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BETELGEUSE: HOW ITS DIAMETER WAS MEASURED

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The remarkable feat of measuring the diameter of the bright star Betelgeuse, recently accomplished at the Mt. Wilson Observatory, has attracted wide attention. At the recent meeting of the American Association for the Advancement of Science, in Chicago, Prof. Michelson briefly explained how it was done, and perhaps the following elementary account of it may be acceptable.

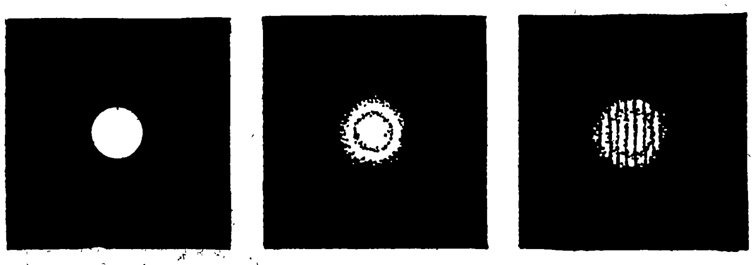

Fig. 1 Fig. 2 Fig. 3

Fig. 1, Image of a planet when viewed by a telescope.
Fig. 2, Image of a star, showing diffraction ring.
Fig. 3, Image of a star when a plate with two slits in it is placed over the objective.

Everyone who has used a telescope has remarked the difference between the images of a planet and a fixed star. The former shows a sharply-defined disc (Fig. 1) which appears larger, the higher the magnification; the latter appears only as a bright spot, without any clear boundary. Many people expect a great telescope to exhibit a star, such as Sirius or Arcturus, as a flaming fire, but the larger the instrument, provided it is of good quality, the smaller the image is, though, of course, the image in a large telescope is *brighter* than in a small one. On closely examining the image of a star, however, there is seen a faint dark ring surrounding the bright spot (Fig. 2). There are in reality several rings, but usually only one can be detected. These rings are due to diffraction, or the bending of the waves of light from their straight paths, the dark rings being produced by the interference of the waves. This phenomenon is explained in any work on light or on the telescope.

In 1890 Michelson described some experiments on which the method followed in measuring Betelgeuse is based. He placed a disc with two slits in it in front of the objective of a telescope which was pointed at an artificial 'star' formed by a bright light behind a

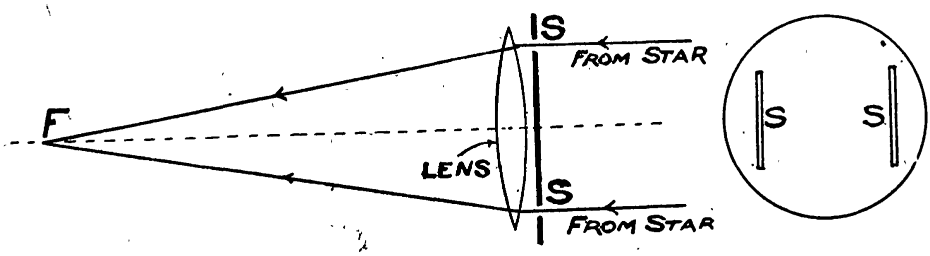

Fig. 4.—Showing a plate with two slits in it over the objective. Plan of plate with slits to the right. An image of the star is seen at *F*, with fringes across it.

small hole in a metal plate, placed a considerable distance away (Fig. 4). In this case there was seen at the focus F, the usual bright spot and ring, but in addition a series of dark bands, or fringes, across the image (Fig. 3). Then as the hole in the plate was enlarged, that is, as the 'star' was given an appreciable diameter, the fringes altered and at last vanished. Michelson showed by theoretical calculation, which was verified by experiment, that, when the fringes vanish a simple relation exists between the size of the hole, the distance between the slits and the wave-length of light. In Fig. 5 let MN be the hole in the plate, (i.e. the artificial 'star'), D be the distance between the slits S, S, α be the angle MCN, and λ the wave-length of light.

Then, $\alpha = 1.22\ \lambda/D$, (radians). If now the distance d of the star is known, its linear diameter can be determined. It is equal to αd.

The paper in which this result was given was published in the *Philosophical Magazine* in 1890, and in it Michelson remarks that the method might be used in measuring the diameters of small planets, satellites and possibly the fixed stars. Next year, by invitation of the Lick Observatory, he tested his method on the satellites of Jupiter with decided success, his results being near to the mean of measurements made by astronomers with the micrometer. (See Michelson, *Light-Waves and their Uses*, p. 142.)

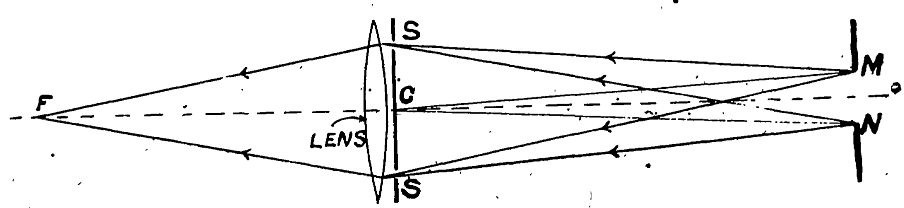

Fig. 5—Light from a source *M N* passes through slits in a plate and is then converged to *F*. When *M N* has a certain width the fringes at *F* vanish.

No further applications of the method were made until quite recently. Experiments on the interference of light-waves are notoriously hard to perform, requiring very accurate adjustments; and as the atmosphere is always in a disturbed condition it was feared that an attack on the fixed stars would be difficult and probably unsuccessful. However some preliminary experiments with the great 40-inch refractor of the Yerkes Observatory, made in August 1919, gave hopeful results; and at the request of Dr. Hale, director of the Mt. Wilson Observatory, Michelson went thither to try out the method with the 100-inch Hooker telescope. As this is a reflector some modification of the original arrangement was necessary. This is illustrated in Fig. 6.

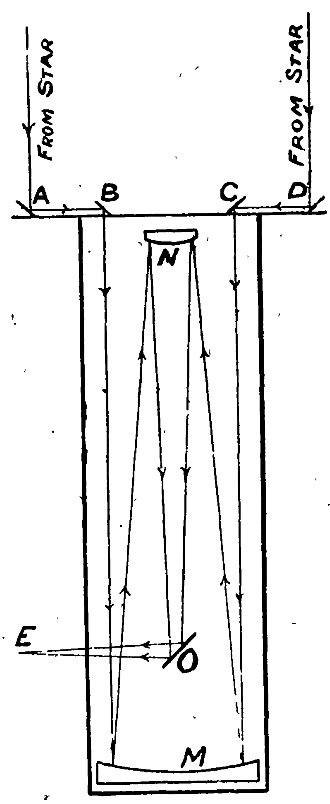

Fig. 6.—Diagram illustrating the optical arrangement used in the measurement of the star's diameter.

A steel beam was bolted to the upper end of the tube of the telescope and four plane mirrors, A, B, C, D, were mounted on it. The light from the star followed the path shown in the figure. One beam was reflected from A to B, then down to the great mirror M, then up to the convex mirror N, then back to the plane mirror O and then out to E. Another beam entered by D and C, and, after following a similar path, also came out to E, where the two sets of waves could interfere and the fringes be observed. The mirrors A and D in this arrangement correspond to the slits S, S, in Figs. 4 and 5. The mirrors B and C were 4 feet apart and, to begin with, A and D were 6 feet apart. The telescope was directed at Betelgeuse and with much patience the fringes were obtained. Then A and D were separated. When about 8-feet apart the fringes showed sings of change and when 10-feet apart they vanished. That is, the distance *D* was 10 feet or say 3000 mm. The wave-length of the light was taken to be 0.000555 mm.

Hence $\alpha = 1.22 \times 0.000555/3000$ radians,

$= 0''.046.$

The parallax of Betelgeuse is approximately 0″.018, or its distance 181 light-years; from which it follows that the diameter of the star is about 240,000,000 miles.

To test whether the apparatus was really in adjustment yet the telescope was turned towards Procyon and the fringes appeared. This showed that the vanishing of the fringes had not been due to the apparatus being out of adjustment, and that the angular diameter of this star was not as great as that of Betelgeuse.

The actual experimenting was done by Dr. Anderson and Mr. Pease of the Observatory staff and it was described as "tedious and difficult;" to them much credit is due for the successful outcome.