FOURIER ANALYSIS OF ASTEROID LIGHTCURVES: SOME PRELIMINARY RESULTS

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Asteroid lightcurves have been used for the purposes of determining periods of rotation, studying the shapes and pole orientations of the bodies, and for phase relation studies. For all of these applications, it is generally necessary to construct a composite lightcurve, overlaying data from different days to place all of the data within a single rotation cycle. In the past, this has generally been done by informal "eyeball" methods (e.g., Harris and Young, 1983). I report here a formal procedure for constructing the composite by Fourier analysis of the data, allowing each individual lightcurve to be offset from the others by a constant magnitude. the resulting Fourier coefficients precisely define the amplitude of variation and the "epoch of extremum", and the individual harmonics can be used for various shape and pole studies (e.g., Ostro and Connelly, 1984; Lumme, et al, 1985). The constant magnitude offsets define the mean absolute magnitudes at the the phase angles of observation and can be directly used to construct the phase relation. Furthermore, formal error estimates can be obtained for each of the solution parameters (including the period of rotation). The present method differs from the above referenced work in that the Fourier fit starts with the raw data, rather than an already composited lightcurve. In addition to yielding the period determination and phase relation, this method reduces the addition of "noise" due to inaccurate construction of the composite.

The formulation employed is as follows:

$$m_i = M_j + \sum_{k=1}^{n} (A_k \sin k\, t_i + B_k \cos k\, t_i),$$

where m_i is the ith observation of magnitude at time t_i, M_j is the mean absolute magnitude at the phase angle of the jth lightcurve, A_k and B_k are the Fourier coefficients, and is the rotation frequency. For a set of p lightcurves, there are 2n+p constants of the solution, and one equation of condition for each observation. In practice, a weighted least squares approach is used, where each observation is weighted by the inverse square of its magnitude uncertainty. For typical cases, there are about ten individual lightcurves containing a total of 100-200 observations. Good solutions require Fourier terms up to about 10, hence the observation matrix may contain as many as 10^4 terms. Typical inversions require only about 10 seconds on an IBM AT computer, thus the problem is very tractable on a micro. Sample results for three asteroids follow. Figures 1 through 6 are the composite lightcurves and phase relations for each asteroid. The best Fourier fit is plotted in each lightcurve, and the best fit Lumme-Bowell-Harris (LBH) phase relation (Bowell, et al, in preparation) is shown in each phase plot.

3 Juno. This asteroid was observed from October, 1979 to March, 1980 from Lowell Observatory and Table Mountain Observatory. The "best" solution is of order 11, with a period of 7.21084 hours. The probable error in the period is $\pm$0.00015 hour. The "one sigma" level of significance of the harmonics is at an amplitude of about 0.0015 magnitude. Harmonics of order 1 through 5 are highly significant, with amplitudes of .055, .028, .004, .004, and .006, respectively. The higher order components are of only marginal significance. The total amplitude of variation (peak to peak) is 0.157 magnitude. It is noteworthy that most of the power is in the first harmonic, which is unusual for asteroid lightcurves. Since Juno has been observed to exhibit the same general shape and amplitude lightcurve at several longitudes and at low phase angle, one must conclude that the viewing aspect is fairly nearly equatorial, and that the light variation is primarily due to albedo variation rather than shape. Unfortunately, no observations were obtained at low phase angle in 1979-80, so the phase relation is not very definitive.

24 Themis. Unlike Juno, a campaign was mounted for the specific purpose of

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observing Themis at low phase angle. Observations were obtained from Table Mountain, Lowell, and Torino Observatories from November, 1979 to March, 1980. Because of the low total amplitude of variation, 0.092 magnitude, the period is less well determined. The best fit value is 8.374 ±0.001 hours. Harmonics 1 through 4 are highly significant with amplitudes of 0.021, 0.017, 0.013, and 0.016, respectively. Harmonics of order 5 through 9 are all small, but formally significant. As with Juno, the largest amplitude is the first harmonic, suggesting that the principal cause of variation may be albedo, however the pole of Themis is unknown, so a firm statement cannot be made. The phase relation was very well covered, and the data show significant deviations from the best fit LBH phase relation plotted in the same figure.

261 Prymno. This asteroid was observed along with Themis in November and December, but because it was fainter, it was not observed at Torino, nor in March, when it was even fainter. The light variation is more ordinary, with most of the power in the second harmonic, although orders 1 through 4 are all highly significant, with amplitudes of .019, .062, .013, and .021, respectively. Orders 5, 6, and 7 are of marginal or no significance, but order 8 is again formally very significant with an amplitude of .008 magnitude. The period is 8.0018 ±0.0015 hours. The peak to peak amplitude of variation is 0.174 magnitude. The phase relation appears marginally more peaked at low phase angle than predicted by the best fit LBH phase relation.

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