

ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2012 MARCH - JUNE

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Lightcurves for 34 asteroids, including a new Hungaria binary, were obtained at the Palmer Divide Observatory (PDO) from 2012 March to July: 1656 Suomi, 3169 Ostro, 3266 Bernardus, 4116 Elachi, 4483 Petofi, 4490 Bambery, 5968 Trauger, 6107 Osterbrock, 6354 Vangelis, 6517 Buzzi, 6670 Wallach, 7087 Lewotsky, (11304) 1993 DJ, (17129) 1999 JM78, (17590) 1995 CG, (20996) 1986 PB, (23482) 1991 LV, (24702) 1991 OR, (31182) 1997 YZ3, (31881) 2000 FL15, (42811) 1999 JN81, (47143) 1999 LL31, (48307) 2002 LP53, (49674) 1999 SB5, (51302) 2000 KY54, (51381) 2001 BG51, (51386) 2001 CN35, (74081) 1998 OU1, (79472) 1998 AX4, (88259) 2001 HJ7, (326732) 2003 HB6, 2011 WV134, 2012 AA11, and 2012 DO. The Hungaria asteroid (79472) 1998 AX2 showed what appeared to be mutual events (occultations/eclipses) in its lightcurve, likely indicating a satellite. Analysis of the data gives an orbital period of 25.95 ± 0.02 h and size ratio of $D_s/D_p \sim 0.32 \pm 0.03$.

CCD photometric observations of 34 asteroids were made at the Palmer Divide Observatory (PDO) from 2012 March to July. See the introduction in Warner (2010a) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling. The “Reduced Magnitude” in the plots is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying $-5 \cdot \log(r\Delta)$ with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., $\alpha(6.5^\circ)$, using $G = 0.15$ unless otherwise stated.

For the sake of brevity in the following discussions on specific asteroids, only some of the previously reported results are referenced. For a more complete listing, the reader is referred to the asteroid lightcurve database (LCDB, Warner *et al.* 2009). The on-line version allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files, including the references with Bibcodes, is also available for download at <http://www.minorplanet.info/lightcurvedatabase.html>. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

1656 Suomi. This Hungaria asteroid was previously worked by Stephens (2004), Brinsfield (2008), and by Warner (2009a), among others. The three found periods of about 2.59 h. The most recent results from PDO are in agreement with that period.

3169 Ostro. There are numerous reports in the LCDB for this Hungaria, e.g., Wisniewski (1991), Descamps (2007), Warner (2009a), and Hamanowa (2011). The period of 6.503 h reported here is in agreement with the earlier results.

3266 Bernardus. The author worked this Hungaria two times before (Warner, 2009b; Warner, 2011a). The period reported here is consistent with those earlier results.

4116 Elachi. This was the third time this asteroid was observed at PDO (Warner, 2006a; 2011a). All three results are in agreement.

4483 Petofi. Angeli (1996) reported a period of 4.480 h. Warner (2008; 2009b; 2011a) found a period of about 4.334 h. The latest results confirm the shorter period.

4490 Bambery. Three previous results from PDO (Warner, 2006b; 2009b; 2011b) confirm the period of 5.827 h reported here.

5968 Trauger. Warner (2006a) first reported a period of 7.560 h for this Hungaria. A second look at the same data (Warner, 2011a) found a period of 3.783 h. The asteroid was observed again in 2010 (Warner, 2011a), when a period of 6.341 h, $A = 0.30$ mag was found. Analysis of the 2012 PDO observations found 3.7879 h with an amplitude of 0.19 mag. The 2010 and 2012 data sets cannot be reconciled against one another and so the true period remains uncertain.

6354 Vangelis. Stephens (2003) found a period of 4.115 h based on two nights of observations separated by 11 days. The 2012 PDO observations consisted of two nights separated by 4 nights. Analysis found a period of 4.039 h. Stephens kindly lent his data where the period spectrum showed a solution of 4.039 h that was almost identical in RMS value to the 4.115 h solution. The period spectrum for the PDO data showed a possible solution at 4.125 h but the RMS was noticeably more than at 4.039 h. There was no solution near 4.115 h. In both cases, a third night, not so much removed from either of the existing two nights would have served to reduce or eliminate alias solutions.

6517 Buzzi. This was the third apparition this asteroid was observed at PDO. The results from the two earlier data sets (Warner, 2005; 2009a) are statistically identical the period of 8.648 h reported here.

6670 Wallach. Pletikosa *et al.* (2011) reported a period of 4.08 h. Analysis of the 2012 PDO data gives the same result.

7087 Lewotsky. Carbo *et al.* (2009) reported observing this Hungaria but unable to find a period. Warner (2011a) found a period of 5.15 h from data obtained in 2010. The analysis of the 2012 PDO data give 3.934 h with $A = 0.42$ mag. Since this seems to be a secure result given the amplitude, the 2010 data from PDO were rechecked. A number of solutions between 3 and 6 hours were found, all about equally the same RMS fit. The plot for 2010 included here shows the data forced to a solution to within 3.9-4.0 h. The fit is statistically as good as for the original solution at 5.15 h.

(11304) 1993 DJ. Warner (2009a) reported a period of 95.7 h. The result of 94.5 h reported here is reasonably consistent with that earlier result given the lack of coverage. The tumbling damping time for this asteroid (see Pravec *et al.*, 2005) is longer than the age of the Solar System. The sparse coverage does not allow saying one way or the other if the asteroid is tumbling.

(17129) 1999 JM78. Dittion *et al.* (2011) reported a period of 6.2615 h. The PDO 2012 data analysis gives 6.2618 h. Originally, the analysis found 6.09 h. After consulting with Dittion to see if their data would fit that period, it was ruled out.

Number	Name	2012 (mm/dd)	Pts	Phase	L _{PAB}	B _{PAB}	Period	P.E.	Amp	A.E.
1656	Suomi (H)	06/02-06/20	512	22.0 20.0	274	34	2.5879	0.0002	0.11	0.01
3169	Ostro (H)	05/30-06/01	145	12.1 11.7	251	17	6.503	0.003	0.79	0.02
3266	Bernardus (H)	06/26-07/12	157	9.4 13.7	272	11	10.760	0.003	0.27	0.02
4116	Elachi (H)	04/10-04/24	418	11.0 13.7	206	15	38.143	0.005	1.02	0.02
4483	Petofi (H)	04/25-04/30	126	13.6 16.1			4.334	0.002	0.85	0.02
4490	Bambury (H)	06/23-06/25	181	16.1 15.6	282	23	5.827	0.002	1.00	0.02
5968	Trauger (H)	03/17-03/28	171	19.4 23.2	154	-15	3.7879	0.0004	0.19	0.02
6107	Osterbrock (H)	05/28-05/31	127	26.0 26.2	233	33	2.372	0.002	0.09	0.01
6354	Vangelis	05/05-05/09	122	14.3 15.2	206	20	4.039	0.002	0.54	0.02
6517	Buzzi (H)	05/28-06/01	191	21.2 20.5	256	29	8.648	0.002	0.71	0.03
6670	Wallach	05/05-05/10	171	11.6 12.3	217	25	4.080	0.001	0.40	0.02
7087	Lewotsky (H)	05/30-06/02	101	11.9 13.5	233	8	3.934	0.002	0.42	0.02
11304	1993 DJ (H)	03/23-04/09	443	21.0 20.5 20.8	198	29	94.5	0.2	1.0	0.1
17129	1999 JM78	05/05-06/02	209	12.9 9.2 9.5	245	19	6.2618	0.0003	0.51	0.02
17590	1995 CG (H)	06/23-07/13	216	21.0 23.3	267	27	16.10	0.01	0.18	0.02
20996	1986 PB (H)	04/20-04/30	344	21.8 22.3	216	35	43.6	0.2	0.38	0.02
23482	1991 LV (H)	06/26-07/13	153	20.5 17.0	300	22	3.1388	0.0002	0.27	0.02
24702	1991 OR (H)	03/23-04/09	330	14.6 18.2	180	26	59.5	1.0	0.19	0.02
31182	1997 YZ3 (H)	05/30-06/19	355	21.6 25.9	227	27	380	25	0.62	0.05
31881	2000 FL15 (H)	04/23-04/28	128	15.0 13.8	226	14	4.16	0.01	0.21	0.03
42811	1999 JN81 (H)	06/23-06/26	142	28.0 28.1	281	36	3.897	0.002	0.15	0.01
47143	1999 LL31 (H)	04/20-04/22	113	19.2 19.0	224	32	3.32	0.01	0.31	0.02
48307	2002 LP53	05/09-05/10	82	6.2	232	18	3.79	0.05	0.34	0.03
49674	1999 SB5 (H)	04/17-04/18	125	13.2 13.1	206	22	7.56	0.05	1.22	0.03
51302	2000 KY54	04/30-05/28	132	7.5 15.6	218	12	2.46	0.01	0.08	0.01
51381	2001 BG51	04/30-05/10	236	24.3 24.0	229	35	47.1	0.5	0.38	0.03
51386	2001 CN35 (H)	03/25-04/09	213	8.9 6.9 8.9	190	9	48.0	0.2	0.36	0.03
74081	1998 OU1 (H)	04/10-04/30	363	23.1 24.6	205	36	46.1	0.2	0.23	0.02
79472	1998 AX4 (H)	03/17-04/09	573	20.2 22.0	178	34	2.8802 ¹	0.0002	0.21	0.02
88259	2001 HJ7 (H)	06/09-06/12	136	12.4 13.9	245	12	4.175	0.005	0.15	0.02
326732	2003 HB6	06/12-06/20	146	24.1 29.7	250	16	9.436	0.004	0.19	0.01
	2011 WV134	06/02-06/11	183	27.4 18.9	262	17	10.105	0.003	0.23	0.02
	2012 AA11	03/29-04/10	279	58.9 28.8	158 183	15 3	14.19	0.01	0.72	0.03
	2012 DO	04/17-04/25	377	17.4 19.5	216	11	38.7	0.5	0.24	0.02

¹ Rotation period of primary in a binary system.

Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. The phase angle (°) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. LPAB and BPAB are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

(23482) 1991 LV. Analysis found a weak secondary period at around 13.8 hours. Removing this produced a significantly better RMS fit of the data to the 3.1388 h period reported here. However, the data were far from conclusive. Two plots are provided below: first is one after subtracting the secondary period and then one without subtraction. The hints of something unusual make this a prime target for detailed, high-precision observations in the future.

(42811) 1999 JN81. This Hungaria was observed in 2007 by Warner (2008). A period of 3.902 h was reported. The new results of 3.897 h are consistent with that earlier finding.

(79472) 1998 AX4. Several apparent “mutual events”, occultations and/or eclipses due to a satellite, were observed. The effect of these were subtracted from the data using the dual period search in MPO Canopus, which found a period for the primary of 2.8802 ± 0.0002 h. The orbital period of the, presumably, tidally-locked satellite, was found to be 25.95 ± 0.02 h. The depths of the events were about equal, $A \sim 0.12$ mag. This gives the size ratio $D_s/D_p \sim 0.32 \pm 0.03$.

(88259) 2001 HJ7. Pravec *et al.* (2010) found a period of 4.166 h. The best fit of the PDO data give 4.175 h, although they can be forced to the shorter period with only a very slight increase in the RMS value.

2011 WV134, 2012 AA11, and 2012 DO. These are near-Earth asteroids that were observed to help build the rotational statistics for this group of asteroids and for potential support of radar observations.

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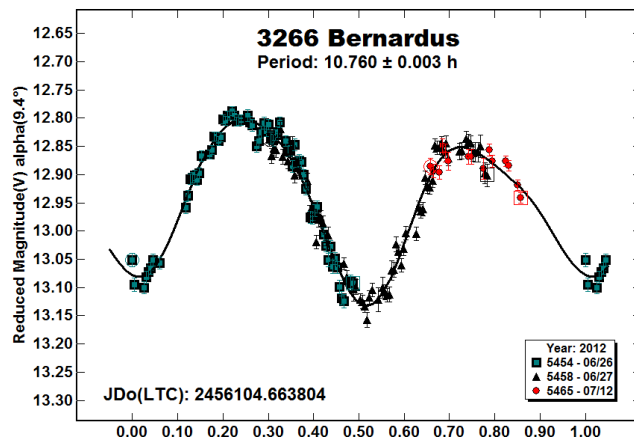
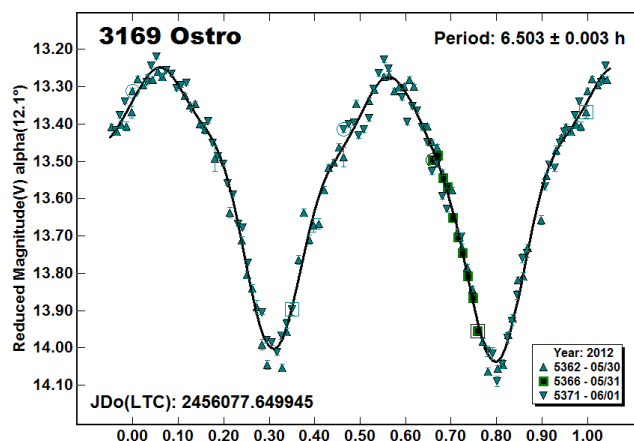
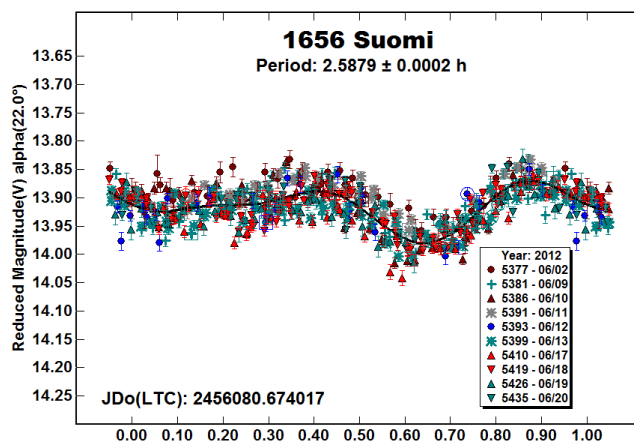
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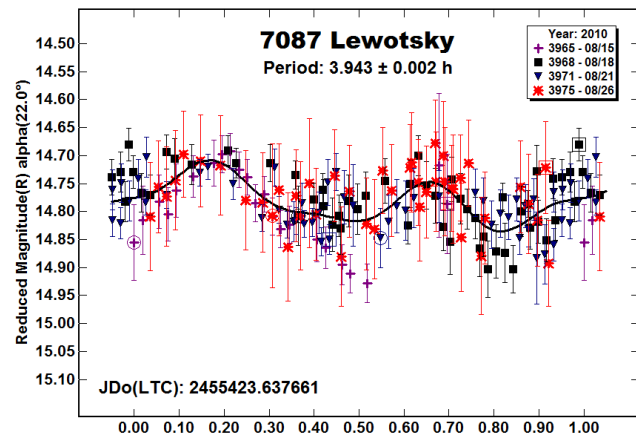
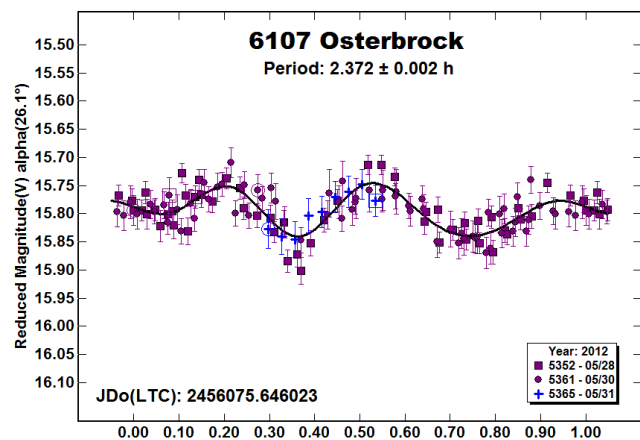
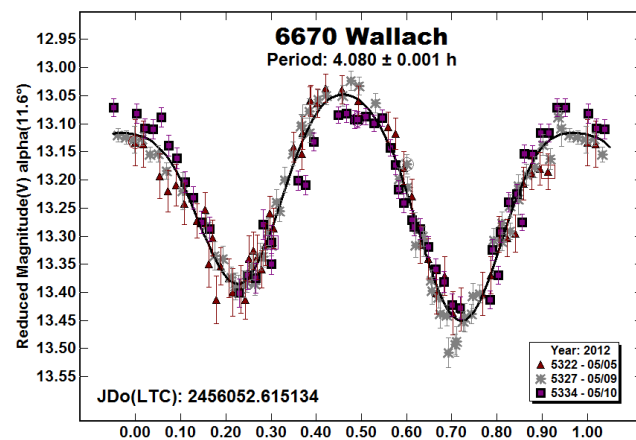
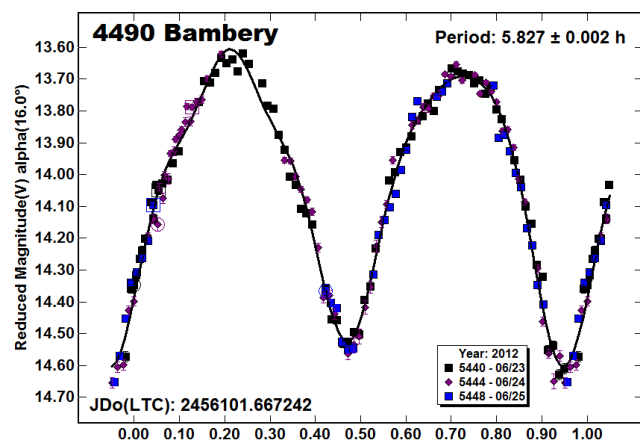
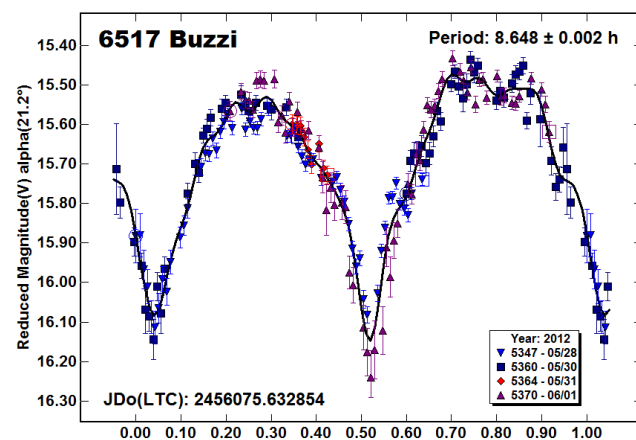
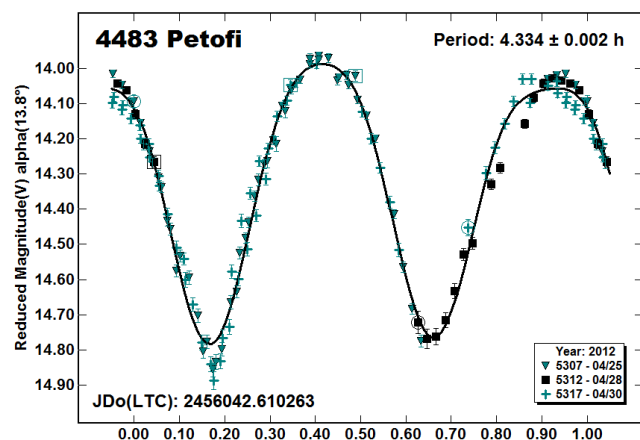
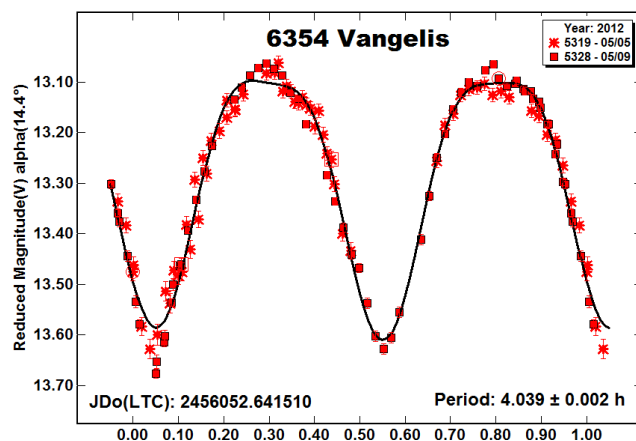
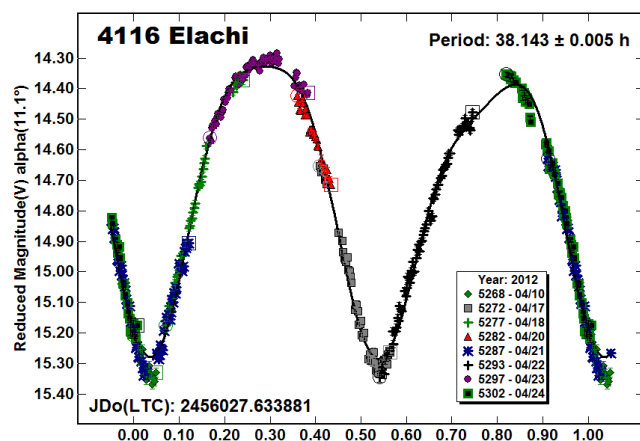
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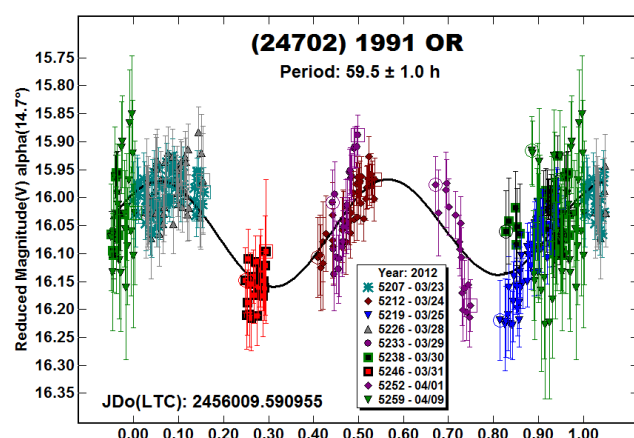
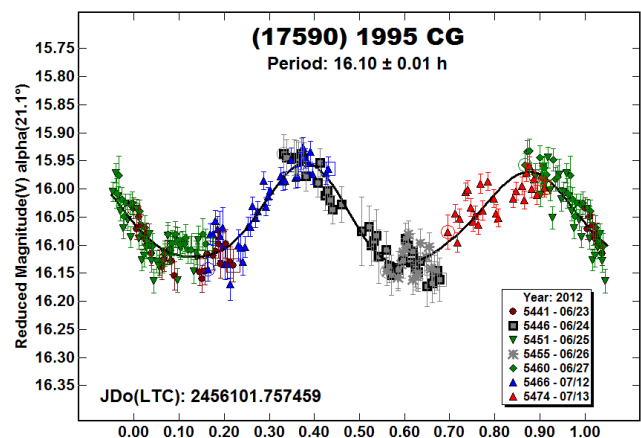
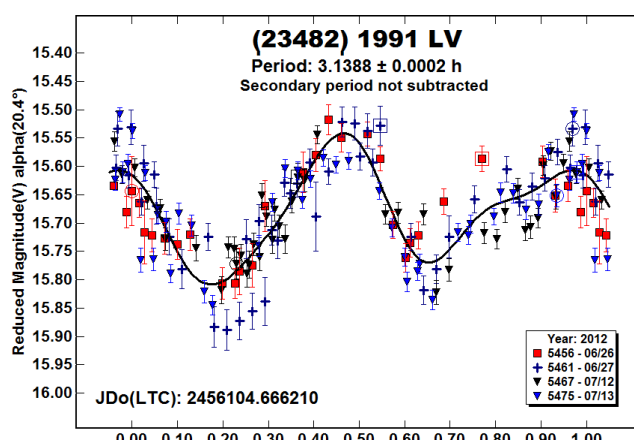
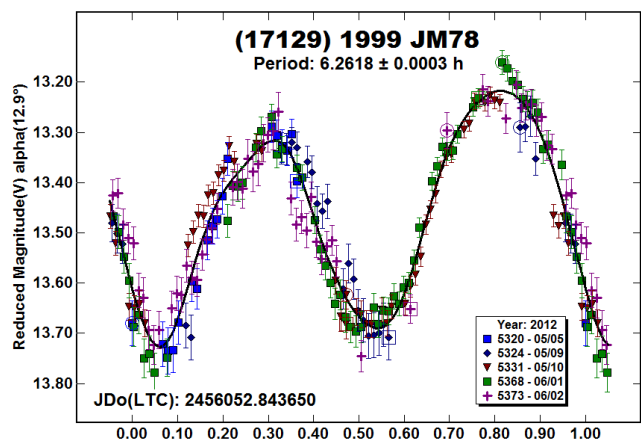
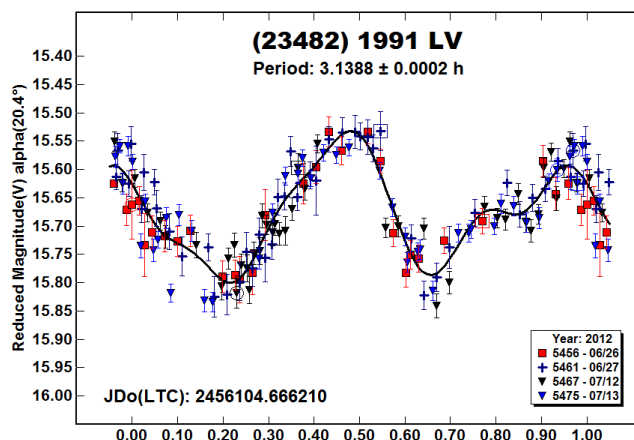
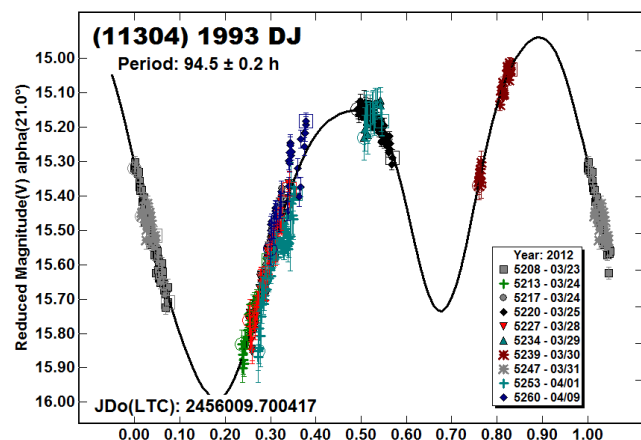
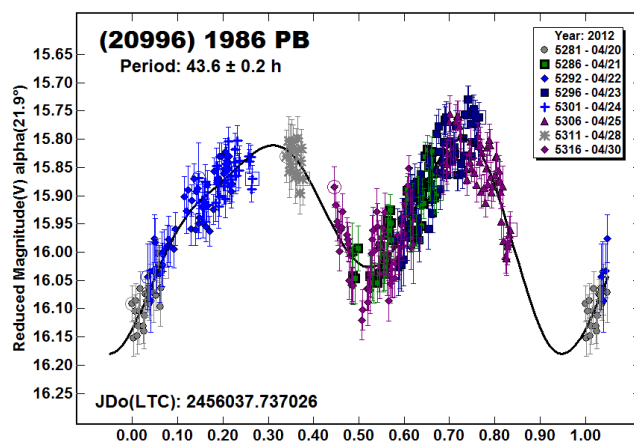
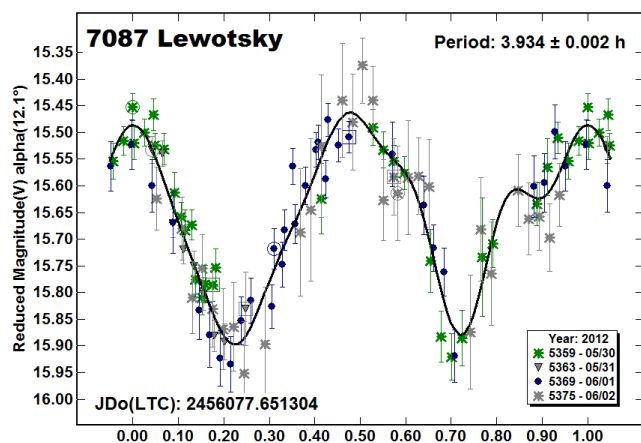
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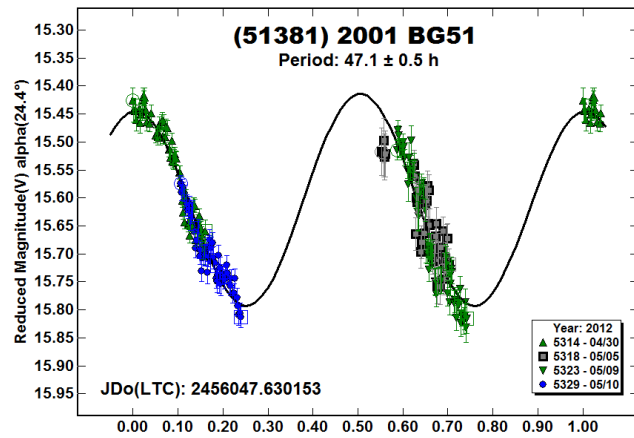
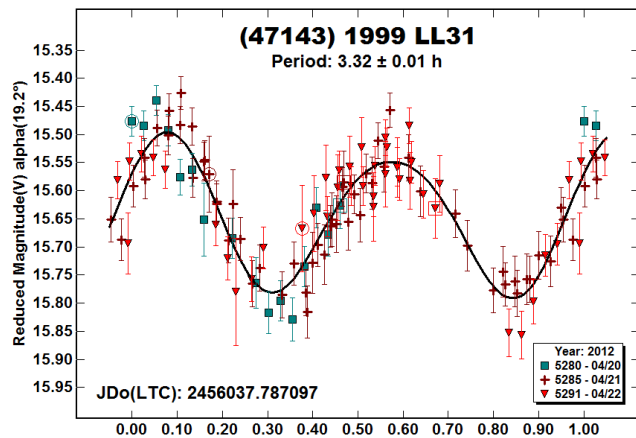
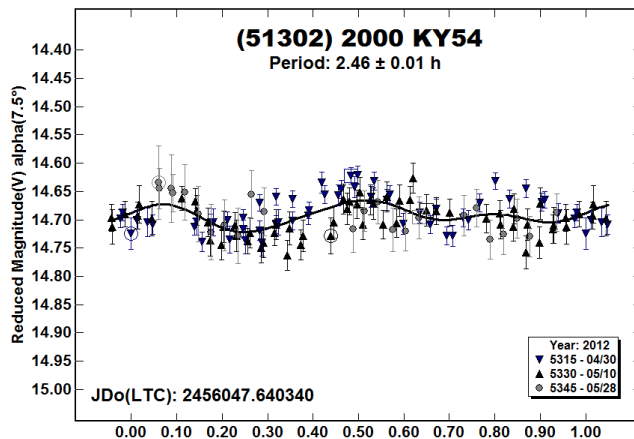
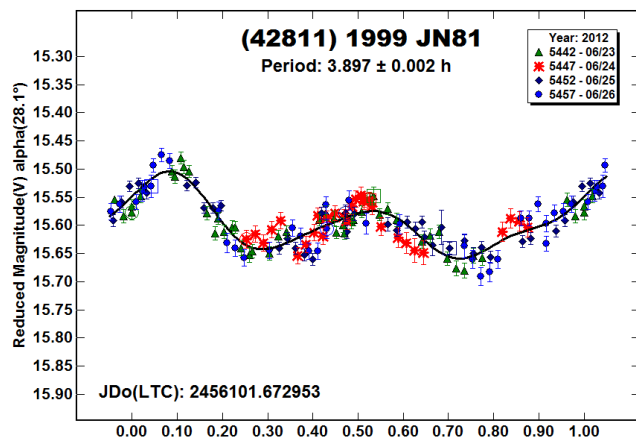
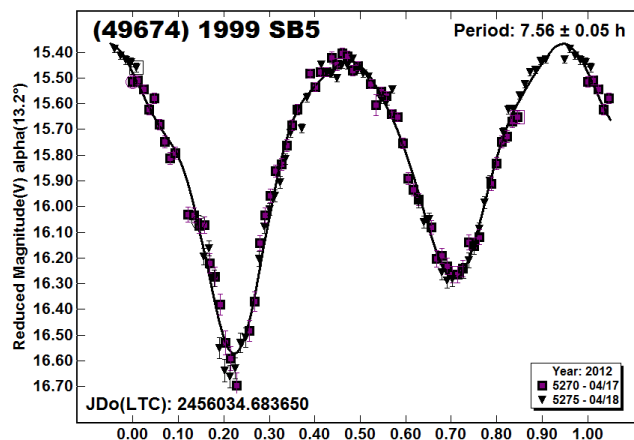
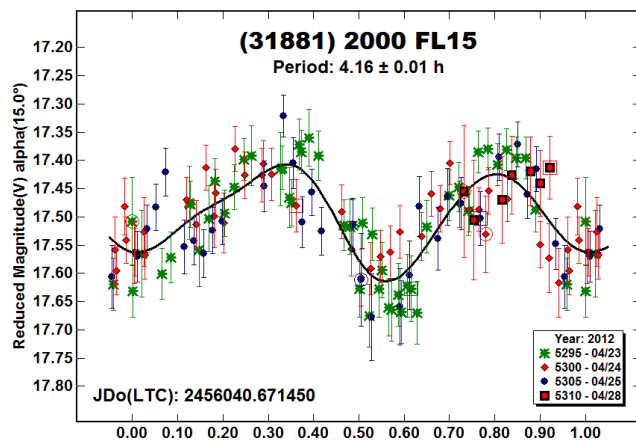
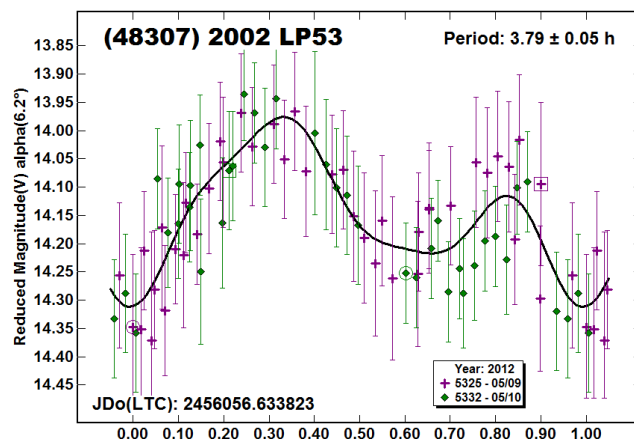
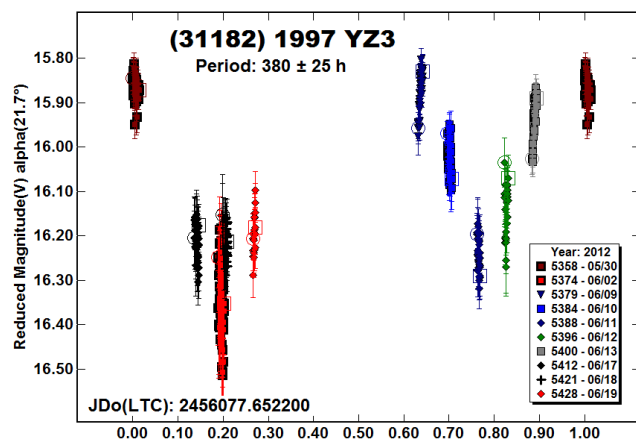
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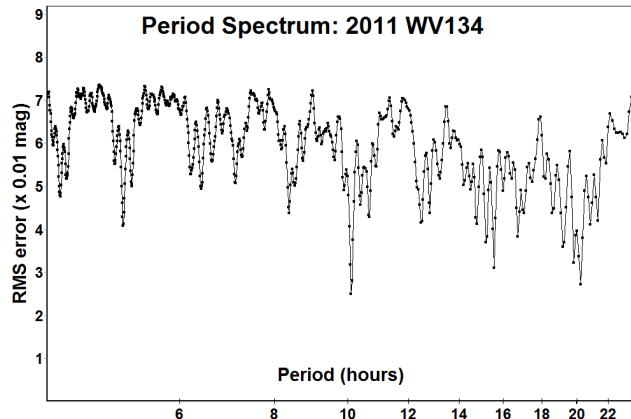
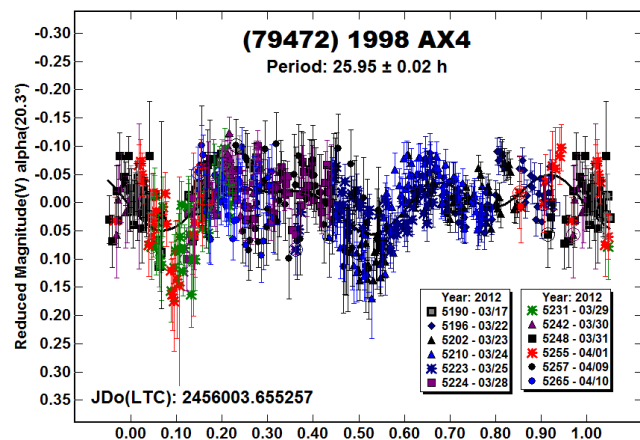
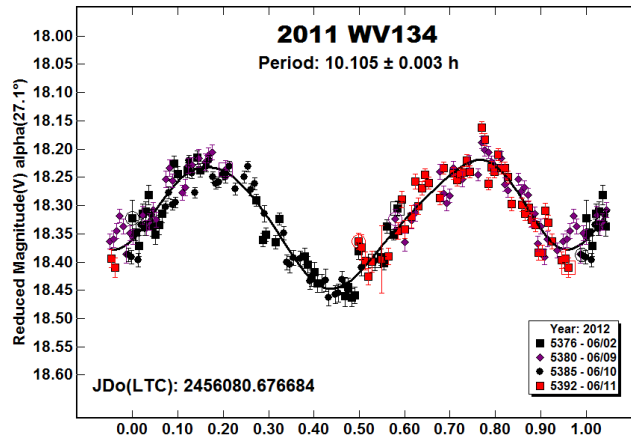
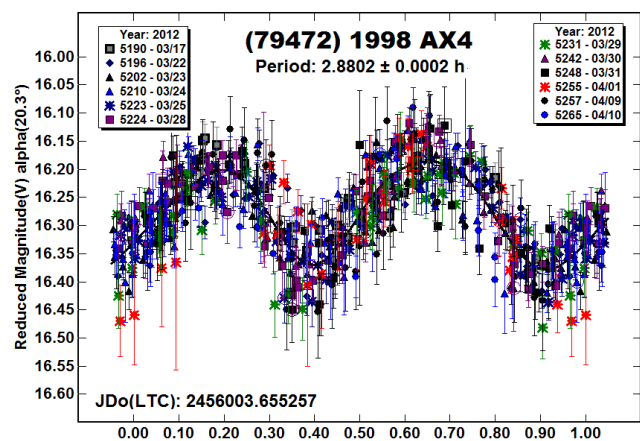
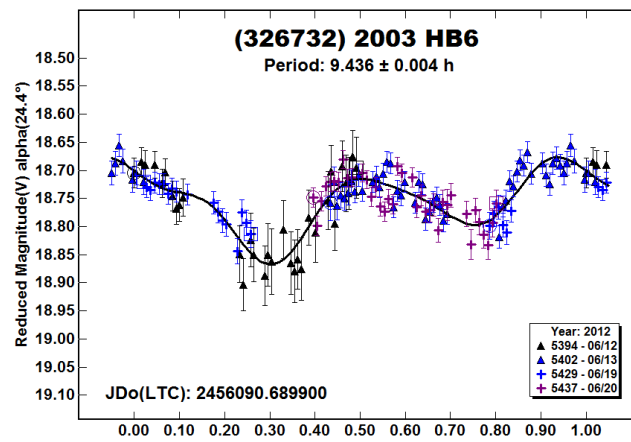
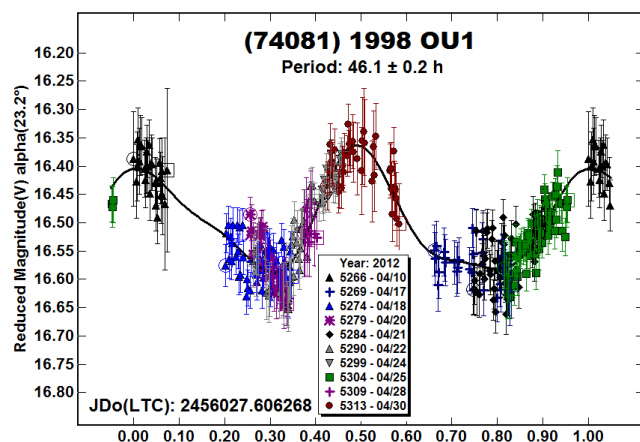
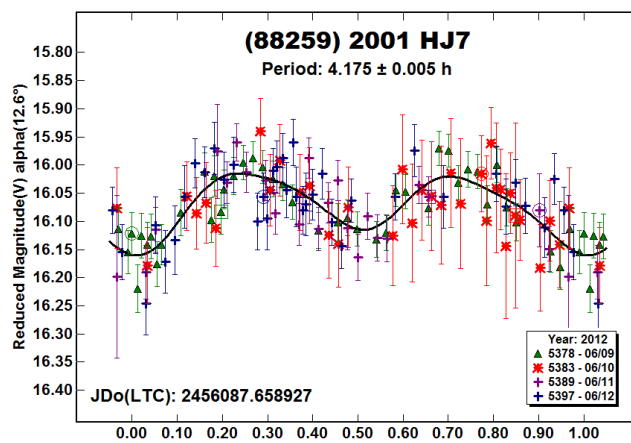
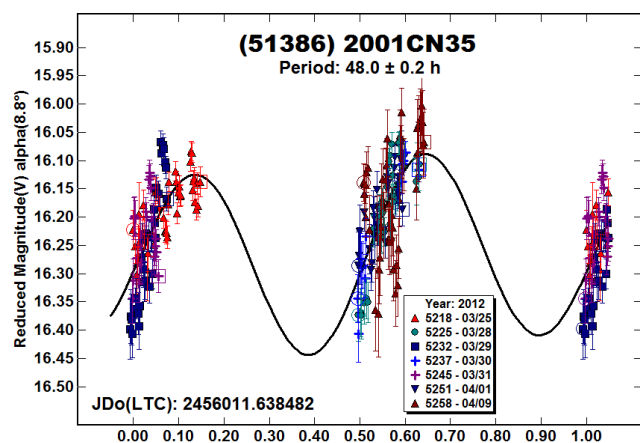
Wisniewski, W.Z. (1991). "Physical studies of small asteroids. I - Lightcurves and taxonomy of 10 asteroids." *Icarus* **90**, 117-122.

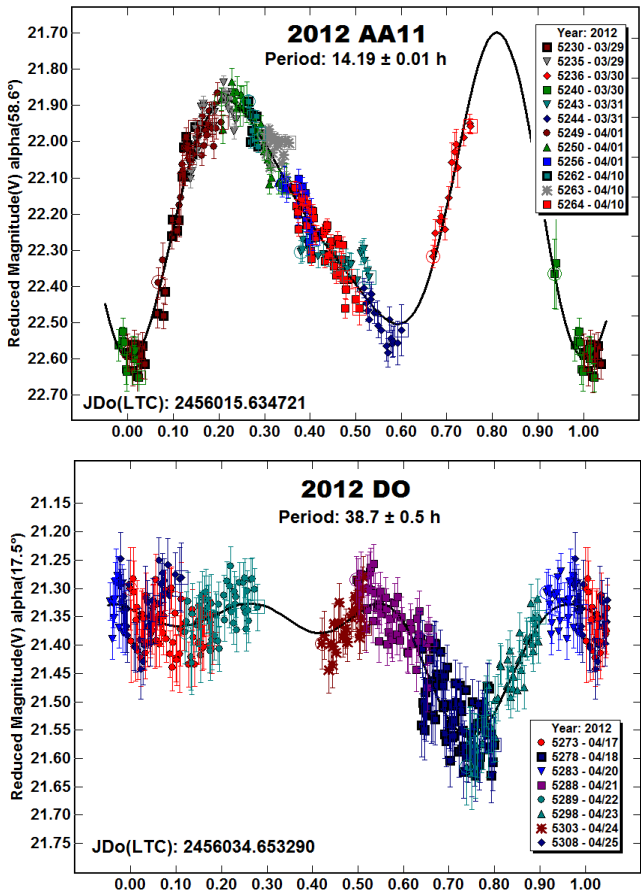












LIGHTCURVE FOR NEA 2012 LZ1

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Analysis of CCD photometric observations of the near-Earth asteroid 2012 LZ1 during a flyby in 2012 June found a synodic rotation period of 12.87 ± 0.01 h and amplitude $A = 0.28 \pm 0.03$ mag. The data are being used to supplement analysis of radar and other optical observations obtained at the time.

The near-Earth asteroid 2012 LZ1 was discovered on 2012 June 11 by Rob McNaught at Siding Spring Observatory in Australia. Three days later, it made its closest approach to Earth (about 5.4 million km; roughly 14 times the lunar distance). Sky motion at that time was too extreme for useful photometry. The authors waited until June 16 to begin photometric observations to determine the rotation period of the asteroid. This information would supplement radar and other optical observations to determine physical characteristics of the asteroid. Table I gives basic observer and equipment information

Observer	Observatory	Equipment
Warner	Palmer Divide	0.35-m SCT, STL-1001E
Sherrod	Arkansas Sky	0.51-m DK, ST-2000 XM
Bacci/Franco	San Marcello	0.60-m Newt, Alta U6
Pollock	PROMPT	0.46-m SCT, Alta U47

Table I. List of observers and equipment.

All images were unfiltered. The data from the several nights at Palmer Divide were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*,