A SIMPLE ECLIPSE OBSERVATION BEARING ON RELATIVITY.

By WILLIAM H. PICKERING.

Recent total eclipses have been observed with such elaborate and expensive apparatus that the average astronomer, while anxious to see an eclipse for his own sake, and to get some photographs of it, yet feels that the value of any scientific results that he might be able to attain would hardly justify the expense of the expedition, or even the expense of transportation of his instruments. This last objection will not apply to the experiment here suggested. It is nevertheless believed that any results secured might be of distinct advantage to science. Before describing the apparatus however, we will first discuss the information that we desire to obtain, and explain its bearing on our present knowledge.

In my paper on "Relativity since 1922" it was shown that while the Lick observations in Australia apparently fully confirmed the view that for minute bodies like the ether waves, or the electrons, the mass was dependent merely on the velocity, yet for more massive bodies like the planet Mercury, our formula gave too large a result. The same is true for ether waves approaching us directly from the sun; the formulae of relativity fail to conform with the facts, and give an entirely erroneous value, which in both cases is too large.

In the paper above mentioned, the error in the case of the perihelion of Mercury was found to be 12.6 per cent. But there is another fact not mentioned there which would unquestionably tend to increase the error still further, possibly even to a hundred per cent, in other words to show not merely that the formula is inaccurate, but that there is no truth in it whatever as applied to Mercury. Dr. Poor in fact believes that such is the case (*Scientific American,* 1921, **3**, 484). Following other computers, he suggests that the whole of the required advance may be accounted for by the attraction of a dense ring of meteoric matter surrounding the sun. He suggests in fact three rings, a dense one lying at a distance of 0.5 from the sun's center, or 4,000,000 miles from its surface, and two others much less dense, one of them extending out beyond the orbit of the earth.

The chief objection to this hypothesis is that any substance lying so near the sun as he suggests would certainly be vaporized, and repelled by the repulsion of light. If it were not repelled, its spectrum would be visible as a series of bright lines surrounding the chromosphere, at the time of a total eclipse. By means of an objective prism the spectrum of the corona as far as the green has been traced to a height of 1,000,000 miles above the sun's surface, but no bright lines were found in it. The coronal line disappears at a much less elevation. Long exposure photographs indicate that during an eclipse, beyond 2,000,000 miles from the limb, the light of our sky is practically uniform for a distance of at least 10°. The added light within the 2,000,000 miles is doubtless due to a faint extension of the corona.

Although therefore a ring of the dimensions suggested appears to be improbable, yet a ring of some sort undoubtedly exists, and the effect that it will produce on the orbit of Mercury depends merely on its location and mass. The required mass can be determined by computation, the actual brightness by observation during a total eclipse, and its surface can be computed by comparison with the light of our moon. Given the mass and the surface we can compute the average size of the component meteors. We can then see if our result appears plausible. If not, then the Relativity formula must account for the greater part of the advance of the perihelion.

A preliminary investigation showed at once that the meteors would be large, so the question at once arises, how large are any bodies that are likely to exist in great numbers in the vicinity of Mercury, or between it and the sun. It is known that the average diameter of a meteor of the 3d magnitude is about 2 millimeters, or 1/12 of an inch (POPULAR ASTRONOMY, 1919, **27**, 203). It might seem at first sight that this is about the size that we should expect to find near the sun. We must remember however that most of this matter has been exposed to an intense light pressure for many millions of years, and has therefore long ago been swept out of this portion of the solar system.

From another point of view the resemblance between comets and asteroids is marked. Thus the short period comet Neujmin, 1913, *c*, was practically entirely nucleus. For only a brief interval did photography show a very faint coma. None was certainly visible in the telescope, although a slight haziness was once suspected by Barnard. This is one of Saturn's comets, revolving in a period of 18 years. Up to 1915 four asteroids were known whose eccentricities ranged as high as from 0.41 to 0.54. Probably more have since been discovered. Four comets, namely Holmes, $Temple_1$, Brooks, and 1890 VII, have eccentricities ranging as low as from 0.41 to 0.47. Had either of these been seen without a coma, like Neujmin's, since their periods are similar to those of the asteroids, it would certainly have been classed as one of those bodies. Possibly some of the more eccentric asteroids may have comas when near perihelion.

The periodic comets, as they constantly return to the sun, continue to lose their comas. One of the more striking ones is Encke's comet, which was first discovered in 1786. It was visible to the naked eye in 1795, 1805, 1829, 1848, 1858, 1871, and 1881, usually at intervals of about ten and thirteen years, when it was most favorably situated for observation. In 1805 and 1848 it had a visual tail over a degree in length. During the past forty years on the other hand, it has never been visible without instrumental aid, although in 1914 it could be seen with an opera glass.

Elliptical orbits even in a slightly resisting medium tend in time to become circular. If a comet having as large a nucleus as Neujmin's had been captured once every million years by Jupiter, since the surface of the earth solidified, several thousand million years ago, and had since lost its coma and part of its eccentricity, there would now be several times as many asteroids belonging to our system as have yet been discovered. An asteroid indeed may be described as a nucleus bearing comet of small eccentricity that has already lost its coma. The majority of the known asteroids are believed to be at least ten miles in diameter, though doubtless there are many smaller ones yet undiscovered. If the nuclei of the comets are composed of single pieces, some of them must be fully as large as that.

While the mass of Mercury is small, yet many more comets pass near it than approach any other planet. Encke's comet is one of these, and since its aphelion lies far inside the orbit of Jupiter, it is quite possible that this comet properly belongs to Mercury. During the enormous period of time that has elapsed since Mercury came into existence, there has been time enough for it to have captured many comets, and for their comas to have vanished completely. Once captured by Mercury the larger portions of the comet would rarely escape, but would revolve forever in small orbits about the sun.

Assuming then that a ring of small asteroids captured by Mercury, and formed from cometary debris, lies within Mercury's orbit, as indeed must almost necessarily be the case, we must next attempt to determine its dimensions. The mean distances of most of the known asteroids lie between 2.2 and 3.2, that of Jupiter being 5.2. The same proportions should be maintained for Mercury, in order to retain the same relations of their periods. The asteroids would then lie between 15,000,000 and 22,000,000 miles from the sun. If they were condensed into a single planet at their mean distance, 0.20, or 18,500,000 miles, they would have to possess a mass equal to ¼ that of Mercury in order to produce the observed advance of its perihelion. We shall assume that the whole group of asteroids possesses this mass. Leverrier found that at a distance of 0.12 the mass of Vulcan would have to be 2.67 times that of Mercury in order to produce the observed perturbation, but at a distance of 0.27 it would have to be only 0.17 as great, in order to produce the same effect.

In his concluding sentences Dr. Poor, in the above mentioned article, refers to the desirability of determining the actual distribution and density of matter in the vicinity of the sun. He says "In 1908-10, before Einstein had developed his astronomical theories, I called attention to the desirability of doing this; but the astronomical world could not see the need of the investigation and it was never made." If Dr. Poor had chanced to turn to the Harvard Annals **32**, 98 he would have found a statement that the intrinsic actinic brightness of the Oceanus Procellarum on the moon, as determined on two evenings, ranged from 1.14 to 1.29 units, the unit being there described. On p. 103 the statement is made that the brightness of the full moon ranges from 1180 to 2140 thousandth units. We may therefore take the brightness of Mare Tranquilitatis, the darkest of the lunar seas, at 1.20 units at the time of full moon, and the brighter areas at 2.14. On p. 105 the average brightness of the full moon is given at 1.66 units, and in the same table the brightness of the sky surrounding the corona, as measured during the total solar eclipse of 1886, as 0.0007 units. The brightness of the sky in front of the moon was found to be zero. It therefore appears that the light surrounding the sun and the corona came from a region beyond the moon, and not from our own illumined atmosphere. As these measures were made and published some twenty years before Dr. Poor made his criticism of the supineness of the astronomical world, it is perhaps quite excusable that he should have overlooked them.

These statements as published in the Annals are of course only bare facts. Now as to their application. If the meteoric matter within the orbit of Mercury is black, and therefore similar in reflective power to the Mare Tranquilitatis, it makes no difference whether we compare them visually or photographically, as we should obtain the same result. According to these measures Tranquilitatis was 1700 times as bright as the matter illumined by the sun, and lying beyond the moon. Now it is clear that no appreciable light can be reflected from those meteors lying between us and the sun. Therefore the light must have come from a section of this assumed meteoric ring lying beyond the sun, and extending from fifteen to twenty-two million miles away from it. This section which is seven million miles deep shines then with a light which is intrinsically 1/1700 as bright as Mare Tranquilitatis.

We now propose to find out the average size of the meteors composing this ring. It is obvious that an approximate solution is all that the accuracy of the observations will bear. Having determined their size, we shall then consider if the result seems plausible, and may therefore furnish a probable explanation of the advance of the perihelion of the orbit of Mercury. We must expect to find a very great range of sizes, and the average neither very small nor very large. Our ideas of what is plausible are clearly very vague, and this indeed must be the chief criticism of our result. We can however fix a maximum size, by assuming that if brighter than the 9.0

magnitude those asteroids would have been already discovered during some solar eclipse by means of photography.

Let us take the diameter of Mercury as 3000 miles, and its mean stellar magnitude when in opposition at —1.0. If placed as near the sun as the average asteroid composing the ring, its magnitude would be —2.4. An object having the same albedo, and 11.4 magnitude fainter than Mercury, would have 1/190 of its diameter, or 16 miles. Any asteroid at mean distance from the sun whose diameter exceeded this figure might therefore have been discovered by photography. We cannot place any lower limit to the size of these asteroids, and it is very probable that there may be a certain amount of meteoric dust of recent accumulation in this region. The great bulk of it however must have been eliminated millions of years ago.

In order to determine their probable size, we shall begin by assuming that the cross section of the ring of meteoric matter or asteroids is circular, and that the ring is therefore what is technically known as a torus or anchor ring. The meteors we shall assume to be spherical in shape. In our investigation we shall for convenience employ the meter and metric ton as units. The mean radius of the ring, 18,500,000 miles, expressed in metric units is 3.0×10^{10}, and the radius of its cross section, 3,500,000 miles, is 5.6×10^{9} meters. Its volume V is therefore 1.9×10^{31}. The mean distance of the full moon from the sun is 93,100,000 miles, equal to 15×10^{10} meters. The meteor at mean distance is therefore illumined by 25 times the amount of light received by the full moon. The circular area presented to us on the section of the ring at mean distance from the sun, and beyond it, which will give the observed brightness, must therefore have 25×1700 times the projected area of the meteor. The radius of the meteor we will call r, its projected area πr^2 and the circular area on the ring $42{,}500\,\pi r^2$. The volume v of the cylinder containing one meteor will equal this area times the thickness of the ring, or $4.2\,\pi r^2 \times 10^4 \times 1.1 \times 10^{10} = 1.4 \times 10^{15} r^2$. The volume of the meteor will be $4\pi r^3/3$, and if of iron its mass m, which will be identical with that of the cylinder, will be $33\,r^3$.

The mass of the earth we shall take as 6×10^{21} metric tons. The mass of Mercury is 0.055 times that of the earth, and the mass of the whole ring of meteors M we shall take as one quarter of that, as stated above, or 8.2×10^{19} tons. We then have $m\,V/v = M$, which equation by substitution of the quantities in the previous paragraph at once gives us the radius of the spherical meteor r, as 180 meters. Reducing this back to ordinary units gives us for its diameter 1200 feet. The average distance between the meteors will be about 5,000 miles. In so crowded a region the smaller masses would gradually be absorbed by the larger ones. Doubtless some will be appreciably larger than this, perhaps several miles in diameter and many very much smaller.

If any are smaller, some must be larger, though not necessarily very much so. These figures will however give us a general idea of what to expect, and also a definite value for the density per cubic mile of material. In terms of the density of the sun this is 6.3×10^{-13}.

While we have no means of checking these results, there is certainly nothing impossible, and perhaps not even improbable in them. Unless the hypothesis of Relativity can be better substantiated in the future in some way than it is at present, and its theoretical conclusions brought into better agreement with the observed facts, the above explanation seems to give at least a plausible way of accounting for the observed advance of the perihelion of Mercury. If it accounts for even an appreciable portion of it, the Relativity hypothesis is further invalidated.

Proposed Apparatus.

Now regarding the proposed eclipse observations, since those already described were made nearly forty years ago, were only a side product of the expedition, and have not as far as I am aware been repeated by anyone else since that time, it would appear to be well to repeat them now, with improved and simplified apparatus. It is proposed that a camera be used without any lens, but in its place a simple round aperture, which might be cut out of cardboard, whose diameter is one-eighth of its distance from the plate. In front of the plate and in contact with it is placed a piece of perforated brass containing numerous minute holes, such as are used for making strainers. Several of these cameras may be mounted on a wooden stand, in such a manner that they can be pointed by means of a sight at an angle of 10° from the sun, one in the direction of the ecliptic, one at right angles to it, etc.

It is believed that an exposure of 20 seconds would be about right with a fairly quick plate, but since the sky surrounding the corona is approximately as bright as the night sky near Polaris three minutes after it first becomes visible in the evening, it is easy to test the matter before the eclipse (H. A. **18**, 105). A similar camera furnished with an aperture whose diameter is one-fortieth as large may be later attached to an equatorial clock-driven telescope, and pointed on the full moon. The exposure should be the same as that given to the sky during the eclipse, and the aperture varied if necessary. If the lunar exposure is also made through perforated brass, then by turning the two developed plates film to film it is easy to compare their density. The reason that the exposures should be of the same duration is in order to eliminate the time correction of the plate (H. A. **32**, 20). For slow plates giving great contrast the time correction is very considerable. It is believed that photographs taken with such simple apparatus, giving measures of the brightness of the sky around the eclipsed sun, would have a very considerable scientific interest in connection with the present discussion of the truth of the hypothesis of Relativity.

Mandeville, Jamaica, B. W. I.
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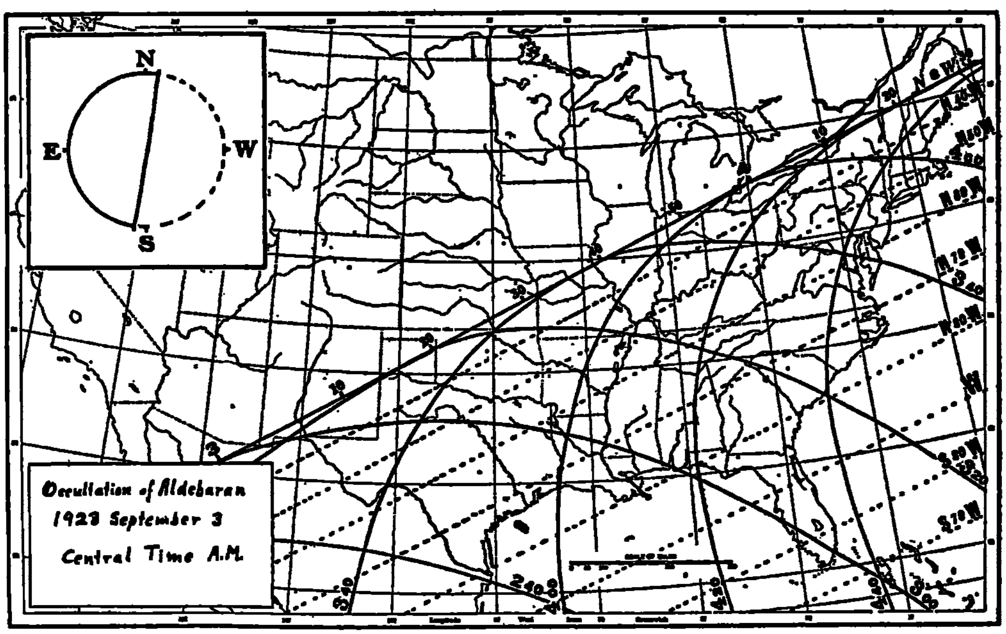
THE OCCULTATION OF ALDEBARAN, 1923, SEPTEMBER 3.

By WILLIAM F. RIGGE.

The occultation of Aldebaran on next September 3 will be visible only to the southeastern half of the United States. It will take place in the early morning, as the annexed map shows. The beginning or immersion, which is given by the eastern or right parts of the time curves, will occur between about 2:40 and 4:00 A. M., Central Standard Time, and the end or emersion, given by the western or left parts of the time curves, from about 3:40 to 4:40 A. M. The Limit Line needs no explanation. The numbers on it denote the times of the grazing contacts from 3:00 to 4:30.



The moon will be only a few hours (6:47 A. M.) from Last Quarter, so that the terminator is practically a straight line, as the insert shows. The dotted lines on the map give the position angles on the dark or western limb of the moon at which the star will reappear. As the northern end of the terminator is 8° 36′ to the west or right of the moon's north point N, it may be convenient to measure the position angles from this point. The grazing contact on the limit line will take place almost exactly on the northern end of the moon's terminator.