SCIENCE

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*THE UNIVERSE AS AN ORGANISM.**

IF I were called upon to convey, within the compass of a single sentence, an idea of the trend of recent astronomical and physical science, I should say that it was in the direction of showing the universe to be a connected whole. The farther we advance in knowledge, the clearer it becomes that the bodies which are scattered through the celestial spaces are not completely independent existences, but have, with all their infinite diversity, many attributes in common.

In this we are going in the direction of certain ideas of the ancients which modern discovery long seemed to have contradicted. In the infancy of the race, the idea that the heavens were simply an enlarged and diversified earth, peopled by beings who could roam at pleasure from one extreme to the other, was a quite natural one. The crystalline sphere or spheres which contained all formed a combination of machinery revolving on a single plan. But all bonds of unity between the stars began to be weakened when Copernicus showed that there were no spheres, that the planets were isolated bodies, and that the stars were vastly more distant than the planets. As discovery went on and our conceptions of the universe were

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enlarged, it was found that the system of the fixed stars was made up of bodies so vastly distant and so completely isolated that it was difficult to conceive of them as standing in any definable relation to each other. It is true that they all emitted light, else we could not see them, and the theory of gravitation, if extended to such distances, a fact not then proved, showed that they acted on each other by their mutual gravitation. But this was all. Leaving out light and gravitation, the universe was still, in the time of Herschel, composed of bodies which, for the most part, could not stand in any known relation one to the other.

When, forty years ago, the spectroscope was applied to analyze the light coming from the stars, a field was opened not less fruitful than that which the telescope made known to Galileo. The first conclusion reached was that the sun was composed almost entirely of the same elements that existed upon the earth. Yet, as the bodies of our solar system were evidently closely related, this was not remarkable. But very soon the same conclusion was, to a limited extent, extended to the fixed stars in general. Such elements as iron, hydrogen and calcium were found not to belong merely to our earth, but to form important constituents of the whole universe. We can conceive of no reason why, out of the infinite number of combinations which might make up a spectrum, there should not be a separate kind of matter for each combination. So far as we know, the elements might merge into each other by insensible gradations. It is, therefore, a remarkable and suggestive fact when we find that the elements which make up bodies so widely separate that we can hardly imagine them having anything in common, should be so much the same.

In recent times what we may regard as a new branch of astronomical science is being developed, showing a tendency toward unity of structure throughout the whole domain of the stars. This is what we now call the science of stellar statistics. The very conception of such a science might almost appal us by its immensity. The widest statistical field in other branches of research is that occupied by sociology. Every country has its census, in which the individual inhabitants are classified on the largest scale and the combination of these statistics for different countries may be said to include all the interest of the human race within its scope. Yet this field is necessarily confined to the surface of our planet. In the field of stellar statistics millions of stars are classified as if each taken individually were of no more weight in the scale than a single inhabitant of China in the scale of the sociologist. And yet the most insignificant of these suns may, for aught we know, have planets revolving around it, the interests of whose inhabitants cover as wide a range as ours do upon our own globe.

The statistics of the stars may be said to have commenced with Herschel's gauges of the heavens, which were continued from time to time by various observers, never, however, on the largest scale. The subject was first opened out into an illimitable field of research through a paper presented by Kapteyn to the Amsterdam Academy of Sciences in 1893. The capital results of this paper were that different regions of space contain different kinds of stars and, more especially, that the stars of the Milky Way belong, in part at least, to a different class from those existing elsewhere. Stars not belonging to the Milky Way are, in large part, of a distinctly different class. Yet, the extent of each of these classes is as great as that of the universe. Throughout the whole of the extent of the latter, we find in one direction a certain class of stars to be predominant and throughout its whole circuit in other directions, a different class.

This supposition was still farther emphasized through the researches of Seeliger on the distribution of the stars in space. He exclaimed, with what we might regard as a pardonable approach to enthusiasm not common in a mathematical discussion, that the Milky Way was now to be regarded as a single object. Another curious fact is that, within it, the stars, so far as we can yet determine, seem to be equally scattered from one extreme to the other. In two opposite directions, that of the poles of the Milky Way, the number of stars which we see are fewest. Their thickness increases, slowly at first, then more rapidly, until we reach the Milky Way itself. So far as has yet been determined there is a perfect symmetry on the two sides of the Milky Way. If, on one side the stars seem to be a little thicker here than on the corresponding side, the case is the reverse in some other regions. The general rule is that if we take two diametrically opposite directions in the heavens, no matter which, and count the number of stars within a given area of, say, ten square degrees in each of these opposite directions, we shall find the number to be nearly the same. The nearer our directions come to the plane of the Milky Way, the more numerous the stars we shall find in the two opposite cases, but the increase in thickness will not be much greater at one end of our line of sight than at the opposite end. Moreover, if we change the direction of this imaginary diameter of the universe, we shall find that, so long as it makes the same angle with the Milky Way, so long will the number of stars around it remain the same. The statistical evidence also shows us that the stars of the Milky Way are, in a general average, several times as bright as those situated elsewhere.

The feature of the universe which should therefore command our attention is the arrangement of a large part of the stars which compose it in a ring, seemingly alike in all its parts, so far as general features are concerned. So far as research has yet gone, we are not able to say decisively that one region of this ring differs essentially from another. It may, therefore, be regarded as forming a structure built on a uniform plan throughout.

All scientific conclusions drawn from statistical data require a critical investigation of the basis on which they rest. If we are going, from merely counting the stars, observing their magnitudes and determining their proper motions, to draw conclusions as to the structure of the universe in space, the question may arise how we can form any estimate whatever of the possible distance of the stars, a conclusion as to which must be the very first step we take. We can hardly say that the parallaxes of more than 100 stars have been measured with any approach to certainty. The individuals of this 100 are situated at very different distances from us. We hope, by long and repeated observations, to make a fairly approximate determination of the parallaxes of all the stars whose distance is less than 20 times that of α Centauri. But how can we know anything about the distance of stars outside this sphere? What can we say against the view of Kepler that the space around our sun is very much thinner in stars than it is at a greater distance; in fact that the great mass of the stars may be situated between the surfaces of two concentrated spheres not very different in radius. May not this universe of stars be somewhat in the nature of a hollow sphere?

This objection requires very careful consideration on the part of all who draw conclusions as to the distribution of stars in space and as to the extent of the visible universe. The steps to a conclusion on the subject are briefly these: First we have a general conclusion, the basis of which I have already set forth, that, to use a loose expression, there are likenesses throughout the whole diameter of the universe. There is, therefore, no reason to suppose that the region in which our system is situated differs in any essential degree from any other region near the central portion. Again, spectroscopic examinations seem to show that all the stars are in motion, and that we cannot say that those in one part of the universe move more rapidly than those in another. This result is of the greatest value for our purposes, because, when we consider only the apparent motions, as ordinarily observed, these are necessarily dependent upon the distance of the star. We cannot, therefore, infer the actual speed of a star from ordinary observations until we know its distance. But the results of spectroscopic measurements of radial velocity are independent of the distance of the star.

But let us not claim too much. We can not yet say with certainty that the stars which form the agglomerations of the Milky Way have, beyond doubt, the same average motion as the stars in other regions of the universe. The difficulty is that these stars appear to us so faint individually, that the investigation of their spectra is still beyond the powers of our instruments. But the extraordinary feat performed at the Lick Observatory of measuring the radial motion of 1830 Groombridge, a star quite invisible to the naked eye, may lead us to hope for a speedy solution of this question. But we need not await this result in order to reach very probable conclusions. The general outcome of researches on proper motions tends to strengthen the conclusions that the Keplerian sphere, if I may use this expression, has no very well marked existence. The laws of stellar velocity and the statistics of proper motions, while giving some color to the view that the space in which we are situated is thinner of stars than elsewhere, yet show that, as a general rule, there are no great agglomerations of stars elsewhere than in the region of the Milky Way.

With unity there is always diversity; in fact the unity of the universe on which I have been insisting consists in part of diversity. It is very curious that, among the many thousands of stars which have been spectroscopically examined, no two are known to have absolutely the same physical constitution. It is true that there are a great many resemblances. α Centauri, our nearest neighbor, if we can use such a word as 'near' in speaking of its distance, has a spectrum very like that of our sun, and so has Capella. But even in these cases careful examination shows differences. These differences arise from variety in the combinations and temperature of the substances of which the star is made up. Quite likely also, elements not known on the earth may exist in the stars, but this is a point on which we cannot yet speak with certainty.

Perhaps the attribute in which the stars show the greatest variety is that of absolute luminosity. One hundred years ago it was naturally supposed that the brighter stars were the nearest to us, and this is doubtless true when we take the general average. But it was soon found that we cannot conclude that because a star is bright, therefore it is near. The most striking example of this has been brought out by the researches of Gill on the parallax of Rigel, the brightest star in Orion, and of Canopus, which is, next to Sirius, the brightest star in the heavens. In both these cases the parallax from a long series of measurements, extending through several years, came out just zero. These stars, then, though of the first magnitude, are immeasurably distant. A remarkable fact is that these conclusions coincide with that which we draw from the minuteness of the proper motions. Rigel has no motion that has certainly been shown by more than a century of observation, and it is not certain that Canopus has either. From this alone we may conclude, with a high degree of probability, that the distance of each is immeasurably great. We may say with certainty that the brightness of each is thousands of times that of the sun and with a high degree of probability, that it is hundreds of thousands of times. On the other hand, there are stars comparatively near us of which the light is not the hundredth part that of the sun.

The universe may be a unit in two ways. One is that unity of structure to which our attention has just been directed. This might subsist forever without one body influencing another. The other form of unity leads us to view the universe as an organism. It is such by mutual action going on between its bodies. A few years ago we could hardly suppose or imagine that any other agents than gravitation and light could possibly pass through spaces so immense as those which separate the stars.

The most remarkable and hopeful characteristic of the unity of the universe is the evidence which is being gathered that there are other agencies whose exact nature is yet unknown to us, but which do pass from one heavenly body to another. The best established example of this yet obtained is afforded in the case of the sun and the earth.

The fact that the frequency of magnetic storms goes through a period of about eleven years, and is proportional to the frequency of sun spots, has been well established. The recent work of Professor Bigelow shows the coincidence to be of remarkable exactness, the curves of the two phenomena being practically coincident so far as their general features are concerned. The conclusion is that spots on the sun and magnetic storms are due to the same cause. This cause can not be any change in the ordinary radiation of the sun, because the best records of temperature show that, to whatever variations the sun's radiation may be subjected, they do not change in the period of the sunspots. To appreciate the relation, we must recall that the researches of Hale with the spectroheliograph show that spots are not the primary phenomenon of solar activity, but are simply the outcome of processes going on constantly in the sun which result in spots only in special regions and on special occasions. It does not, therefore, necessarily follow that a spot does cause a magnetic storm. What we should conclude is that the solar activity which produces a spot also produces the magnetic storm.

When we inquire into the possible nature of these relations between solar activity and terrestrial magnetism, we find ourselves so completely in the dark that the question of what is really proved by the coincidence may arise. Perhaps the most obvious explanation of fluctuations in the earth's magnetic field to be inquired into would be based on the hypothesis that the space through which the earth is moving is in itself a varying magnetic field of vast extent. This explanation is tested by inquiring whether the fluctuations in question can be explained by supposing a disturbing force which acts substantially in the same direction all over the globe. But a very obvious test shows that this explanation is untenable. Were it the correct one, the intensity of the force in some regions of the earth would be diminished and in regions where the needle pointed in the opposite direction would be increased in exactly the same degree. But there is no relation traceable either in any of the regular fluctuations of the magnetic force, or in those irregular ones which occur during a magnetic storm. If the horizontal force is increased in one part of the earth, it is very apt to show a simultaneous increase the world over, regardless of the direction in which the needle may point in various localities. It is hardly necessary to add that none of the fluctuations in terrestrial magnetism can be explained on the hypothesis that either the moon or the sun acts as a magnet. In such a case the action would be substantially in the same direction at the same moment the world over.

Such being the case, the question may arise whether the action producing a magnetic storm comes from the sun at all, and whether the fluctuations in the sun's activity, and in the earth's magnetic field may not be due to some cause external to both. All we can say in reply to this is that every effort to find such a cause has failed and that it is hardly possible to imagine any cause producing such an effect. It is true that the solar spots were, not many years ago, supposed to be due in some way to the action of the planets. But, for reasons which it would be tedious to go into at present, we may fairly regard this hypothesis as being completely disproved. There can, I conclude, be little doubt that the eleven-year cycle of change in the solar spots is due to a cycle going on in the sun itself. Such being the case, the corresponding change in the earth's magnetism must be due to the same cause.

We may, therefore, regard it as a fact sufficiently established to merit further investigation that there does emanate from the sun, in an irregular way, some agency adequate to produce a measurable effect on the magnetic needle. We must regard it as a singular fact that no observations yet made give us the slightest indication as to what this emanation is. The possibility of defining it is suggested by the discovery within the past few years, that under certain conditions, heated matter sends forth entities known as Röntgen rays, Becquerel corpuscles and electrons. I can not speak authoritatively on this subject, but, so far as I am aware, no direct evidence has yet been gathered showing that any of these entities reach us from the sun. We must regard the search for the unknown agency so fully proved as among the most important tasks of the astronomical physicist of the present time. From what we know of the history of scientific discovery, it seems highly probable that, in the course of his search, he will, before he finds the object he is aiming at, discover many other things of equal or greater importance of which he had, at the outset, no conception.

In his study of what is going on among the stars, even the astronomer may for a time fail to grasp the true significance of what he sees through leaving out of account the vastness of the field which he is surveying. A remarkable case of this is seen in the case of the new stars which have been known to burst forth from time to time. In at least two notable cases of this kind within the past ten years, such stars have been found, within a few months after their outburst, to be changed into or surrounded by a nebula. Nothing could, at first sight, seem more natural or easily explained than this occurrence. To whatever cause we may attribute such a catastrophe as the sudden multiplication, within the period of two or three days, of the light of a sun by thousands of times, the cataclysm must result in throwing out a mass of incandescent vapor, rising with great speed. This vapor expanding on all sides, will appear to us as a nebula surrounding the star and continually enlarging. That any difficulty can stand in the way of this view will first appear when we make an estimate of the probable extent of such a nebula. To do this requires that we know something of the distance of the star. This can not be determined by any absolute method, so that our conclusions as to the distance must in part be conjectural. Yet we can say with a high degree of probability that the annual parallax of these new stars can scarcely be much greater than the thousandth of a second. We have two independent bases for this conclusion.

One is that such stars have never blazed forth except in the regions of the Milky Way. We are, therefore, justified in believing them as distant as the Milky Way. Now one of the results of stellar statistics which we need not stop to reason out at the present time is that the distance of the Milky Way can scarcely be much less than that corresponding to the parallax I have indicated. Even this distance falls far short of the estimates of Sir William Herschel, who is stated to have placed the outermost visible stars of our system at a distance which light would require many thousand years to traverse. He supposed us to see all the stars of the Milky Way by pre-Adamite light. But the distance which I have indicated is that over which light would travel in about 3,400 years.

The other argument on the subject may be briefly stated in this form. From what we know of the thickness of the stars in our immediate neighborhood, there is every reason to believe that, out of several hundreds of million of stars in the universe, not more than twenty thousand are within the distance corresponding to a parallax of 0″.02. The chances are, therefore, more than ten thousand to one that any star in the universe, taken at random, would lie within this range of distance from us.

Another reason for placing the Milky Way, and with it the new stars, at this distance is found in the absence of proper motions from such stars. Most careful and refined measures made by Barnard on Nova Persei show a motion of only 0″.01 in the course of a year, which is only saying that no motion has been seen. Although this result is not conclusive, it affords additional very strong evidence in favor of the view that this star was really in the region of the Milky Way.

Assuming, then, that the distance is of this order of magnitude, let us ask at what speed a nebula must rise in order that it may expand as rapidly as observation seems to show the matter around Nova Persei to have flown outward. Calculations would show this speed to beggar all our conceptions. The highest speed which matter has been known to reach is that attained by the eruption of hydrogen and other gases from the sun, which sometimes amounts to several hundred miles a second. But matter moving only with such a speed as this would require centuries to form a nebula of appreciable size at the distance we have assigned to the new stars.

The application of this principle to the case of Nova Persei led to an ingenious suggestion by Kapteyn that the seemingly slow expansion of the nebula which surrounds Nova Persei was not a motion of matter at all, but only an illumination of nebulous matter already existing by the wave of light thrown out from the exploded star. At first sight the reply to this suggestion might be that the observed expansion can not come up to light in speed. One might be astonished to hear that, inconceivably swift as is the motion of light, it might be well that, at such a distance, it would seem to us as slow as the apparent expansion of the nebula in question. But when we put the matter into cold figures, we find that the great difficulty in the way of accepting Kapteyn's explanation is the opposite of this. What we have to deal with is not the apparent slowness of the motion, but the inadequacy of the speed of light to explain the phenomena. If the distance of this star is only 400 times that of α Centauri, the speed of the apparent expansion must have been ten times that of light.

Of all agencies known to be propagated through space in time, light is the swiftest in its motion. We may, therefore, say that no known cause coming into action in February, 1901, could, within the twenty-two months which have since elapsed, have emanated from the star so as to make itself felt outside of a sphere which, at the distance in question, would subtend to our eyes an angle of more than four minutes in diameter. We seem, therefore, forced to the conclusion that either the illumination or nebulosity surrounding Nova Persei during the summer of 1902 existed independently of the outburst of the star, or there exists in the universe a cause susceptible of transmission with a speed several times that of light.

When we look closely into the matter, we find some difficulty in proposing any hypothesis based on the known action of natural agents. A continual course of self discipline is necessary to enable us to appreciate the real significance of the question. The facts, as I understand them, are briefly these: We see by photography an object in the heavens in which certain changes are going on consisting of variations in the appearance of the illuminated portions. Day after day we see that a certain illumination beginning at a point *A*, no matter where, spreads to a point *B*, and perhaps a point of light, *C*, begins to show itself. The natural conclusion is that something is being propagated. The point *B* has received an emanation from *A* and the point *C* has not appeared spontaneously, but has been connected with something going on at some other point, perhaps the central star. In attributing this propagation to that of anything but light and radiant heat, we are met by the difficulty that all other known natural causes which could have operated in such a case fall short of this in their speed of transmission.

Whichever way we turn we meet with difficulties which seem insuperable in constructing any theory that will explain the observed phenomena. The light theory which I have mentioned is rendered more unlikely from the fact that the latest researches upon the Lick photographs seem to show that the emanation did not go out in straight lines with uniform velocity, but branched off here and there, sometimes in one direction and sometimes in another, with varying speed. There is a difficulty in attributing the apparent expansion to the motion of light which seems yet greater than this. The speed of light is perfectly uniform. The outburst was extremely sudden, it being only two or three days from the time when the star became visible until it reached first magnitude. Under the circumstances the outgoing light-wave would have been a well-defined spherical surface, brighest at a point so near the actual surface that its extent would not be visible at such a distance. The star faded away at a rate which reduced it to one half in a very few days and again to one half in a few days more. The light emanating from such an object would, therefore, have presented to our eyes the appearance of a well-defined luminous circular disc, brightest at the circumference outside of which all would have remained in complete darkness. It is true that, owing to the difference of density of the material reflecting the light, the disc would not have been uniform. It might have many gaps here and there and present a cloudy appearance. But with all these differences the boundary would have been as well defined as if the disc had been turned in a lathe.

This would suggest our having recourse to the corpuscles of which the investigation is now beginning and may be the main subject of physical research during the next generation. But here, if we accept the theoretical result of Professor J. J. Thomson, we meet with the difficulty that these entities can not travel with a greater speed than that of light. Under these circumstances nothing seems left for us in the present state of our knowledge but to turn over to our successors the problem of explaining the phenomena.

The main point I desire to bring out in this review is the tendency which it shows towards unification in physical research. Heretofore differentiation—the subdivision of workers into a continually increasing number of groups of specialists—has been the rule. Now we see a coming together of what, at first sight, seem the most widely separated spheres of activity. What two branches could be more widely separated than that of stellar statistics, embracing the whole universe within its scope, and the study of these newly-discovered emanations, the product of our laboratories, which seem to show the existence of corpuscles smaller than the atoms of matter? And yet, the phenomena which we have reviewed, especially the relation of terrestrial magnetism to the solar activity, and the formation of nebulous masses around the new stars, can be accounted for only by emanations or forms of force, having probably some similarity with the corpuscles, electrons and rays which we are now producing in our laboratories. The nineteenth century, in passing away, points with pride to what it has done. It has become a word to symbolize what is most important in human progress. Yet, perhaps its greatest glory may prove to be that the last thing it did was to lay a foundation for the physical science of the twentieth century. What shall be discovered in the new fields is, at present, as far without our ken as were the modern developments of electricity without the ken of the investigators of one hundred years ago. We can not guarantee any special discovery. What lies before us is an illimitable field, the existence of which was scarcely suspected ten years ago, the exploration of which may well absorb the activities of our physical laboratories, and of the great mass of our astronomical observers and investigators for as many generations as were required to bring electrical science to its present state. We of the older generation can not hope to see more than the beginning of this development, and can only tender our best wishes and most hearty congratulations to the younger school whose function it will be to explore the limitless field now before it.

S. NEWCOMB.

*PLANS OF THE NEW BUILDINGS FOR THE NATIONAL BUREAU OF STANDARDS.**

THE work for which the National Bureau of Standards was established includes research and testing in the domain of physics, extending into the field of chemistry on the one hand and of engineering on the other. The union of research and testing in one institution is of supreme importance, the investigations being, of course, primarily designed to carry the work of standardization and testing to the highest possible efficiency. The Physikalisch-Technische Reichsanstalt is an illustrious example before all the world of how much can be accomplished where research and testing are combined in one institution; and that the union should be intimate is further shown by the fact that more or less research is carried on in the second, or technical, division of the Reichsanstalt, instead of being confined to the first

* A paper read before the Philosophical Society of Washington, October 25, 1902.