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# THE DIMENSIONS OF (6) HEBE AS A RESULT OF OCCULTATION OBSERVATIONS

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RESUMEN

Mediante la observación visual de la ocultación de la estrella γ Ceti por el planeta menor (6) Hebe se obtiene como diámetro mínimo para este último $d = 190.4 \pm 7.1$ Km.

ABSTRACT

From visual observations of the occultation of the star γ Ceti by the minor planet (6) Hebe we obtain as a lower limit for the diameter of the latter $d = 190.4 \pm 7.1$ Km.

*Key words:* **ASTEROIDS — OCCULTATIONS.**

## I. INTRODUCTION

Although predictions for occultations of stars by minor planets—especially by the four brightest of these—have been systematically calculated since 1952, the actual observations of such phenomena were not carried out until quite recently. Since 1973 the Leningrad Institute of Theoretical Astronomy has computed daily ephemeris for about 30 minor planets, from which the Royal Greenwich Observatory has been able to obtain occultation predictions. The observations reported in this paper are a direct consequence of these programs.

## II. PREDICTIONS

Preliminary predictions of the occultation of γ Ceti by (6) Hebe made by Taylor at Greenwich and by Dunham in the US showed an occultation path passing through Central Mexico. However, an error of only 1 arcsec in the position of either the star or the minor planet causes a shift of the occultation path by 1760 kilometers. The estimated errors in the predictions would thus put the occultation path anywhere between the southern US and Colombia in South America. In view of these uncertainties, an effort was made to alert as many observers as possible, both in the southern US and in Mexico.

In an attempt to improve the accuracy of the predictions Harrington obtained plates of Hebe on February 17, March 1 and March 3 at the US Naval Observatory. Another plate of Hebe was taken by Taylor on February 21 at RGO.

From the February 17 plate an occultation path passing through Cuernavaca (about 70 Km south of Mexico City) was obtained, with an uncertainty of several tenths of a second of arc in the declination of Hebe. However, the February 21 and March 1

plates gave a path passing through northern Mexico, Texas and Florida. These large uncertainties showed that further improvements in the calculations were necessary.

From the last plate, taken on March 3, a path passing 150 Km north of Mexico City was obtained. Unfortunately the quality of this plate was not very high, due to the closeness of the Moon. Therefore, the uncertainty of the predicted occultation path persisted.

The results of the observations showed, nevertheless, that the predictions obtained from the March 3 plate were the most accurate ones, in spite of the poor quality of this plate. This is due to the fact that only on March 3 (2 days before the occultation) was it possible to photograph both the star and the minor planet on the same plate. The predictions made from the previous plates were affected by frame-of-reference errors.

## III. OBSERVATIONS

In order to increase the likelihood of observing the occultation, and with the active participation of the Sociedad Astronómica de México and other amateur astronomers, a grid of visual observers was set up between Mexico City (latitude $\simeq$ 19°.3) and Monterrey (latitude $\simeq$ 26°.0). An attempt was made to evenly space the observers at intervals of less than 200 km. in latitude. Other observers were located at Cuernavaca in Mexico and at Texas and Florida, in the USA.

The difference in magnitude between the two observed at and near Mexico City by different observers. Table 1 summarizes the observational results. It is worth pointing out that the Jilotepec, Mex. observations can be regarded as independent, even though they were made at only a few meters distance. The reduction of both observations leads to entirely consistent results.

The difference in magnitude between the two components of $\gamma$ Ceti was reported in the original predictions to be 6 mag. The observed drop in magnitude during the occultation of $\gamma$ Ceti amounted to less than 3 mag. This observed difference agrees, however, with the $2^m.78$ published by Strand (1969) and therefore, the value given in the predictions is probably erroneous. The error in the expectd magnitude drop caused some uncertainty in the observed durations of the occultation, especially in the Mexico City UNAM observations.

The Pedregal observation did not provide precise timings of disappearance, but the duration should be accurate. As for the UNAM observations the time of disappearence is correct, but the time of reappearence, and therefore also the duration are uncertain.

For the reduction of the observations the following ephemeris were used:

*Hebe*

Source: Leningrad Institute of Theoretical Astronomy (adjusted to the time of occultation, March $5^d$ $2^h$ $34^m$ UT)

| Apparent position | Motion per minute |
|---|---|
| $\alpha$: $2^h42^m06^s.8119$ | $+ 0^s.08033$ |
| $\delta$: 3° 8′ 15″.814 | + 0″.5521 |
| Distance: 2.42527 AU | + 0.00001 AU |

$\gamma$ *Ceti*

Source: FK3, corrected for proper motion.

*Apparent position at time of conjunction*

$\alpha$: $2^h42^m06^s.8119$

$\delta$: 3° 8′ 15″.814

Adding vectorially the motion of Hebe to that of the Earth a velocity of 38.857 km. $sec^{-1}$ perpendicular to the line of sight to $\gamma$ Ceti is obtained. (Fig. 1).

## V. RESULTS

From the observational results it was possible to calculate the lengths of the chords on (6) Hebe resulting from the occultation of $\gamma$ Ceti. These lengths are given in Table 2.

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TABLE 1

OBSERVATIONAL RESULTS

| Station | Observer | Aperture (mm) | Geodetic Latitude | Longitude | Height (m) | Time of disappearance UT (*) | Duration (*) | Notes |
|---|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | | h m s | s | |
| Monterrey, N. L. | Bertrand *et al.* | 150 | ~26 | ~100 10 | .... | .... | .... | Cloudy |
| Zacatecas | M. Ríos | 150 | 22 46 01 | 102 32 56 | .... | .... | .... | No occultation |
| | R. Reséndiz | 500 | 22 43 56 | 102 32 56 | .... | .... | .... | No occultation |
| | F. Diego | 150 | 22 27 00 | 102 46 33 | .... | .... | .... | No occultation |
| San Luis Potosí | G. Mallén | 150 | 21 40 44 | 100 44 12 | .... | .... | .... | No occultation |
| Guanajuato | M. Izaguirre | 150 | 21 01 01 | 101 15 20 | .... | .... | .... | No occultation |
| Queretaro | J. de la Herrán<br>M. A. Moreno | 200 | 20 49 58 | 100 28 40 | 2000 | .... | .... | No occultation |
| Jilotepec, México | C. Cárdenas | 200 | 19 53 20 | 99 37 10 | 2625 | 2 34 54.1(1) | 4.9(1,2) | Occultation |
| | A. Castañeda | 125 | 19 53 20 | 99 37 10 | 2620 | 2 34 54.1(1) | 4.9(1) | Occultation |
| Atizapán, México | L. Zepeda | 200 | 19 33 44 | 99 14 44 | 2280 | .... | $3.5\pm0.5$(2) | Occultation |
| México, D. F. UNAM | R. Costero | 80 | 19 19 34 | 99 10 40 | $2300\pm5$ | 2 34 55.9(1) | $2.6\pm^{0.4}_{0.2}$(1) | Occultation |
| | J. Warman | 200 | 19 19 31 | 99 10 40 | $2310\pm5$ | 2 34 55.7(1) | $3.3\pm0.1$(1) | Occultation |
| México, D. F. Pedregal | R. Robles Gil | 200 | 19 18 42 | 99 12 54 | 2371 | .... | 2.4(2) | Occultation |

(*) Recording Method. Method 1: magnetic recording of WWV signal and observer's signals. Method 2: Stopwatch.
The times of disappearance given above are uncorrected. For the reductions a correction of $+0^s.2$ was applied (mean reaction time of observer or "personal equation").

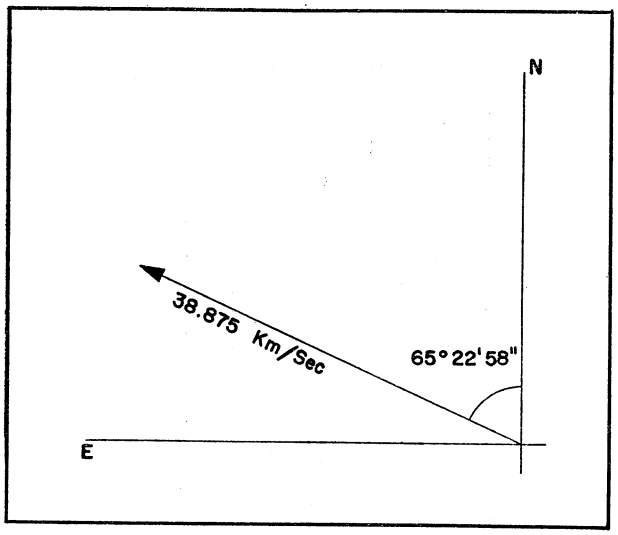


FIG. 1. Apparent motion of (6) Hebe during the occultation.

TABLE 2

OCCULTED LENGTH FOR EACH OBSERVER

| Observer | Duration of occultation (sec) | Occulted length |
|---|---|---|
| J. de la Herrán | | |
| Moreno | .... | .... |
| Cárdenas | | |
| Castañeda | 4.9±0.2* | 190.4±7.8 |
| Zepeda | 3.5±0.5** | 136.0±19.4 |
| Costero | $2.6\pm^{0.4}_{0.2}$** | $101.0\pm^{15.5}_{7.8}$ |
| Warman | 3.3±0.1** | 128.2±3.9 |
| Robles Gil | 2.4±0.2* | 93.3±7.8 |

* The errors given are the usual response times when observing visual occultations.
** The errors given were estimated by the observer.

Figure 2 shows the results of Table 2 in graphical form. As can be seen in the figure, the shape of Hebe cannot be clearly determined from the observational results. A spherical or quasispherical shape, although not obvious, is compatible with the results, especially when the probable errors are taken into account. It is important to note that other observational methods, based on light curves (Gehrels and Taylor 1977) have suggested a fairly regular shape for Hebe.

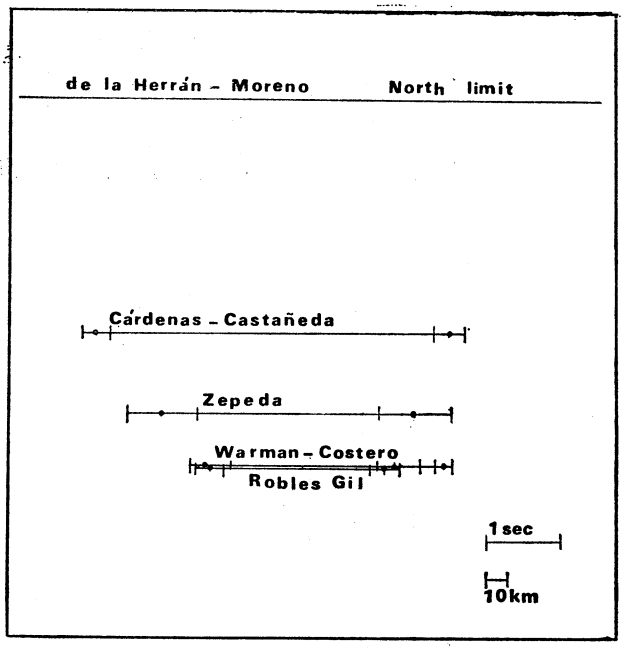


FIG. 2. Path of γ Ceti behind (6) Hebe, as seen from various locations.

Because of the ambiguity of the data as regards the shape of Hebe, its size cannot be precisely determined. However, the Jilotepec observations probably represent some kind of mean diameter of Hebe. This mean diameter is in good agreement with other determinations (Morrison 1977).

## VI. CONCLUSIONS

From a successful observation of γ Ceti by (6) Hebe we were able to obtain as a lower limit for the diameter of Hebe $d = 190.4 \pm 7.8$ km. in agreement with the values obtained by other, less direct methods. The importance of having predictions based on plates containing the images of both objects in stressed. Occultation methods can also give an approximate idea of the form of the object, as we have shown for the case of Hebe.

It is a pleasure to thank all observers, and particularly the Sociedad Astronómica de México, for enthusiastically contributing their results.

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