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SPIN VECTOR AND SHAPE OF 532 HERCULINA

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LIGHTCURVES AVAILABLE

Herculina has been observed during 7 oppositions: 1954 (*Groeneveld and Kuiper, 1954*), 1963 (*Chang and Chang, 1963*), 1978 (*Harris and Young, 1979*), 1982 (*Drummond et al., 1985; Weidenschilling et al.,1990*), 1984 (*Taylor et al., 1987*), 1985 (*Erikson et al.,1991*), and 1987 (*Lebofsky et al., 1988; Weidenschilling et al., 1990*). This asteroid has very unusual lightcurves. They exhibit two maxima and minima in 1978, 1984 and 1987, and only one maximum and minimum in 1954, 1963 and 1982 per rotation cycle of about 9.4 hours. The 1985 lightcurve which is very close in aspect to those from 1963, shows two maxima and minima. The primary minimum is very similar to a single minimum in 1963, while the secondary one is only 0.06 mag deep. In 1963 no secondary minimum was visible.

PREVIOUS RESULTS

Drummond et al.(1985) observed Herculina by speckle interferometry techniques on 17 and 18 January 1982. These observations yielded triaxial ellipsoid dimensions of $263 \times 218 \times 215\mathrm{km}^3$ and a north pole with ecliptic coordinates $\lambda_p = 132°, \beta_p = -59°$. In addition a *spot* some 75% brighter than the rest of the asteroid was inferred from both speckle interferometry and Herculina's lightcurves. This bright *spot*, centered at asterocentric latitude −35° , longitude 145° − 165° has a diameter of 55° (115 km). With this model *Drummond et al. (1985)* were able to reproduce the observed lightcurves from the oppositions 1954-1982, but their amplitudes were greater then the observed ones.

Using the *Photometric astrometry* method and the minima of Herculina's lightcurves from the 1954–1984 period, *Taylor et al.(1987)* obtained the retrograde rotation, $\lambda_p = 276°, \beta_p = 1°$ and $P_{sid} = 0^d\!.3918711$. In order to explain the lightcurves of Herculina, they proposed a new model of this asteroid. The model was a sphere with two dark regions that were each about 0.13 times the brightness of the surrounding surface. The regions were at 0° asterocentric longitude, +15° latitude, with radius of 30° , and 170° longitude, −38° latitude, with a radius of 26° . This model, sidereal period and north pole generated lightcurves consistent with both the observed amplitudes and the timings of extrema during the 1954–1984 the period.

Applying the *Standard Thermal Model* for asteroids, *Lebofsky et al. (1988)* could produce lightcurves at both reflected and emitted wavelengths, for the model proposed by *Taylor et al. (1987)*. In the reflected wavelength, maxima occur when high-albedo areas are visible, while minima occur when dark areas are in view. In the thermal infrared, more solar insolation is absorbed by the darker areas and reemitted, so that maxima occur when warmer dark areas are visible. Thus, for Herculina's model, the two lightcurves should be about 90° (in rotation) out of phase with one another. Also, the amplitudes should be very different. Thermal lightcurve amplitudes tend to be smaller than those of reflected lightcurves. *Lebofsky et al. (1988)* observed Herculina by infrared technique. Their reflected and thermal lightcurves were in phase. The amplitudes of both lightcurves were close to each other. This was contrary to the predictions based on the albedo-variation model proposed by *Taylor et al. (1987)*. These results argued that the lightcurves were dominated by shape or topography rather than by albedo. *Lebofsky et al. (1988)* concluded that Herculina was nonspherical and probably irregular in shape, but they had not yet been able to explain the lightcurves with single maxima and minima.

NON-ELLIPSOIDAL SHAPE OF HERCULINA

Recently, *Cellino et al. (1989)* and *Kwiatkowski (1991)* obtained numerically modelled lightcurves of non-ellipsoidal bodies. In their method the shape was formed by merging together eight octants of ellipsoids having different semiaxes with the constraint that adjacent octants must have two equal semiaxes in common. Moreover, the homogeneous internal density distribution was assumed. Such shapes can produce lightcurves which are very similar to those observed in the case of Herculina (see Fig.1).

Having in mind conclusions derived from infrared observations by *Lebofsky et al. (1988)*, we decided to check a possibility of fitting the non-ellipsoidal model to observed light variations of Herculina. Using the pole obtained by *Taylor et al. (1987)* we calculated a wide set of synthetic lightcurves for systematically changed parameters describing the shape of the asteroid. Unfortunately we have not obtained a shape which could reproduce both the observed amplitudes and number of extrema. An example of good approximation to Herculina's amplitudes but big discrepancy in overall shape of lightcurves is presented in Fig.2.

Table 1. Results for Herculina

Pole λ_p	Pole β_p	Axial ratios $\frac{a}{b}$	Axial ratios $\frac{b}{c}$	Sidereal period (days)	Sense of rotation	Ref.
284±9	**+34±8**	**1.13±0.04**	**1.05±0.04**	**0.3918764±8**	**P**	**PW**
276	+1			0.3918711	R	T
312	+59	1.21	1.01		R	D

Sense of rotation: P–prograde, R–retrograde
References: PW–present work, T–Taylor et al. 1987 ,D–Drummond et al. 1985

NEW POLE

Because of our inability to obtain the non-ellipsoidal model of Herculina we tried to verify pole coordinations obtain by the others. We have decided to use only the lightcurves with two maxima and minima. In our method (*Michałowski 1988, 1991; Michałowski and Velichko, 1990*) we used the epochs, magnitudes of maxima of brightness, and the amplitudes, all taken from 17 lightcurves from the 1978, 1984, 1985, and 1987 apparitions. We have obtained the sidereal period, sense of rotation, pole, and triaxial ellipsoid which should be a rough estimation of the shape of Herculina (see Table 1). The results by *Drummond et al. (1985)* and *Taylor et al. (1987)* are given for comparison.

CONCLUSIONS

A visible discrepancy in the coordinates of Herculina's pole obtained by different methods, indicate a necessity to use a qualitatively new method. It should make it possible to obtain simultaneously the pole, sidereal period, sense of rotation and non–ellipsoidal shape of the asteroid. Of course, other possibilities (regular ellipsoid with albedo variegation, and/or internal density gradient) should not be neglected. According to the estimated poles, nearly in all observations Herculina was seen from its northern hemisphere. Therefore, new observations showing the southern parts of its surface are required.

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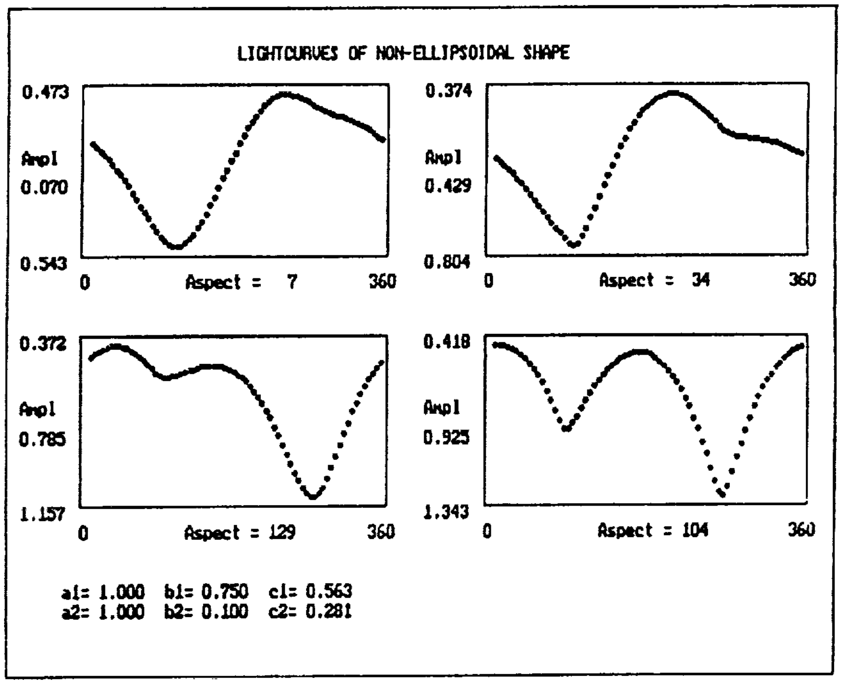

Fig. 1. Examples of lightcurves obtained from a non-ellipsoidal model (Lommel-Seeliger scatering law, pole coord. $\lambda = 276$, $\beta = 1$)

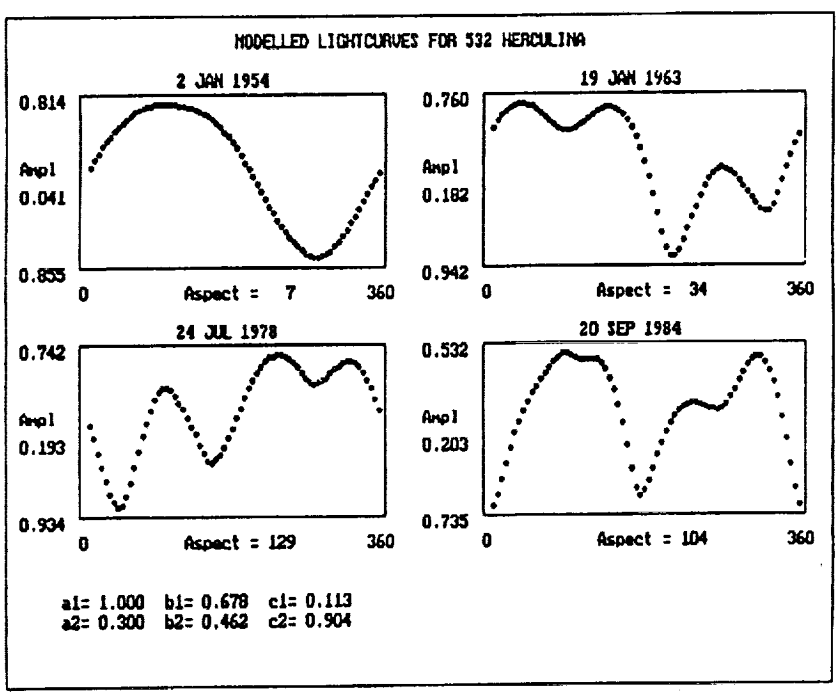

Fig. 2. Lightcurves obtained from the non-ellipsoidal model of Herculina, reflecting observed amplitudes (Lommel-Seeliger scatering law, pole coord. $\lambda = 276$, $\beta = 1$).