PHOTOELECTRIC OBSERVATIONS OF THE OCCULTATION OF 136 TAURI BY VENUS

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Abstract. The occultation of 136 Tau on May 11, 1988 was observed at the Observatorium Hoher List. The ingress was recorded photoelectrically by the dual beam photometer while the egress was observed visually. A bona fide curve fitting reduction yielded a scale height differing from earlier p.e. occultation results and is in better agreement with theoretical expectations.

1. Introduction

The probability that a bright star is occulted by Venus is greater than for any other planet. This is caused by its rapid apparent motion, its large apparent diameter, and its large parallax angle. On the other hand the observability of such events is poor because of the limits imposed by its small elongation range from the Sun. Therefore, only one photoelectrically recorded event of this type is widely discussed in the literature: namely, the famous occultation of Regulus in 1959. Results were published by de Vaucouleurs and de Vaucouleurs (1961) and further discussed by Hunten and McElroy (1968) and by Veverka and Wasserman (1974). Two other occultation events of second magnitude stars took place in 1981 and 1984. But so far no descriptions of photoelectric observations seem to be available.

2. Observations

The occultation of 136 Tau was predicted (Dunham, 1988) to occur at the Observatorium Hoher List only half an hour after sunset during civil twilight (altitudes of the Sun and the star are 5.5 and 24 deg., respectively). We observed the phenomenon with the dual beam photometer at the 106 cm telescope. The photomultipliers were two uncooled Hamamatsu 647-04 tubes with bialkaline cathodes. For a suppression of the bright sky background red filters for the definition of the R-band were chosen. The telescope was operated at full aperture, but the high voltage of the photomultipliers was reduced considerably. The signal from the two channels were amplified with Knick amplifiers and recorded with a Philips two channel strip chart recorder at a rate of 2.5 mm s^{-1}. One of the photometer channels was used to control the sky brightness while the other ($13''.4$ diameter) was centered on the star. During the observations extended, moderately homogeneous sheets of cirrus clouds appeared, which did not change the transparency of the sky significantly but influenced the brightness of the sky background. The egress could

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not be observed photoelectrically because the signal even from the non-occulted star would have been 8 magnitudes fainter than the light from the illuminated side of Venus. The event was therefore watched visually at the 36 cm refractor. For the timing of the egress we tried to allow for seeing effects – we saw the star separating from the bright limb rather than brightening – and estimated the moment of reappearance at UTC $19^h59^m20^s \pm 15^s$. Although this error margin seems to be large this observation turned out to be quite useful for our further conclusions.

The paper-tape record of the ingress was digitized in steps of 0.2^s. A good fit to the simultaneously recorded sky illuminance in the comparison photometer channel could be obtained with a fifth order polynomial. This was scaled down in the zeroth and first order to match the level in the signal channel as recorded before and after the occultation observations, and then subtracted from the star plus sky signal to extract the p.e. signal of star alone. It turned out that the full signal of the star was only 5% of the sky background. Nevertheless, we obtained a satisfactory light curve for the occultation ingress. This is shown in Figure 1. The peculiar structure of tilted lines results from the digitizing and fitting process. The accuracy of the light curve does not seem to allow statements with respect to spikes on timescales of one or a few steps of 0.2 s. Shortly after the tail of the light curve was reached flashes caused by scintillation/seeing of the nearby tip of the cusp of Venus were recorded in the channel of the star terminating further observations. No exact astrometric informations on the occultation track were available for our geographical position.

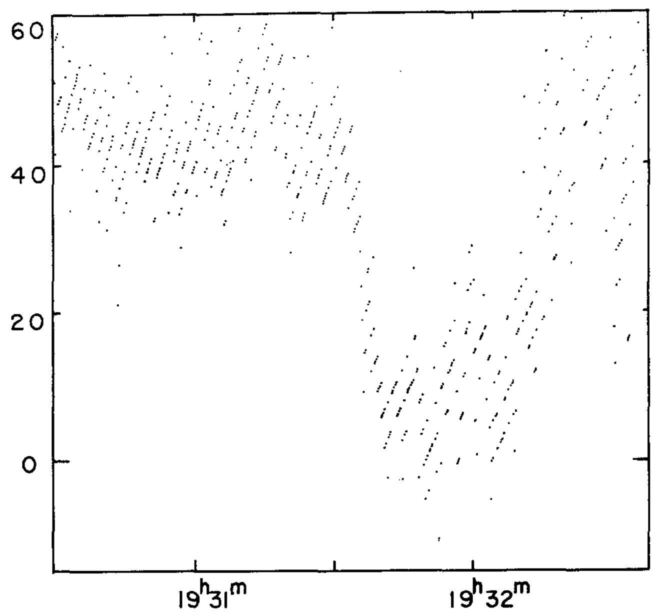

Fig. 1. The occultation light curve of 136 Tau after sky background subtraction. 100% intensity corresponds to 45 units.

We therefore reconstructed the occultation geometry from our ingress and egress timings. The following data were taken from the Astronomical Almanac 1988:

Apparent angular diameter of Venus	39″.81
Apparent daily motion (May 11.8)	1398″.03293
Position angle of motion	95.606 deg.
Distance	0.4196 AU
Solid surface diameter	12104 km

The angular diameter agrees at the given distance with the solid diameter. The efficient angular diameter for the illuminated cloud layer or for the half intensity layer (occultation) is therefore larger. It was calculated that for an error of 60 km of the height of the half intensity layer the height interval that the star passes between the intensity levels of 0.90 through 0.20 would be in error by 1%. This error is small with respect to the accuracy of the determination of the scale height (see below).

The position angle of ingress was found to be 143.7 deg., that of the egress 227.5 deg. The relative speed of Venus was 4.9197 km s^{-1} which means that each second 3.30336 km of atmospheric height were passed by the rays of the star. Assuming a thickness of 0″.2 of the atmospheric ring visible at a phase angle of 180 deg., the star disappeared only 10″.0 from the southern tip of the cusp. The path of the star with respect to Venus is sketched to Figure 2. It should be noted that the apparent diameter of the star can be estimated to 0.4 milliarcseconds according to its spectral type and apparent brightness. This corresponds to 0.12 km at the distance of Venus. The actual track turned out to be shifted about 600 km away from the southern limit compared with the prediction available to us.

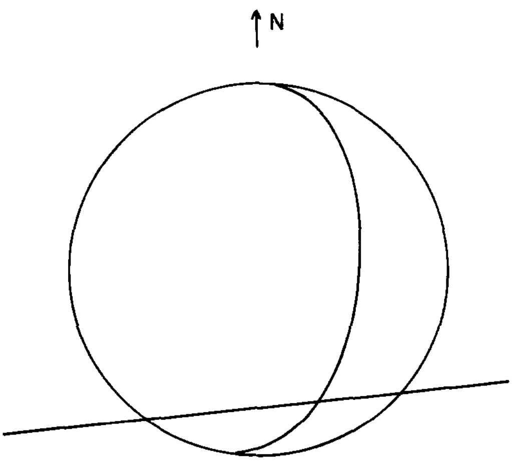

Fig. 2. Path of 136 Tau behind Venus for the Observatorium Hoher List. The motion was direct, and the crescent (west) was illuminated.

3. The Scale Height

The occultation light curve of 136 Tauri seems to be the first to test the results on the atmospheric scale height derived from the Regulus occultation in 1959 by de Vaucouleurs and de Vaucouleurs (1961) which was observed in full day light. According to more recent informations on the Venus atmosphere (Marov, 1972) their results are somewhat unexpected. A new discussion of the original data led Veverka and Wasserman (1974) to the conclusion that the observations used for the analysis may have been influenced by some unknown systematic errors. In particular, during the last 15 sec. before the rapid fading of Regulus large fluctuations of the incident light flux are visible on the reproduced original recording strip, amounting to about one third of the total occultation amplitude. An underestimation of the preceding light flux would lead to a smaller occultation amplitude and thus increase the resulting scale height. A second ingress light curve of the Regulus event recorded at Bloemfontein (de Vaucouleurs and Menzel, 1960) shows even more noise, in particular at end of the phenomenon. For our occultation observations we hope that such a systematic error is less probable because we have the simultaneous information on the sky brightness from the comparison channel of our photometer and applied the resulting corrections on the more profound fluctuations in our reduction process (the sky brightness was sampled in an area about 5′ from the occulted star). There is one uncertainty, however, which could not be avoided: we do not exactly know if there is a small variable amount of straylight from the brilliant nearby Venus leaking into our diaphragm because of turbulence in the terestrial. For the interpretation of the occultation light curve we therefore decided to:

(1) neglect any light curve features resembling the seeing flashes of Venus at the end of the ingress;

(2) find a fit of the timings of individual intensity levels (rather than the opposite) and assign weights according to the slope of the light curve corresponding errors of 0.3 sec. near the 0.60-intensity level and 2.0 sec. at the 0.20-intensity level;

(3) construct a theoretical light curve according to the fitting method and compare it with the one to be expected from the scale-height determined by de Vaucouleurs and de Vaucouleurs.

We were aware of the problems involved in this method as discussed by Wasserman and Veverka (1973), but we could not expect a good solution by the curve inversion method because different parts of the occultation light curve resulted in quite different scale heights on smaller scales which are obviously not caused by the atmosphere of Venus. Our eye estimated fit resulted in a scale height of 4.9 km with an estimated error of ± 1.2 km. The fit is shown in Figure 3, as well as the theoretical light curve for a scale height of 6.8 km, the result for the Regulus occultation. This latter curve deviates significantly near the 0.30 intensity level while it is still within our estimated error margin in the other parts of the light curve. Our value of the scale height is close to the value of the scale height suggested by Hunten

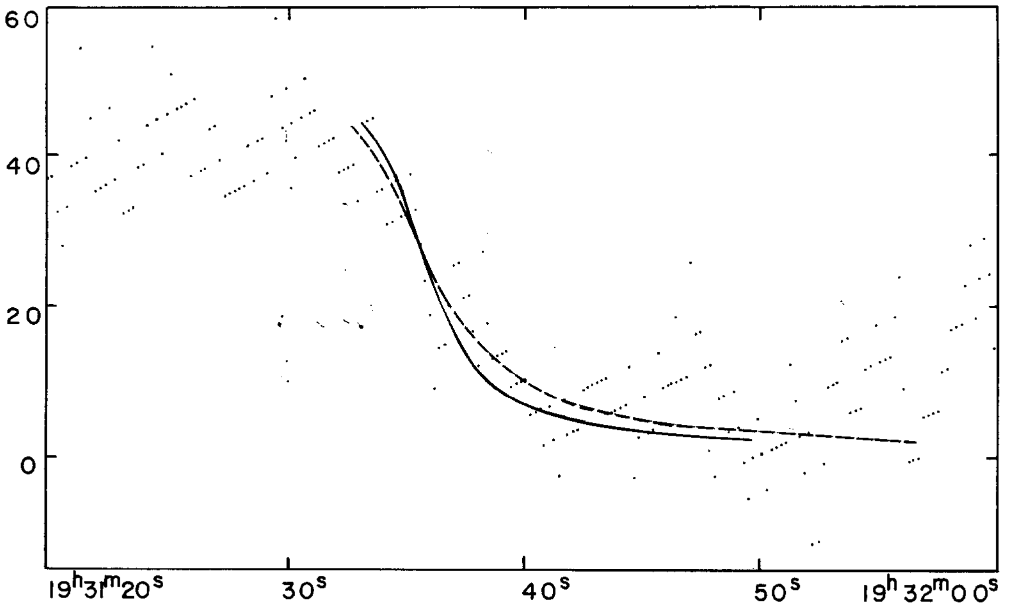

Fig. 3. Enlarged part of the ingress light curve. The solid line represents a theoretical light curve with a scale height of 4.9 km, the interrupted curve corresponds to the scale height derived from the Regulus occultation (6.8 km).

and McElroy (1968) (4.4 km s^{-1}) at the atmospheric levels for a typical stellar occultation – disregarding any deviations from an isothermal approximation.

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