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9.

CCD PHOTOMETRY OF 466 TISIPHONE

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CCD observations were made of 466 Tisiphone on four nights in August and September 1997. The synodic period of rotation was found to be 8.824 ± 0.009 hours and the observed lightcurve had an amplitude of 0.114 ± 0.011 magnitudes.

Observations

The asteroid 466 Tisiphone is a C-type asteroid (Tholen, 1989). Its orbit has a semi-major axis of 3.36 AU. The observations of 466 Tisiphone we report here were made at the Paul Feder Observatory, located on the Buffalo River Site of the Moorhead State University Regional Science Center. This facility is 15 miles east of Moorhead, Minnesota (Fargo, North Dakota) and is adjacent to the Buffalo River State Park. Data were collected the nights of August 27, August 30, September 1, and September 5, 1997.

The observatory has a 16-inch computer controlled Cassegrain telescope made by DFM. The associated Photometrics Star 1 CCD camera system was used to collect data. In all, 163 images were made of the asteroid during the four nights. Of these, 131 were used in the analysis. The others were rejected because the asteroid image was too close to a star image or because they were taken too close to dawn.

The exposures were 3 minutes long and typically separated by 10 minutes. No filter was used. Dark current and flat field

corrections were made to the data. Five stars were used as magnitude standards for each image. The magnitudes were taken from the Guide 2 program (Hubble Guide Star Catalog). A least squares fit was done for each image and the relation between the magnitude and the log of the total count determined. The magnitude of the asteroid was then determined from this relationship. A photometric aperture of 7 pixels radius, corresponding to about 11 arcseconds, was used and an equal sized region of background nearby used for the background correction.

Results

Times were corrected for travel time from the asteroid to the Earth and were taken

to be at the mid-times for the images. Lightcurves were made for each of the four nights. Relative magnitudes from night to night were uncertain as different comparison stars were used. This was dealt with by using additive constants for the second, third and fourth night magnitudes to bring them into agreement with the first night. A single lightcurve for the four nights was then least squares fit to a Fourier series including eight harmonics. The additive constants for the second through fourth nights and the period were then adjusted so that the fit minimized the sum of the squares of the residuals. The resulting values were a period of 8.824 ± 0.009 hours, the additive constant for the second night was 0.111, for the third night was -0.068, and for the fourth night was

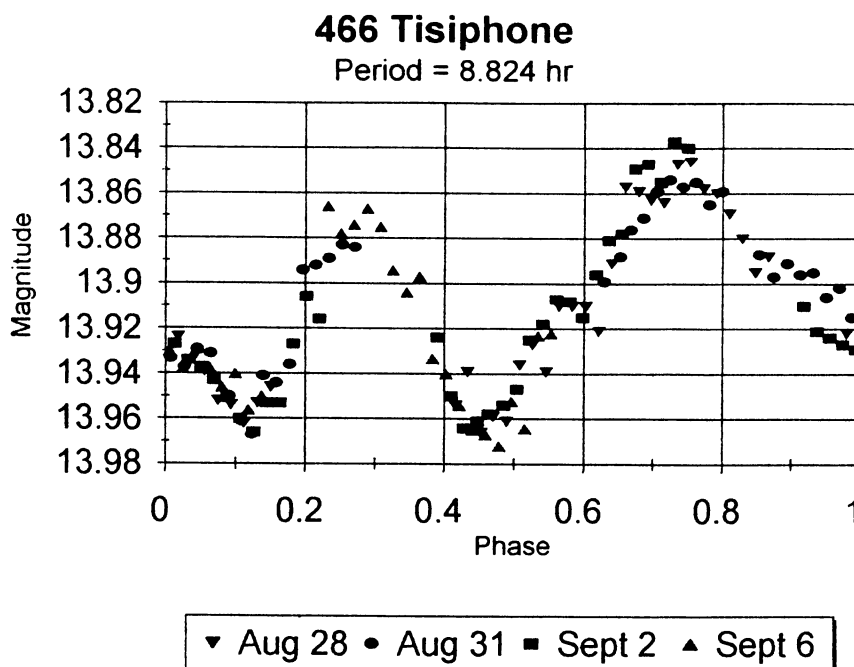


Figure 1. Composite lightcurve for 466 Tisiphone assuming our solution period of 8.824 hours. Zero phase corresponds to 0 hours UT on August 28, 1997. The magnitude scale is on the photometric system of the Hubble Guide Star catalog and must be considered to be uncertain by ± 0.40 magnitudes in its overall calibration. However, the point-to-point relative magnitudes are uncertain only by about ± 0.009 magnitudes.

0.078 magnitudes. These are reasonable as the uncertainties in the Hubble Guide Star Catalog are given to be about ± 0.4 magnitudes. The standard deviation of the residuals was 0.009 magnitudes which should be a good measure of the uncertainty in the relative magnitudes.

A period of 8.824 hours was assumed and the second through fourth night data were translated to fall on the first night data to give the composite lightcurve shown in Figure 1. The time scale is given in rotational phase with the zero corresponding to 0 hr on August 28, 1997 UT. There are clearly two maxima and two minima per rotation. The amplitude of the light curve is 0.114 ± 0.011 magnitudes. The phase angle during the observations varied between 7.2° and 8.6° .

Acknowledgments

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ASTEROID AND PLANET CLOSE ENCOUNTERS

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The well-known case of 1997 XF11 and its Earth encounter in Oct. 2028 raised public attention to the danger posed by Near-Earth Objects (NEOs). Astronomers also realized that discovery and follow-up of this kind of object is the primary step toward mitigating the hazard. As soon as the orbital parameters have been obtained from observations, the computation of the Minimum Orbital Intersection Distance (MOID) gives some information about the orbital distance between asteroid and planet orbits. (Bowell and Muinonen 1994; Bowell 1995; Carusi and Dotto 1996).

Sormano Observatory has been involved since its foundation, ten years ago, in astrometric measurements of such objects. Recently software to obtain the MOID from the first set of measurements has been developed in order to plan additional astrometric observations (Sicoli and Manca 1996; Matarazzo 1997) and eventually to compute real planetary encounters (Sicoli 1997). Two separate lists that include close approaches of asteroids to the inner planets have been then compiled and both are accessible through the net (Sicoli and Manca 1998).

The first one is named the Minor Body Priority List (MBPL). This list refers only to the Earth encounters for three centuries: one hundred years in the past (could be useful to search precovery images as 1997 XF11 demonstrated) and two hundreds years in the future. As a rule of thumb, we list, as potentially dangerous, the bodies (H magnitude less than or equal to 22) having an Earth MOID distance lower than the following thresholds (as a function of the timespan covered by the astrometric observations available):

Observation arc or no. of oppositions	Earth MOID limit (AU)
Asteroids	
from 3d to 30d	0.074
from 31d to 60d	0.064
from 61d to 3 opp.	0.044
4 or more opp.	0.014
Periodic Comets	0.084

Predicted minimum separation is computed (Testa, 1998), just for those bodies with at least 2 months arc, starting from the MPC orbital solution, and including perturbations by all the planets (except Pluto) and the Moon as a separate body. Finally some tests have been carried out in order to compare the accuracy of the results with other sources (Yeomans and Chodas 1994; Chodas 1998).

An integer number, suggesting just a rough estimate of the accuracy of date and close approach prediction, has the following meaning:

- (1) good
- (2) quite good
- (3) uncertain
- (4) very uncertain

As of mid-August 1998, 96 unnumbered and 19 numbered minor planets (plus 10 comets) are included. For 68 of these, minimum separation with our planet is listed. Table I presents a examples of

MBPL entries for the case of 1998 DV9 and (2340) Hathor.

The second list we have prepared is called the Planetary Close Encounters List (PCEL). The PCEL catalogues only multi-opposition minor planets with a MOID-Planet lower than 0.02 a.u. The objects have been selected from the orbit intersection page (Koehn and Bowell 1998) and the minimal distance from Mercury, Venus, and Mars has been calculated with the same software. Table II presents an interesting PCEL example detailing the next close approach between minor planet 1991 VE and Mercury. It should be noted that since we have not considered relativistic effects and especially because of uncertainties in the orbital elements (obtained just from two oppositions), slight differences could occur from these results.

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