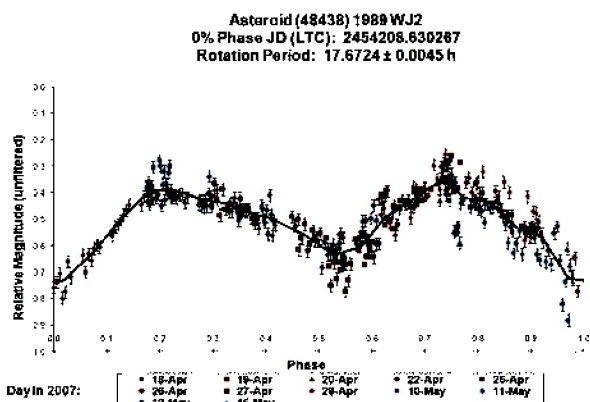
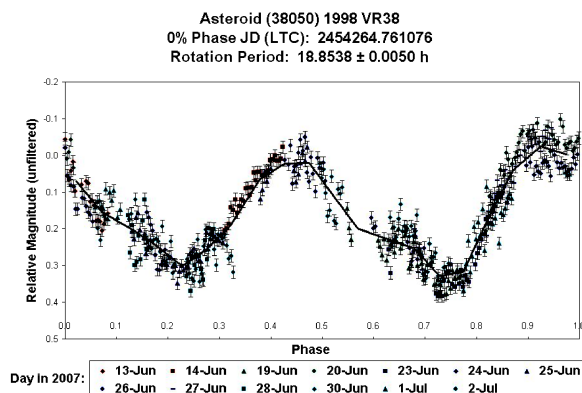
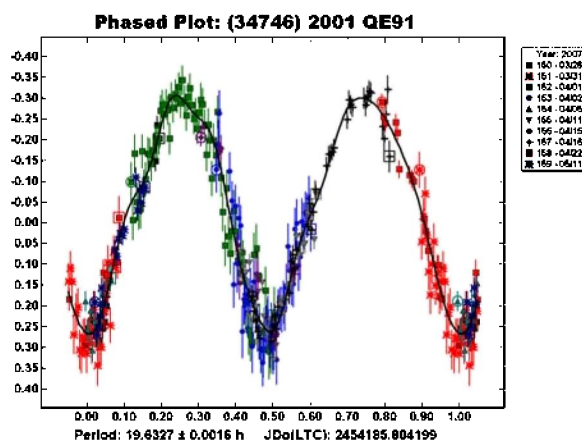
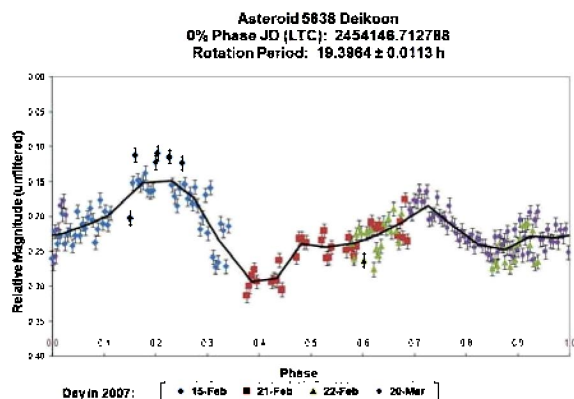




A PRELIMINARY SHAPE AND SPIN AXIS MODEL FOR 76 FREIA

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Photometric observations from the 2007 apparition of main-belt asteroid 76 Freia were combined with those from earlier apparitions to determine a preliminary shape and spin axis model. The combined data set was not extensive, resulting in more than one reasonable solution. Regardless, the solutions showed two consistent results for the pole (geocentric ecliptic coordinates): $\lambda = 139^\circ$, $\beta = +25^\circ$ or $\lambda = 0^\circ$, $\beta = +40^\circ$.

Stephens observed 76 Freia for three nights in December, 2007: December 8 at GMARS (0.35m Modified Ritchey-Chretien); December 11-12 (0.30m Modified Ritchey-Chretien). Both telescopes were equipped with an SBIG STL-1001 CCD camera, yielding a pixel scale of approximately $1.2''/\text{pixel}$. Exposures were 60 seconds. Over the four-day span, the phase angle decreased from $6^\circ.5$ to $5^\circ.0$. The Phase Angle Bisector (PAB) remained nearly constant at $\lambda = 91^\circ.5$, $\beta = -2^\circ.3$. The combined data set of 559 points yielded a lightcurve with synodic period of 9.969 ± 0.002 h and amplitude of 0.10 ± 0.01 mag. (Fig. 1). This is in good agreement with previous results, including Harris et al. (1992) and Armstrong et al. (1996).

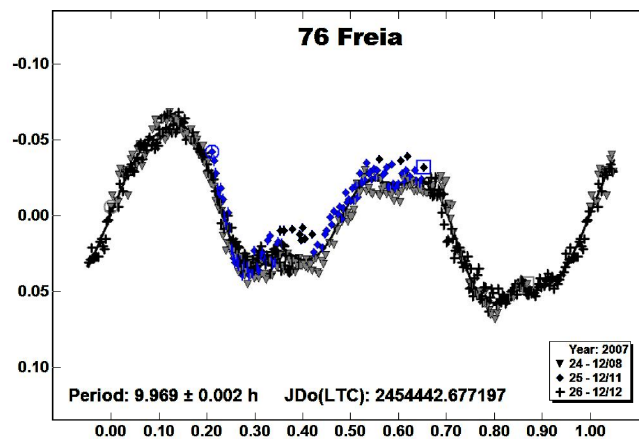


Fig. 1. The lightcurve for 76 Freia based on data obtained in 2007.

Stephens communicated his results to Warner, who reviewed available lightcurve data in the Standard Asteroid Photometric Catalog (<http://www2.astro.helsinki.fi/SAPC/index.jsp>) and found data from apparitions in 1981 and 1984 (Lagerkvist et al.) along with 1994 (Kryszczynska et al.). While the overall time-span of the data was more than 20 years, the number of lightcurves on the SAPC site was not extensive. A review of the lightcurves by Armstrong and Harris showed them to be fairly sparse and of little

additional use. They were not included in this study. Furthermore, all data were within an arc of heliocentric longitude of 180° . Better results are obtained when the data cover as much of the orbit as possible. The next apparition in 2009 continues this trend, being similar to the 1984 observations. Despite these shortcomings, Warner attempted to model the asteroid using MPO LCInvert (Bdw Publishing), which is based on the source code provided by Mikko Kaasalainen and Josef Durech. The documentation and core library source code are available as free downloads on the MPO LCInvert web page.

Analysis and Results

A period search was run on the combined data set, which found a sidereal period of 9.968240 h. This was used as the free-floating period in the subsequent model searches. The initial weighting of the “dark area” (see the several Kaasalainen references) was set to 0.1 for the first search and 0.5 for a second run. This provided a check on the size of the “dark area” in the two models. A tendency for the dark area towards a higher value may indicate albedo variations. In this case, there were no significant tendencies and so the presumption is that the lightcurve variations are due almost exclusively to shape with no significant albedo effects.

The final result of the modeling was to find two dominant pole solutions, at least in the terms that there were several solutions near the two solutions in each group of 15 test conditions. Those two solutions are listed in Table 1, along with an average of the sidereal periods. The preferred solution is given first. The χ^2 values themselves did not have as large of spread as would be liked to assert a definitive solution. Figure 2 shows the model for the preferred solution (139° , $+25^\circ$) as seen from the asteroid’s equatorial plane at local noon.

λ	β	Sidereal Period
$139^\circ \pm 5^\circ$	$25^\circ \pm 5^\circ$	9.968286 ± 0.000009 h
$0^\circ \pm 5^\circ$	$40^\circ \pm 5^\circ$	

Table 1. Poles and periods for the two best shape model solutions.

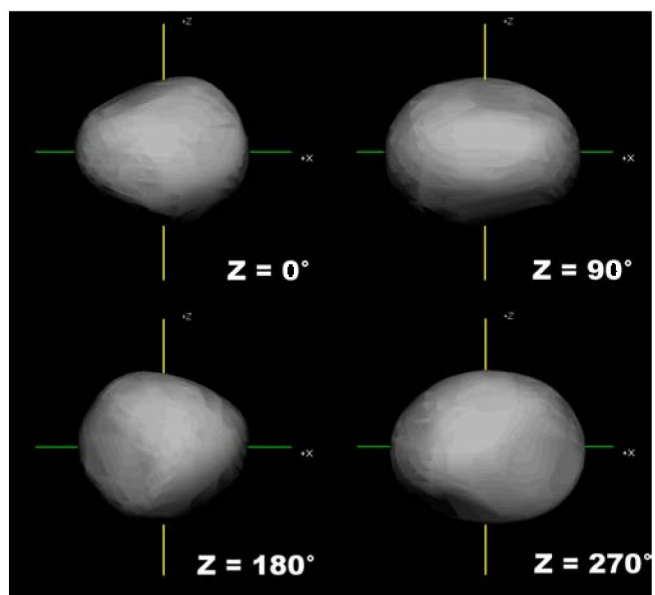


Fig. 2. Equatorial view of (139° , 25°) solution.

The use of relative-only data prevents the modeling process from finding a definitive height of the Z-axis, i.e., the a/c or b/c ratios. Only the a/b ratio is found with any certainty. The theoretical

lightcurves of the (139° , $+25^\circ$) model fit the original data well (Fig. 3), more so than the model curves of the alternate solution (0° , $+40^\circ$). However, the differences are only just statistically significant and so either solution remains a possibility. The models also show some large flat spots, possibly indicating large craters or concavities.

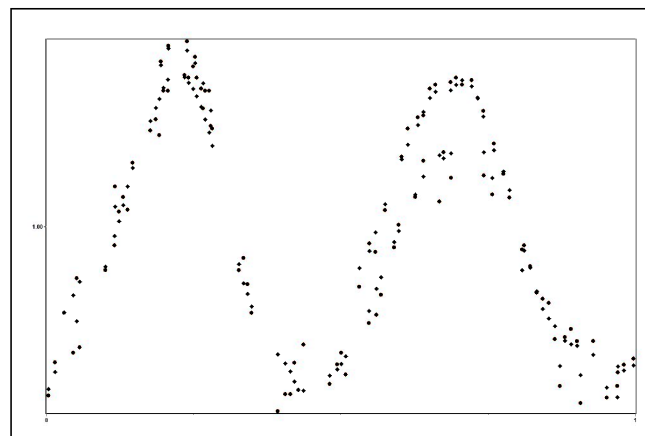


Fig. 3. Comparison of theoretical (black/dark) and actual (red/light) data using 1984 data and best solution from 0.1 initial weighting.

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