ASTRONOMY
The Transit of Venus

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Venus is nearest the earth at the time of inferior conjunction; but it can then be seen only in the daytime. It is, therefore, impossible to ascertain the displacement of Venus, as seen from different stations, by comparing her distances from a fixed star. Occasionally, at the time of inferior conjunction, Venus passes directly across the sun's disk. The 1ast of these transits of Venus occurred in 1874, and the next will occur in 1882. It will then be over a hundred years before another will occur.

Suppose two observers, A and B (Fig. 158), near the poles of the earth at the time of a transit of Venus, -The observer at A would see Venus crossing the sun at V, and the one at B would see it crossing at V1. Any observation made upon Venus, which would give the distance and direction of Venus from the centre of the sun, as seen from each station, would enable us to calculate the angular distance between the two chords described across the sun. This, of course, would give the displacement of Venus on the sun's disk. This method was first employed at the last transits of Venus which occurred before 1874; namely, those of 1761 and 1769. There are three methods of observation employed to ascertain the apparent direction and distance of Venus from the centre of the sun, called respectively the contact method; the micrometric method, and the Photographic method.

(a) In the contact method, the observation consists in noting the exact time when Venus crosses the sun's limb. To ascertain this it is necessary to observe the exact time of external and internal contact. This observation, though apparently simple, is really very difficult. With reference to this method Professor Young says,- " The difficulties depend in part upon the imperfections of optical instruments and the human eye, partly upon the essential nature of light leading to what is known as diffraction, and partly upon the action of the planet's atmosphere. The two first-named causes produce what is called irradiation, and operate to make the apparent diameter of the planet, as seen on the solar disk, smaller than it really is; smaller, too, by an amount which varies with the size of the telescope, the perfection of its lenses, and the tint and brightness of the sun's image. The edge of the planet's image is also rendered slightly hazy and indistinct. " The planet's atmosphere also causes its disk to be surrounded by a narrow ring of light, which becomes visible long before the planet touches the sun, and, at the moment of internal contact, produces an appearance, of which the accompanying figure is intended to give an idea, though on an exaggerated scale.

Fig. 159.

The planet moves so slowly as to occupy more than twenty minutes in crossing the sun's limb; so that even if the planet's edge were perfectly sharp and definite, and the sun's limb undistorted, it would be very difficult to determine the precise second at which contact occurs. But, as things are, observers with precisely similar telescopes, and side by side, often differ from each other five or six seconds; and, where the telescopes are not similar, the differences and uncertainties are much greater. Astronomers, therefore, at present are pretty much agreed that such observations can be of little value in removing the remaining uncertainty of the parallax, and are disposed to put more reliance upon the micrometric and photo- graphic methods, which are free from these peculiar difficulties, though, of course, beset with others, which, however, it is hoped will prove less formidable."

(b) Of the micrometric method, as employed at the last transit, Professor Young' speaks as follows:- "The micrometric method requires the use of a heliometer, -an instrument common only in Germany, and requiring much skill and practice in its use in order to obtain with it accurate measures. At the late transit, a single English party, two or three of the Russian parties, and all five of the German, were equipped with these instruments; and at some of the stations extensive series of measures were made. None of the results, however, have appeared as yet; so that it is impossible to say how greatly, if at all, this method will have the advantage in precision over the contact observations."

(c) The following observations, with reference to the photographic method, are also taken from Professor Young:- "The Americans and French

placed their main reliance upon the photographic method, while the English and Germans also provided for its use to a certain extent. The great advantage of this method is, that it makes it possible to perform the necessary measurements (upon whose accuracy every thing depends) at leisure after the transit, without hurry, and with all possible precautions. The field-work consists merely in obtaining as many and as good pictures as possible. A principal objection to the method lies in the difficulty of obtaining good pictures, i.e., pictures free from distortion, and so distinct and sharp as to bear high magnifying power in the microscopic apparatus used for their measurement. The most serious difficulty, however, is involved in the accurate determination of the scale of the picture; that is, of the number of seconds; of arc corresponding to a linear inch upon the plate. Besides this, we must know the exact Greenwich time at which each picture is taken, and it is also extremely desirable that the orientation of the picture should be accurately determined; that is, the north and south, the east and west points of the solar image on the finished plate. There has been a good deal of anxiety lest the image, however accurate and sharp when first produced, should alter, in course of time, through the contraction of the collodion film on the glass plate; but the experiment of Rutherfurd, Huggins, and Paschen, seem to show that this danger is imaginary. …The Americans placed the photographic telescope exactly in line with a meridian instrument, and so determined, with the extremest precision, the direction in which it was pointed. Knowing this and the time at which any picture was taken, it becomes possible, with the help of the plumb-line image, to determine precisely the orientation of the picture,- an advantage possessed by the American pictures alone, and making their value nearly twice as great as otherwise it would have been." The figure below is a representation of one of the American photographs reduced about one-half.

Fig.160

V is the image of Venus, which, on the actual plate, is about a seventh of an inch in diameter; aa' is the image of the plumb-line. The centre of the reticle is marked with a cross." The English photographs proved to be of little value, and the results of the measurements and calculations upon the American pictures have not yet been published. There is a growing apprehension that no photographic method can be relied upon. The most recent determinations by various methods indicate that the sun's distance is such that his parallax is about eighty-eight seconds. This would make the linear value of a second at the surface of the sun about four hundred an fifty miles.

Transits of Venus.-When Venus happens to be near one of the nodes of her orbit when she is in inferior conjunction, she makes a transit across the sun's disk. These transits occur in pairs, separated by an interval of over a hundred years. The two transits of each pair are separated by an interval of eight years, the dates of the most recent being 1874 and 1882. Venus, like Mercury, appears surrounded with a border on passing across the sun's disk, as shown in Fig. 262.