding to a parallax of one-tenth of a second of arc or thirty-two and six-tenths light years. This relation of absolute magnitude to spectral type shows that our own sun is a typical star of about the fifth absolute magnitude and neither a giant nor a dwarf, but is classed as a "G" type star.

Today astronomers are divided, as to the extent and form of our stellar system, into two camps. One, whose leader is Dr. Shapley, conceives of our stellar system as practically unlimited in extent and similar in arrangement to star clusters. To quote again from Dr. Shapley's paper, "One consequence of accepting the theory that clusters outline the form and extent of the galactic system is that the sun is found to be very distant from the middle of the galaxy. It appears that we are not far from the center of a large local cluster or cloud, but that cloud is at least fifteen thousand light years from the center of the "Milky Way." Answering the suggestion made by Newcomb in *The Structure of the Universe* that the appearance of the "Milky Way" is due to

the fact that we are situated in its center, Dr. Shapley suggests that we have been misled due to our restricted methods of measuring distances and by chance position of the sun near the center of the subordinate system, into thinking that we are in the midst of things. In much the same way the ancient man was misled by the rotation of the earth, with its consequent apparent daily motion of our heavenly bodies around the earth, into believing that even this little planet was the center of the universe and that his earthly gods created and governed the whole.

If I were summarizing the world concept of adherents of this school, I would say that our stellar system (the galaxy) is a cloud or star cluster of about three hundred thousand light years in its longest diameter and about one-tenth of this distance in the shortest, which is passing through a spiral nebula about at right angles to its plane. This was probably first definitely postulated by Dr. Comstock of the University of Wisconsin. I quote him: "There is here presented the concept of a definite group of stars moving through a much more widely extended chaos, as the best working hypothesis at present attainable with reference to our stellar system." The globular clusters are typical galaxies or remote systems and the spiral nebulae are not island universes but are purely nebulous in character and probably a part of our own system. The other camp of astronomers reject the practically unlimited dimensions assigned to our stellar system and support what is known as the Island Universe theory. The unconformity of the characteristics assigned to the spirals forms the principal basis for the hypothesis. Their distribution (clustered at the poles of the galaxy) is extremely difficult to account for in any theory of stellar evolution. Why should we find no spirals in the plane of the galaxy if they are part of our own system? By what peculiar law of nature do they all recede from the galactic plane, Andromeda excepted? If they are surrounded by rings of absorbing material as the dark markings on typical spirals seem to indicate, their absence in the plane of the "Milky Way" is simply accounted for on the theory that they are obscured by our system. The extreme difference in their sizes is difficult to understand if they are all within approximately the same distance from our system. If, on the other hand, they show a great variety of distances, say from about twenty thousand light years for the Andromeda spiral to say a hundred million light years for the smallest ones which can barely be detected as spirals on photo-

graphs taken by our most powerful telescopes, then their diversity of apparent diameter is easily accounted for. Their spectra, too, are most easily explained on the basis of external galaxies, if we assume that Dr. Fath's results on the integrated spectrum of the "Milky Way" is taken as criterion. The further fact that *novæ* or new stars have never been found outside our galaxy except in spirals, gives strong support to the hypothesis of external systems. Of course the extreme distances postulated above would demand that the novæ should be of very high order of absolute magnitude. But they would compare in this particular very favorably with known novæ in our own system. The most baffling argument against the theory that the spirals are island universes is found in their proper motions. If Slipher's measurements at Flagstaf and Van Maanen's at Mt. Wilson on the rotation of spirals are verified by subsequent observations in other systems, it would seem absolutely necessary to abandon the Island Universe theory. At the close of his admirable article, Dr. Shapley says: "But even if spirals fail as galactic systems, there may be elsewhere in space stellar systems equal to or greater than ours, as yet unrecognized and possibly quite beyond the power of existing optical devices and present measuring scales."

No discussion of this subject, however inadequate, should be concluded without some recognition of Einstein's "Theory of Relativity." It, at least, escapes the criticism of being an hypothesis created "ad hoc." Schleck points out that the general theory of relativity has the inestimable advantage of giving us an unmistakable answer, whereas the previous Newtonian theory left us in total uncertainty, and could only rescue us from forming a highly undesirable picture of the universe by making new and unconfirmed hypotheses.

According to Einstein, if we suppose the matter of the universe to be distributed with absolute uniformity, space is spherical in structure, but if we consider the density of distribution as the mean, it is quasi-spherical. Now, while a sphere is bounded by its surface, spherical space is unbounded, but not a part of infinite space, that is: it is finite. We therefore have finite yet unbounded space and we should be able to determine its limits. Einstein gives us the formula. V (volume) equals 7 times 10 raised to the 41st power, divided by the square root of p cubed (where p is the mean density of matter). The postulate that star clusters are universes would seem not to be at variance with relativity. It

might be urged that the universe has no plural and that to think of island universes is to fall into the old fallacy of Euclidian space. But Einstein shows that in the Euclidian universe the average density of matter is necessarily zero. Interpreting then, the structure of the universe by the general theory of relativity, all the difficulties of the Newtonian theory are overcome, leaving us free to indulge in a world picture as unbounded as we please, yet complete and finite. There is no danger that it will ever become destroyed, because no energy or matter can dissipate into infinity since space is not infinite. The infinity of the cosmos is thus rejected without arbitrary setting of boundaries. As Schleck in a bit of ecstacy phrases it: "By combination of physical, mathematical and philosophic thought, genius has made it possible to answer by means of exact methods questions concerning the universe which seemed doomed forever to remain the objects of vague speculation."

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