The President's Address.

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THE CENTRE OF THE VISIBLE UNIVERSE.

Is there a Central Sun ?

FROM time immemorial those who gazed at the sky have speculated on the shape of the heavens. Ancient literature abounds in references to the structure of the sky and the arrangement of the host of stars. We no longer think that the stars are fixed in a crystal vault, but as we probe further and further into space we still have to re-adjust our ideas from time to time in the light of wider and wider knowledge. Now and again we have to halt and take stock of our knowledge and see whether the latest additions to our store of information lead us to change any of the views we have hitherto held.

Copernicus, in his treatise " De Revolutionibus " concludes that the Universe is spherical, because it is the most perfect figure ; because it is the most capacious figure, fittest to enclose and preserve all things ; because all observed things celestial—the Sun, the Moon—are seen to have that shape, and because all things capable of assuming the shapes they prefer, such as drops of water and other liquids, always select the figure of a sphere.

Copernicus had no sooner enunciated his hypothesis of the mechanism of the Solar system, placing the Sun in the centre with the planets, and the Earth as one of them, circling round the Sun, than an objection was raised that if the Earth really moved round the Sun in an orbit millions of miles in diameter this movement carried the observer first to one side of the Sun and then to the other side so that the stars ought to appear very differently as viewed from opposite sides of the Earth's orbit; the stars ought to be displaced with respect to each other, the nearer stars seeming to move most and those more distant moving less. As no such movement could be seen, this was considered an insuperable objection to the Copernicus theory. It is true that Copernicus himself provided the answer. He said that the great distances of the stars as compared with the dimensions of the Earth's orbit prevented the star displacements from being observed. His contemporaries, however, were unable to imagine a universe so vast, and later in the same century another eminent astronomer, misled by the apparent size of the discs of first magnitude stars, suggested a variation of the Copernican theory, which for a time had a number of supporters. With the application of the telescope to astronomy, just 300 years ago, Galileo thought he would be able to observe some displacements of the stars, and proposed to observe pairs of stars, believing that where stars seemed to be close together they were merely lying in the same line of sight and were at different distances. He failed to measure any parallax, neither were his successors for 200 years any more successful. When Sir William Herschel in his turn attempted to make use of this method he also did not succeed in finding any measurable parallax; but he made another extremely interesting discovery. He found that some of the pairs of stars he was observing were not only in the same line of sight but were also about the same distance from us and proved them to be binary systems revolving round their common centre of gravity.

It was not until near the end of the eighteenth century that the parallax of a star was first detected, and not until near the middle of the nineteenth century that accurate measurements were made, but the number of the stars whose parallax has been reliably measured is now considerable. The earlier measures were very discordant, as might be expected from measurements of quantities that were barely within the grasp of the instruments with which the observations were made, but as more and more powerful telescopes have been employed a greater reliability of measurement has resulted, which has become apparent in more corcordant results. If we could measure the parallax, and thereby the distance, of every visible star we should be able to map out exactly the shape of the visible universe, but many of the distances are far beyond our instrumental reach and we are forced to fall back upon other methods of research to supplement our measured soundings into the depths of space.

Following Plato, many philosophers have believed that the stars are arranged in a uniform manner, and it is necessary to examine this idea. Imagine a star sphere with a radius equal to the distance of the nearest star. Upon the surface of such a sphere there can be placed twelve stars at equal distances from each other and from the centre. Around this sphere imagine another of double the radius; the surface of this sphere will be four times that of the inner sphere and four times the number of stars can be placed upon its surface at the same distances from each other. Outside this imagine another sphere with a radius three times that of the inner one, and its surface will be nine times the inner one and therefore nine times as many stars can be placed upon its surface. And so on, the number of stars the same distance apart that can be placed on the surface of a sphere is in proportion to the square of the radius, and if there is no loss of light in transmission through space each sphere of stars would send the same quantity of light to the centre. If we assume the light from the stars of one sphere to be equal to a hundredth part of the light of the Moon, then the light from a hundred such spheres would be equal to the light of the Moon, and from six hundred million such spheres would be equal to the light received from the Sun. If stars are distributed throughout infinite space, not uniformly but so that every region is, roughly speaking, equally rich in stars, a line drawn from the Earth in any direction would reach a star and consequently the whole sky should be a continuous blaze of light, with no spaces between, if there is no loss of light in travelling through space.

As, however, the stars visible in even the largest telescopes are separated by areas of sky, we are forced to one of four conclusions. Either the visible universe is not infinite, or the light of the most distant stars is absorbed in its journey through space, or the greater part of the light of the stars is obscured by dark bodies, or large regions of space are devoid of stars.

There is evidence of the existence of dark bodies in space, of a size similar to that of the stars with which they are associated, and if the light of the stars is obscured by such as these it would require far more dark stars than bright stars to reduce a visibly continuous mass of stars to the isolated points of light we see. But it would be quite possible for somewhat small masses of matter, small stones or even dust, diffused in space, to obscure the light of distant stars, but no possible arrangement of dark masses of matter that we can imagine could account at the same time for the gradual increases in the number of stars and also for the delicate streams of nebulous light associated with some of the groups of stars.

The possible limitation of stellar light by dark masses not being a sufficient explanation of the dark spaces in the sky we have to consider whether the possible loss of light in transmission through space will limit the visibility of a star. There are various grounds for believing either that the ether is not perfectly elastic or that diffused matter in space acts the part of a fog in preventing part of the light of a star from reaching us. If the light of a star is diminished in this way in passing through space it is only necessary to imagine the star removed to a sufficient but limited distance in order for its light to be so diminished as to render it invisible altogether to us. There are several grounds for believing that light is absorbed in space; one is that the number of faint stars of successive magnitudes is less than we should expect as compared with brighter stars, which suggests that many of the faint stars are fainter than they ought to appear, and another ground is the difficulty in photographing faint stars; they are photographically fainter than their visibility would indicate.

As to the extent to which light is absorbed in space there have been attempts at estimates of the distance from which the light of a star would be reduced by one magnitude, and applying these figures to the visible stars it means that the stars of, for example, the Milky Way, are really one or more magnitudes brighter than they seem to be.

When the arrangement of the stars is closely examined it is found that in several respects they are grouped with some reference to the Galaxy. In the first place there is a more or less well-defined belt of bright stars, almost, but not quite, following the line of the Milky Way. Whenever the faint stars are blotted out, as by moonlight, so that the Milky Way cannot be seen, its position can be made out by the brighter stars which are then visible.

A careful count of the stars away from the Galaxy shows that, generally speaking, there are fewer and fewer stars in the parts of the sky further and further remote from the Milky Way; so that, commencing at the galactic poles there is a gradual increase in the star-density as we approach the Milky Way. This indicates, on the assumption that apart from the Milky Way stars are not very differently distributed in the different regions of space, that the visible universe is more extended in the direction of the Milky Way than in the direction of the galactic axis, and the number of stars counted in the different areas suggest that the visible stars may be contained in a spheroid whose "equatorial" measurement in the plane of the galaxy is two or three times as great as the measurement on the galactic axis. The galaxy does not exactly describe a great circle round the sky, that is to say, it tends a little to one side, and this means that the solar system is not exactly in the plane of the galaxy, but is displaced in the direction of the north galactic pole. The deviation of the line of the galaxy from a great circle is about or somewhat less than two degrees, as found by Professors Seeliger, Pickering and Newcomb, and we may take it as undoubted that the galactic plane lies to the south of the solar system.

A further inquiry was made by Mr. Walkey, and the results were published last year, as to whether the solar system was only displaced along the galactic axis or whether it was also displaced in a direction parallel to the galactic plane. This was done by an examination of star densities with reference to galactic longitude and involved the examination of the places of over 900,000 stars, divided into different areas, some near the galaxy and others in higher galactic latitude. The resultant direction indicated by each group was found, and it varied from 222 degrees to 270 degrees galactic longitude, the galactic longitude being reckoned eastward from the intersection of the celestial and galactic equators in Aquila. Having done this Mr. Walkey further examined a group of stars arranged in order of spectral type, taking the 7 types of stars classified in the Harvard Annals, and the resultant direction indicated by these varied from 230 degrees to 274 degrees of galactic longitude.

The third estimate was made by taking the B type stars alone, grouping the stars of this type in different quadrants and also grouping them by sextants. The resultant found from the B type stars by each means of grouping was 230 degrees galactic longitude. The reason for assigning greater importance to indications given by B type stars than others is because these stars are at greater distances from our system and their proper motion is small. From the B type stars the indication is given that the centre of the visible universe lies approximately in the direction from us of the 230th galactic meridian, and as our system is displaced to the north of the central plane, the centre appears to us to be in the south galactic latitude. Four hundred of the B type stars used for this investigation have been estimated to have a mean distance from us of 500 light-years and the "equatorial" radius of the containing spheroid may be estimated at some larger figures, say, perhaps, 1,000 light-years. Assuming these dimensions, the displacement of our system from the centre would place us some 400 light-years from it and the distance of the galactic main stream must be something of the order of 5,000 to 6,000 light-years.

It is curious that the indication so given of the direction of the centre of the universe from us should point very closely to the star Canopus. Canopus has several peculiarities. In the first place its observed motion is such as to show that it is stationary in space with respect to the B type stars. In the second place it is very distant, its parallax is exceedingly small, giving an estimated distance of nearly 500 light-years. Canopus is enormously large. Calculating its distance as 500 light-years, it is 49,000 times as bright as our Sun. From a study of binary systems whose dimensions are known, the surface brightness of the different spectral types have been derived, and for stars of the spectral type of Canopus the surface is $2\frac{3}{4}$ times brighter than that of the Sun. Having the relative brightness per unit of surface we can calculate the actual dimensions of Canopus, which is thus found to be 134 times the diameter of our Sun.

The observed movements of the stars near Canopus are such as to indicate that the mass of Canopus is not less than 800,000 times, and is probably 1,400,000 times, that of the Sun, and it is very curious that the motion of our Sun in space, crosswise to Canopus, is 3·86 miles a second, just what would result from the movement of our Sun in an orbit about Canopus if the mass of Canopus is 1,400,000.

The facts as far as known may be summed up as follows :—

(1) The centre of the visible universe is about the 230th galactic meridian, and the direction of the centre from us dips to the south on account of our displacement parallel to the plane of the galaxy. This direction points very closely to the star Canopus.

(2) Taking the B type stars alone, the distance of the centre from us is estimated at 400 light-years.

(3) The distance of Canopus from us is calculated at nearly 500 light-years.

(4) Canopus' enormous size is known from his distance and brightness. His mass, calculated from the motions of faint stars in his neighbourhood, and is such as to account for the speed of the Sun's motion in space.

(5) The Solar antapex is in the same galactic latitude as Canopus.

(6) If the indicated direction of the centre of the visible universe be correct, and Canopus is situated at the centre, around which the galaxy describes a great circle on the equatorial circumference of the containing spheroid, the following measures result :—

(7) Displacement of the solar system from the centre of the universe, at right-angles to the plane of the galaxy, 440 light-years.

(8) Displacement parallel to the plane of the galaxy, 200 light-years.

(9) Distance of the galaxy from the centre, about 6,780 light-years.