SCIENCE

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THE SPACE-PENETRATING POWER OF LARGE TELESCOPES.[1]

UNLESS there is some small star or dimly shining body with a large parallax which has not yet been detected, our nearest neighbor amongst the stars is the double star α Centauri. It is situated about thirty degrees from the southern pole of the heavens, and therefore is not visible in England. The two stars together shine with a light which is a little greater than that of a first magnitude star, for the larger of these twin suns is ranked by Professor Gould as being exactly of the first magnitude of the photometric scale, and the smaller star is of the $3\frac{1}{2}$ magnitude.

According to this photometric scale of magnitudes, which is now universally used, a star of the first magnitude gives just a hundred times as much light as a star of the sixth magnitude. Consequently, if the larger star of the pair, which is known as α^2 Centauri, were removed to ten times its present distance, it would appear as a star of the sixth magnitude; but this would only be the case if there were no loss of light in travelling from its more distant position. If there were any absorption of light in passing through such a vast distance of space it might appear smaller, and would probably not be visible to the naked eye, for few people see stars with their unaided eyes which are ranked as smaller than the sixth magnitude. According to the photometric scale, a star of any magnitude gives about two and a half times as much light as a star of the magnitude immediately below it. Thus a star of the sixth magnitude gives 2.512 times as much light as a star of the seventh magnitude, and a star of the seventh magnitude gives 2.512 times as much light as a star of the eighth magnitude. Consequently a star of the sixth magnitude gives 6.31 times as much light as a star of the eighth magnitude, and 15.85 times as much light as a star of the ninth magnitude, 39.81 times as much light as a star of the tenth magnitude, and 100 times as much light as a star of the eleventh magnitude.

Let us suppose that α^2 Centauri was removed to one hundred times its present distance, then, neglecting the absorption of light in space, it would shine as a star of the eleventh magnitude of the photometric scale, and would only just be visible with a telescope of two and a half inches aperture. This calculation is based on the assumption of Professor C. A. Young (Text Book of General Astronomy, sec. 822) that, for normal eyes, with a good telescope, the minimum visible for a one-inch aperture is a star of the ninth magnitude — an estimate which about corresponds to what might be expected from the diameter of the pupil of the eye.

I have measured the diameter of the pupils of several persons whom I believed to have keen sight, amongst others, the observing eyes of the Rev. T. W. Webb, Mr. Burnham, and the late Dr. H. Draper, and have found that about a quarter of an inch generally corresponds to the maximum dilation of the pupil in viewing faint objects. A telescope of one inch diameter would consequently collect about sixteen times as much light as would enter the pupil of the unassisted eye, and ought, with a suitable eye-piece, to show stars giving about one-sixteenth the light of a sixth magnitude star just visible to the naked eye. As we have seen above, a sixth magnitude star gives 15.85 times as much light as a ninth magnitude star of the photometric scale. Consequently, neglecting the absorption of light by the lenses, and the reflection from their surfaces, a one-inch telescope ought, with a suitable eye-piece (which collects and sends into the pupil of the eye the whole of the light from the object-glass), to render stars of the ninth magnitude just visible.

The power used with a telescope makes some difference, as it increases the contrast between the brightness of the star and the background on which it is seen, — the light of the background being dimmed by magnification, while the star in a good defining telescope is but slightly dimmed by moderate magnification. Thus Dawes found that he could see a star of the sixth magnitude with a telescope having an aperture of only 0.15 of an inch when a power of $16\frac{1}{2}$ was used. In the case of the one-inch telescope above referred to, the loss of light by absorption and reflection at the surfaces of the lenses seem to be about balanced by the increase of contrast with the background, due to the power employed.

Let us suppose that α^2 Centauri were removed to a thousand times its present distance, then, neglecting the absorption of light in travelling through space, it would appear as a star of the sixteenth magnitude, and would only just be visible with a telescope of 25.12 inches aperture; and if it were removed to 1,585 times its present distance, it would shine as a star of the seventeenth magnitude of the photometric scale, and would only just be visible in a telescope of 39.81 inches aperture. That is, it would not be visible in the great Lick 36-inch refractor.

These calculations are based on the assumption that there is no absorption of light in passing through great distances of space, and also on the assumption that there is no loss of light in passing through such thick lenses. The thickness of the object-glass of the Washington 26-inch refractor at its centre is nearly three inches; thus, the flint glass lens is there 0.96 of an inch thick, while the crown glass lens is 1.88 inches thick at its centre. Such a thickness more than halves the intensity of the emergent pencil; and the loss of light by absorption in passing through the glass near the centre of the Lick object-glass must be considerable. Exact measures of the absorption of light by such great lenses would be of much interest. We may, however, probably assume with some confidence, that if α^2 Centauri were removed to twelve hundred times its present distance it would not be visible in the Lick telescope, even though there were no absorption of light in space; and α^2 Centauri is probably larger and brighter than our sun. (Assuming, with Mr. Gore, a period of 77 years for this binary, and a parallax of .75 of a second, the sum of the masses of the components will be 2.14 times the mass of the sun.)

Stars smaller than our sun would be lost to sight at smaller distances. Consequently the Milky Way must either be nearer to us than a thousand times the distance of

[1] A. C. Ranyard, in Knowledge for August.

α Centauri, or the smallest stars visible in it with a telescope as large as the Washington 26-inch refractor must be larger than our sun, a supposition at which the mind rebels when we remember the vast size this would imply for the larger stars evidently involved in or associated with the Milky Way. For example, in the Pleiades group there are observable with the eye at the telescope a range of some thirteen magnitudes of the photometric scale, which, translated into ordinary language, means that the larger stars of the cluster give more than a hundred and fifty thousand times as much light as the smaller stars of the cluster.

In the photographs of the Pleiades cluster we have evidence of a range of at least fifteen magnitudes, which means that the larger stars give a million times as much light as the smaller stars, and in the photograph of the coal-sack region of the Milky Way there is evidence of a still greater range of magnitudes. The star α Crucis, which is of 1.3 magnitude, is evidently associated with a dense cluster of small stars, branches from which can be traced far across the coal-sack region, and extending to a considerable distance over the Milky Way or into the Milky Way to the north of α Crucis. We seem to have in this instance evidence of a range of at least seventeen magnitudes. α Crucis is a double star with components about five seconds apart, and there are several small companions that have been observed in the telescope. In the glass photograph by Mr. Russell the spurious disk of the large star is, when examined with a magnifier, seen to contain several small stars forming a cluster about the large one. Indeed, some seven or eight of these small stars may be recognized with a magnifying-glass on the edge of the spurious disc of the large star.

Though the mind may at first be staggered by the conception of stars giving a million times as much light as our sun, we are not in a position to deny the existence of such vast sun-like bodies. Indeed those who accept the nebular hypothesis as giving the most probable explanation of the origin, or rather of the birth, of the planets of the solar system, must be prepared to believe that there was a time when the sun had a diameter as large, or nearly as large, as the diameter of the orbit of Neptune. If before these more than geologic ages of radiation into space the surface or photosphere of the solar mass did not shine as brightly as it shines now, it must, at least, have been a nebula with a very definite surface, which, as seen from a distance a hundred times as great as that of α Centauri would have presented a disc nearly half a second in diameter. No disc has at present been observed to any star; we may therefore feel some confidence that there is no such vast sun-like body within a distance from us equal to fifty times the distance of α Centauri.

In the forthcoming part of the "Old and New Astronomy," I have shown reason to believe that there is evidence of absorption of light in space, and that we can, from the numbers of the stars of the various magnitudes, make a rough minimum estimate as to the amount of absorption of light in space, due either to a want of perfect elasticity in the light-transmitting ether, or to dark bodies cutting out or obliterating the light in its passage through space. This greatly reduces our idea of the magnitude of the region we can explore with the telescope and with the camera, — α Centauri would probably be lost to the Lick telescope if it were removed to three hundred times its present distance, — and it also greatly reduces our idea of the distance of the small stars of the Milky Way, and of the scale of the galactic system as well as of the nebular system and of the system of clusters, red stars, and bright line stars which are so evidently associated with it.

It is not so very long ago that it was generally taught that the nebulæ were galaxies of stars more or less similar to the Milky Way that surrounds us, but so inconceivably remote as to appear when observed with the largest telescopes like small spots in the heavens. This theory suited the popular taste, and died hard. It involved the assumption that man could explore with the instruments at his disposal a space so immense that the interstellar spaces which we can just measure or guess at, are dwarfed into points beside the distance from which light travels to us.

The theory should have been disposed of by the observations of Sir William Herschel, who noted that many nebulæ are evidently associated with stars, and observed that the smaller nebulæ were distributed over the heavens in a manner which shows an intimate connection between them and the brighter stars. He noted that the nebulæ in the northern heavens were clustered in the pole of the Milky Way, and descended like a canopy on all sides, leaving a dark space or channel separating the nebulous region from the rich stellar region of the Milky Way. Sir William Herschel also fully satisfied himself that "there were nebulosities which are not of a starry nature," and from his observations of diffused nebulæ he formed his well-known hypothesis of a diffused luminous fluid which, by its eventual aggregation, produced stars. But he did not proceed to the legitimate deduction from his observations as to the general distribution of nebulæ, viz., that nebulæ which are arranged so symmetrically with respect to the stars must belong to the stellar system, and therefore cannot be assumed to lie at immense distances compared with the distance of the Milky Way stars.

Sir John Herschel extended the observations of his father to the southern heavens, and showed that there was a similar clustering of the smaller nebulæ on the southern side of the Milky Way, and a similar intimate connection between the distribution of stars and the distribution of nebulæ in the southern hemisphere (Cape Observations, p. 134); but it was not until 1858 that the obvious conclusion from these observations was drawn by Mr. Herbert Spencer in a remarkable paper on "The Nebular Hypothesis," published in the *Westminster Review*. He remarked, "If there were but one nebula, it would be a curious coincidence were this one nebula so placed in the distant regions of space as to agree in direction with a starless spot in our own siderial system. If there were but two nebulæ, and both were so placed, the coincidence would be excessively strange; what then shall we say on finding that there are thousands of nebulæ so placed? Shall we believe that in thousands of cases these far-removed galaxies happen to agree in their visible positions with the thin places in our own galaxy? Such a belief is impossible."

Mr. Herbert Spencer's paper was not illustrated by charts, and the force of his reasoning was not generally perceived till some ten years afterwards, when Professor Cleveland Abbé drew attention in the Monthly Notices of the Royal Astronomical Society for May, 1867, to the intimate connection between the distribution of nebulæ in space and stars; and Mr. Proctor, in 1869, constructed some charts on an equi-surface projection, which graphically put his readers in possession of the facts and carried conviction to all who read his remarks.

The theory that the nebulæ were distinct galaxies involved the assumption that light can reach us from regions many

thousand times more remote than the stream of stars which compose our own galaxy; and it also involved the assumption that the matter of the universe is aggregated into clusters, separated by immense barren spaces, in which we must assume that there are very few luminous stars, and but few dark stars which would absorb light, as well as comparatively very little opaque matter distributed as meteors are distributed in the region of space we are familiar with.

We have evidence that the greater part of the lucid stars belong to the galactic system, but the large proper motion of some stars, taken in conjunction with their small parallax, affords evidence, as Professor Simon Newcomb has pointed out, that they will in time pass away from our galaxy. (Professor Newcomb has shown in his "Popular Astronomy" that, making the most liberal assumptions as to the number and masses of the stars of our galactic system, the highest speed which a body could attain if it fell from an infinite distance through such a stellar system would be twenty-five miles a second, a velocity which is certainly smaller than that of many stars.) The regions outside our galaxy cannot, therefore, be absolutely barren, but however sparsely luminous stars are distributed through space, if there were no absorption of light in its passage through the ether, and no opaque bodies to blot out the light of distant stars, it would be impossible, as Olbers long ago pointed out, to draw a line in any direction which would not in an infinite universe pass through some luminous star, and the whole heavens ought to shine with the average brightness of such stars.

That the heavens are comparatively dark may, therefore, be taken as proof either that the light-transmitting ether is not perfectly elastic, or that there are numerous dark bodies in space that blot out the light which we should otherwise derive from the more distant parts of the universe.

NOTES AND NEWS.

THANKS to new sanitary measures in England, says the *Medical Record*, there has been a diminution of more than thirty per cent in the death-rate from consumption since 1861.

— In a recent number of the *Archives of Surgery*, Mr. Jonathan Hutchinson says that he has for many years been in the habit of forbidding fruit to all patients who suffer from tendency to gout. In every instance in which a total abstainer of long standing has come under his observation for any affection related to gout, he has found on inquiry that the sufferer was a liberal fruit eater. Fruits are, of course, by no means all equally deleterious; cooked fruits, especially if eaten hot with added sugar, are the most injurious, the addition of cane-sugar to grape-sugar adds much to the risk of disagreement. Fruit eaten raw and without the addition of sugar would appear to be comparatively safe. Natural instinct and dietetic tastes have already led the way in this direction; few wine-drinkers take fruit or sweets to any extent, and Mr. Hutchinson suggests as a dietetic law that alcohol and fruit-sugar ought never to be taken together; and he believes that the children of those who in former generations have established a gouty constitution may, though themselves water-drinkers, excite gout by the use of fruit and sugar.

— A statement, by State Geologist Arthur Winslow, of the operations of the Missouri geological survey during the month of July shows that work on iron ores was begun during the latter part of the month, and inspections were made in Callaway and Wayne Counties. Zinc and lead deposits have been examined and reported upon in Newton, McDonald, Barry, and Lawrence Counties. The occurrence and distribution of coal have been studied in Carroll, Chariton, Howard, Monroe, Buchanan, Nodaway, Gentry, and Davis Counties. Detailed mapping has been prosecuted in Macon, Madison, Ste. Francois, and Ste. Genevieve Counties, and about 160 square miles have been covered. In the laboratory the analysis of some twenty-two samples of mineral waters have been completed. The work on paleontology and general stratigraphy has been actively prosecuted in the north-eastern part of the State along and adjacent to the Missouri River. The quaternary formations in Buchanan, Jackson, Saline, and adjacent counties have received special study. A work recently started, looking towards obtaining an estimate of the total amount and value of the mineral products of the State up to the present date, has been given special attention during the past month, and is now well advanced. In the office, Bulletin No. 5 will be ready for distribution soon. It consists of a paper on the age and origin of the crystalline rocks of Missouri and one on the clays and building stones of certain counties tributary to Kansas City. Considerable progress has been made in the preparation of Bulletin No. 6, and in the draughting of maps for publication. The granites and porphyries in Madison County have further been studied and their areas mapped, and the distribution of the geological formations have been outlined in a part of Greene County. Inspections of building stones and of clay deposits have been made in Stone, Jefferson, Ste. Genevieve, Mississippi, Stoddard, Scott, Cape Girardeau, Madison, Iron, Wayne, Butler, Greene, Webster, Phelps, and Crawford Counties. In connection with the various works above referred to, many photographs have been taken illustrating the occurrences of minerals and other geological phenomena in the State, and a large number of specimens have been collected for purposes of study, test, and exhibit.

— A correspondent of the *American Field*, writing from Sidney, O., says: "A friend of mine, a careful observer, recently related an occurrence he witnessed some years ago. While watching fish through clear ice in shallow water, he saw a muskrat moving about on the bottom, apparently feeding. Presently the animal stopped and emitted the air in his lungs, which came up in small bubbles to the under surface of the ice. He then came up, put his nose to the large bubble and rebreathed the air. This may be old, but it was new to me, and may be to others"

— In a paper on the density of weak aqueous solutions of certain sulphates, read before the Royal Society of Canada on May 28, 1890, Professor J. G. MacGregor of Dalhousie College, Halifax, gives the following as the general results of his study of the subject: (1) In addition to magnesium, zinc, and copper sulphates, already known to form weak aqueous solutions having a volume less than their constituent water would have in a free state, aluminum, cadmium (possibly), cobalt, and nickel sulphates are found to exhibit the same peculiarity; (2) the formation of such solutions is not a property of the sulphates generally; (3) neither is it a property of all the metals of any one of the groups into which the metals are divided by chemists; (4) the formation of such solutions does not seem to depend upon the amount of the water of crystallization of a salt.

— From a series of observations on woodpeckers, made in the region of Mount Chocorua, New Hampshire, Mr. Frank Bolles, in a communication to the *Auk* for July, draws the following conclusions: that the yellow-bellied woodpecker is in the habit for successive years of drilling the canoe birch, red maple, red oak, white ash, and probably other trees, for the purpose of taking from them the elaborated sap and in some cases parts of the cambium layer; that the birds consume the sap in large quantities for its own sake and not for the insect matter which such sap may chance occasionally to contain; that the sap attracts many insects of various species, a few of which form a considerable part of the food of this bird, but whose capture does not occupy its time to any thing like the extent to which sap drinking occupies it; that different families of these woodpeckers occupy different "orchards," such families consisting of a male, female, and from one to four or five young birds; that the "orchards" consist of several trees usually only a few rods apart, and that these trees are regularly and constantly visited from sunrise until long after sunset, not only by the woodpeckers themselves, but by numerous parasitical humming-birds, which are sometimes unmolested but probably quite as often repelled; that the forest trees attacked by them generally die, possibly in the second or third year of use;