LIGHTCURVE ANALYSIS OF AN UNBIASED SAMPLE OF TROJAN ASTEROIDS

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Lightcurve observations of ten Trojan asteroids made at the Calvin Observatory are reported: 1143 Odysseus, 1208 Troilus, 2920 Automedon, 3709 Polypoites, 5144 Achates, 5638 Deikoon, (7352) 1994 CO, (34746) 2001 QE91, (38050) 1998 VR38, and (48438) 1989 WJ2. Synodic rotation periods were determined for all but (7352) 1994 CO, which showed no significant variation. The sample was unbiased with regard to period, and has a median value, 18.9 hours, significantly longer than for similarly sized main-belt objects. This may be evidence for a lower average mass density among the Trojans.

The spin properties of Trojan asteroids have not been extensively studied. For example, the catalog of Harris et al. (2007) has only 14 well determined values. The goal of this project was to study a sample of Trojans unbiased with respect to period length. Data were taken through the spring and summer of 2007. Objects were chosen as observing time allowed based on properties optimizing the chance of successfully determining their periods: proximity to opposition, brightness, and declination. Those asteroids found to vary were pursued for as many at thirteen nights in an attempt to determine every period as well as possible. Secure synodic periods (U = 3) were found for five objects, likely periods with less complete coverage for two (1208 Troilus and 2920 Automedon), and tentative periods (U = 1+) for two (3709 Polypoites and 5638 Deikoon). In every case, we tested all periods shorter than our final values and excluded them as inconsistent with the data. Hence our less secure values may be considered lower limits.

Calvin College operates two identical telescopes (0.4 m OGS Ritchey-Chretiens): one operated remotely in Rehoboth, NM, at an elevation of 2024 m, and a second on our campus in Grand Rapids, MI, at an elevation of 242 m. The Rehoboth telescope has an SBIG ST-10XE camera with a plate scale of 1.31 arcseconds per pixel, while the Grand Rapids telescope has an SBIG ST-8XE camera with a plate scale of 1.58 arcseconds per pixel. For 2007, many Trojans were in opposition in the summer, a time of poorer weather at the New Mexico site, although its darker skies otherwise make it our site of choice. No filters were used, and exposure times ranged from 120 to 300 s. Standard image calibration was done with MaxIm DL. Differential aperture photometry was done both with Canopus 9.3.1.0 (BDW Publishing 2007) and MaxIm DL always using the average of five reference stars with magnitudes comparable to the asteroid. Period analysis was done with Canopus 9.3.1.0 and Peranso 2.20 (Vanmunster 2006), using the Fourier algorithm (FALC) developed by Harris et al. (1989). All times were corrected for light travel. As Trojans have low proper motion, it was possible to directly compare one set of reference stars to the next on adjoining nights. Hence magnitude scales on adjoining nights are tied together (with uncertainty generally less than 0.02 mag). Our results are summarized in the figures and table below, along with additional comments on individual objects as needed.

<u>1143 Odysseus.</u> Each of the data points in this figure represents an average of ten images.

<u>3709 Polypoites.</u> Each of the data points in this figure represents an average of ten images. The reported period, 43.0 ± 0.1 h, is the only one consistent with the data in hand. However, the period is so long that even with nine nights relatively little of the phase range is sampled independently on multiple nights. Further observations are necessary to confirm the period.

<u>(38050) 1998 VR38.</u> Within our uncertainties, these data could be fit either by one or two peaks per cycle. Since the amplitude is 0.37 mag (larger than expected from a pole-on perspective), we consider the bimodal fit more likely.

Since the sample is unbiased with respect to period, it is interesting to compare its median, 18.9 hours, with that of main belt asteroids in the same size range, 60-170 km assuming the typical Trojan albedo found by Fernandez et al. (2003). We explore the median rather than the mean as it is insensitive to the presence of some lower limits. Note also that main-belt asteroids vary little in average rotation across this size range (Pravec et al. 2002). The catalog of Harris et al. (2007) has 396 well-measured objects in this range with a median of 11.5 hours. We use a Monte Carlo calculation to estimate the probability of finding such a high median from a random selection of nine objects from the catalog values: 0.005.

We first considered whether observational bias in the main belt sample could account for the difference. We found the main belt sample is 84% complete (Minor Planet Center 2007). The maximum bias would require the remaining 73 objects all rotate slowly, which would imply a median of 13.0 hours. The likely bias is much less – not enough to resolve the discrepancy with the Trojans. For asteroids in this size range, the spin distribution is a product of collisional evolution, and a longer average period is an indication of a lower average mass density (Harris 1979). If Trojans originated in the outer solar system, as suggested by

#	Name	Date range (2007) (mm/dd)	Images	Period (h)	P. error (h)	Est. amp. (mag)	Observing location
1143	Odysseus	08/13-08/18	340	10.1251	0.0049	0.16	MI
1208	Troilus	04/14-05/15	230	56.172	0.067	0.20	NM
2920	Automedon	07/14-07/23	377	10.2117	0.0015	0.17	NM,MI
3709	Polypoites	07/04-08/08	576	43.0	0.1	0.29	NM,MI
5144	Achates	01/23-02/27	308	5.9583	0.0031	0.32	NM
5638	Deikoon	02/15-03/20	205	19.3964	0.0113	0.14	NM
7352	1994 CO	03/06-03/12	273			<0.10	NM
34746	2001 QE91	03/26-05/11	334	19.6327	0.0016	0.56	NM
38050	1998 VR38	06/13-07/02	504	18.8538	0.0050	0.37	NM
48438	1989 WJ2	04/18-05/15	316	17.6724	0.0045	0.39	NM

Morbidelli et al. 2005, one might expect lower densities. The only well measured Trojan density (0.8 g cm^{-3} for 617 Patroclus, Marchis et al. 2006) is unusually low. A good estimate of average Trojan densities will require much more data.

Acknowledgements

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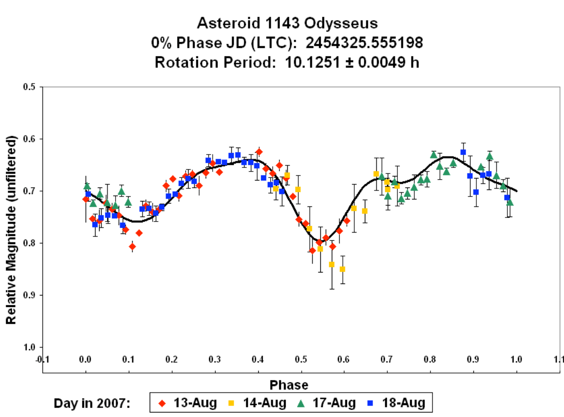
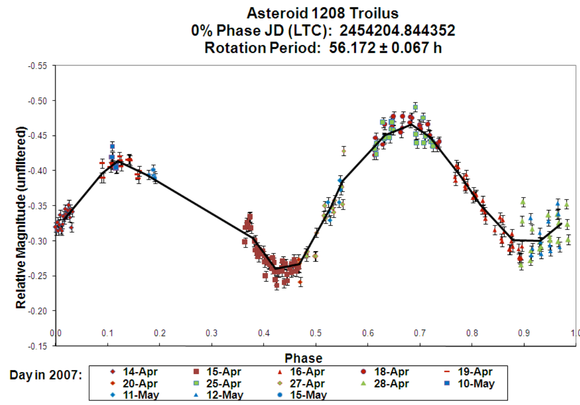
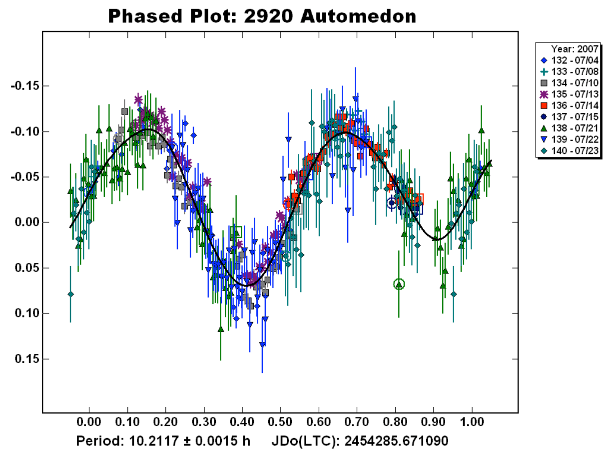
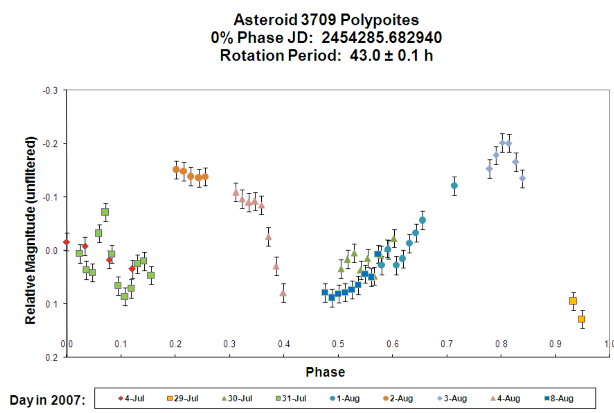
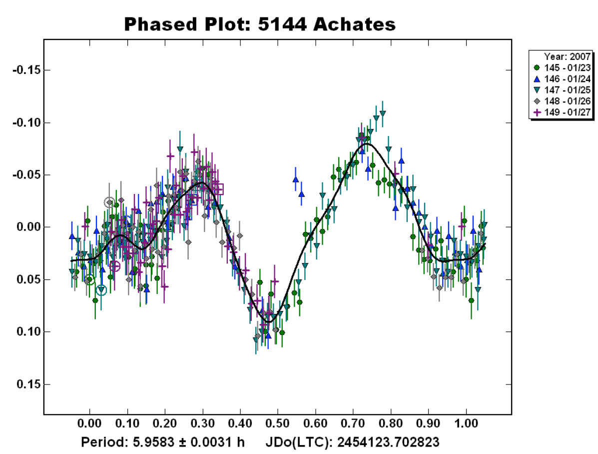
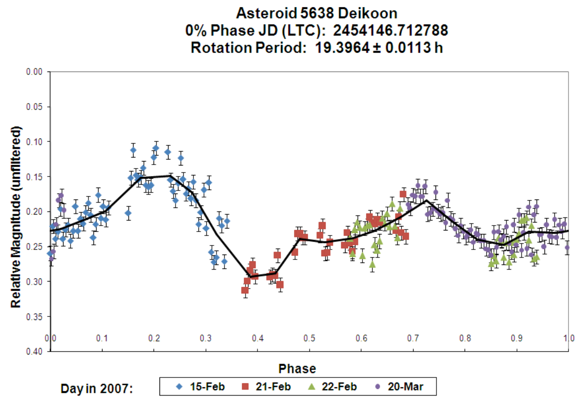


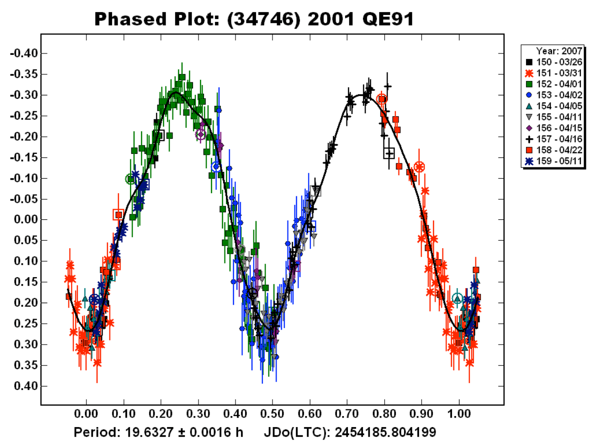


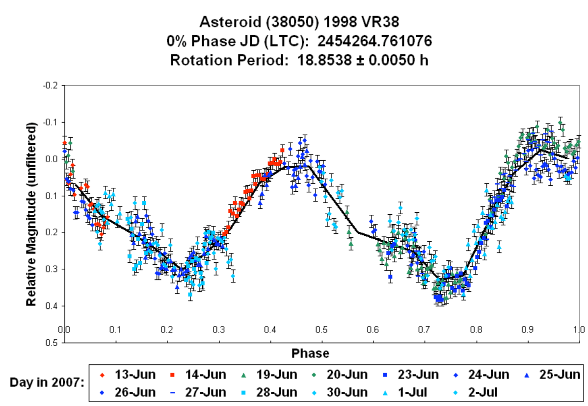


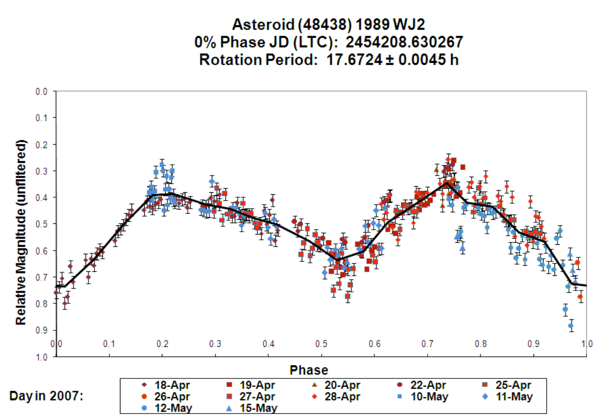





Asteroid 5638 Deikoon
0% Phase JD (LTC): 2454146.712788
Rotation Period: 19.3964 ± 0.0113 h
Relative Magnitude (unfiltered)
Phase
Day in 2007:
15-Feb
21-Feb
22-Feb
20-Mar


Phased Plot: (34746) 2001 QE91
Year: 2007
150 - 03/26
151 - 03/31
152 - 04/01
153 - 04/02
154 - 04/05
155 - 04/11
156 - 04/15
157 - 04/16
158 - 04/22
159 - 05/11
Period: 19.6327 ± 0.0016 h
JDo(LTC): 2454185.804199


Asteroid (38050) 1998 VR38
0% Phase JD (LTC): 2454264.761076
Rotation Period: 18.8538 ± 0.0050 h
Relative Magnitude (unfiltered)
Phase
Day in 2007:
13-Jun
14-Jun
19-Jun
20-Jun
23-Jun
24-Jun
25-Jun
26-Jun
27-Jun
28-Jun
30-Jun
1-Jul
2-Jul


Asteroid (48438) 1989 WJ2
0% Phase JD (LTC): 2454208.630267
Rotation Period: 17.6724 ± 0.0045 h
Relative Magnitude (unfiltered)
Phase
Day in 2007:
18-Apr
19-Apr
20-Apr
22-Apr
25-Apr
26-Apr
27-Apr
28-Apr
10-May
11-May
12-May
15-May