

ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2009 DECEMBER – 2010 MARCH

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Lightcurves for 31 asteroids were obtained at the Palmer Divide Observatory (PDO) from 2009 December through 2010 March: 205 Martha, 379 Huenna, 456 Abnoba, 479 Caprera, 616 Elly, 766 Moguntia, 1069 Planckia, 1364 Safara, 3986 Rozhkovskij, 4764 Joneberhart, 4765 Wasserburg, 4868 Knushevia, 5967 Edithlevy, (6382) 1988 EL, 15786 Clairearmstrong, (18181) 2000 QD34, (19404) 1998 FO5, (31076) 1996 XH1, (33341) 1998 WA5, (33816) 2000 AL42, (36298) 2000 JF10, (41467) 2000 OG29, (43606) 2001 XQ2, (48154) 2001 GT3, (53431) 1999 UQ10, (68547) 2001 XW29, 70030 Margaretmiller, (85839) 1998 YO4, (188077) 2001 XW47, and 2000 CO101. Several of these appear to be in non-principal axis rotation (NPAR). (53431) 1999 UQ10 may have a secondary, additive period of about 38.4 h. Revised results from the 2003 apparition of 70030 Margaretmiller are also reported.

CCD photometric observations of 31 asteroids were made at the Palmer Divide Observatory (PDO) from 2009 December through 2010 March. See the introduction in Warner (2010) for a discussion of equipment, analysis software and methods, and overview of the plot scaling.

The “Reduced Magnitude” in the plots uses R magnitudes corrected to unity distance using $-5 * \log(R_r)$ with R and r being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, i.e., $\alpha(X)$, using $G = 0.15$ unless otherwise stated.

205 Martha. Periods of either 9.7 or 11.9 h have been previously reported for this asteroid (see, e.g., Behrend 2010; Chiorny 2007; Hawkins 2008). The last two reported ambiguous solutions with alternate solutions that matched approximately one of the two periods above. The data obtained at the PDO in 2010 February cannot be fit to either one, and instead fit a period of 39.8 ± 0.1 h.

379 Huenna. This is a known binary system (Marchis 2008) with an orbital period of ~ 2100 h. Even if the satellite were large enough to detect with photometry, the odds of catching an event are extremely small. Harris et al. (1992) reported a period of 7.022 h. The PDO data indicate a period about double that, or 14.14 h.

456 Abnoba. Behrend (2010) reported a period of 18.2026 h based on observations in 2004. The period derived from PDO data revises this value. The Behrend data sets were obtained several months apart, which could result in an incorrect rotational count over the span of observations. The PDO data were obtained over a week, with individual sessions covering a little less than half the derived period.

479 Caprera. Previously reported periods include 9.4277 h (Higgins 2005), 9.425 h (Fauerbach 2005), and 9.376 h (Hawkins

2008). Behrend (2010) reports several periods of approximately 5.25 h. The PDO results give $P = 9.43 \pm 0.02$ h.

616 Elly. This result of 5.297 h agrees with Alvarez (2004).

766 Moguntia. Binzel (1987) found a period of 3.446 h while the PDO data give $P = 4.818$ h. The period spectrum, shown below, strongly favors the longer period.

1364 Safara. This asteroid happened to be in the field of a planned target. It was observed only one night but the data cover a little more than a complete cycle and the amplitude of ~ 0.4 mag allowed eliminating any ambiguous solutions.

3986 Rozhkovskij. Birlan (1996) found a period of 4.26 h. The PDO data yield $P = 3.548$ h, a result clearly favored in the period spectrum.

4764 Joneberhart. The author worked this asteroid in early 2007 (Warner 2007b) and found essentially the same period.

4765 Wasserburg. Earlier work by the author (Warner 2007b) found a period of 3.67 h and amplitude (A) of only 0.04 mag. The amplitude of $A = 0.60$ mag for this work made for a much more reliable result, $P = 3.625$ h. The Phase Angle Bisector longitudes were 70° (2006 December) and 124° (2010 January) or a difference of about 55° . Assuming the asteroid’s pole is near the ecliptic plane (based on the very low amplitude in 2006), one could infer that the longitude of the pole is near 70° or 250° .

4868 Knushevia. When observed by the author in 2008 (Warner 2009), the amplitude of the lightcurve was only 0.09 mag. It was only 0.08 mag for this apparition. The period of 4.54 h is about 0.09 h longer than reported earlier. The data from each apparition cannot be made to fit the period of the other.

5967 Edithlevy. This asteroid is almost certainly in non-principal axis rotation (NPAR). As such, the lightcurve is not the simple addition of two periods but instead is a complex combination of the rotation about the moment of least inertia and the precession of that axis (see Pravec et al. 2005 for a thorough discussion of NPAR and lightcurve analysis). In this case, a period of ~ 66 h dominated the solution but with the given data set it was not possible to find a unique solution for the two periods.

(6382) 1988 EL. This is the third time this asteroid has been worked at PDO (Warner, 2005; Warner, 2007a). The amplitude has always been < 0.10 mag, which makes the prospects for finding a spin and shape axis model less than favorable.

15967 Clairearmstrong. The period of 5.897 h agrees with that found by Brinsfield (2010), who observed the asteroid in early 2009 December. He reported an amplitude of 0.33 mag ($\alpha \sim 10.4^\circ$). By early 2010 January ($\alpha \sim 16^\circ$), the amplitude had increased to 0.41 mag.

(19404) 1998 FO5. A half-period search lead to the solution of $P = 10.6 \pm 0.2$ h.

(31076) 1996 XH1. This is a slow rotator, with $P \sim 350$ h or ~ 700 h. The lightcurve has been fit to 700 h, giving a bimodal solution. However, with $A \sim 0.20$ mag, a monomodal solution (and the half period) cannot be formally excluded.

(33816) 2000 AL242. The lightcurve is fit to a period of 193 h. However, a period of ~ 390 h cannot be formally excluded.

(36298) 2000 JF10. This asteroid shows good indications that it is tumbling but not as dramatically as 5967 Edithlevy. The period given in the plot and table (82 h) is the one that dominated the single period search.

(41467) 2000 OG29. This object was observed only one night, when it happened to be in the same field as a program asteroid. There are several possible solutions. The lightcurve is fit to a period of 6.8 h. However, periods of 10.0 h and 14.5 h cannot be formally excluded.

(43606) 2001 XQ2. This asteroid also shows signs of tumbling (NPAR). The period of 87 h is the one that dominated the single period search.

(53431) 1999 UQ10. The data for this asteroid can be best fit by using two additive periods, $P1 = 2.650$ h and $P2 = 38.4$ h. Plots for each, subtracting out the other period, are included below. Given the noisy data, it is not possible to say with certainty that the two periods are real. On the *presumption* that the two periods do exist, a possible explanation would be a binary system. However, the evidence is too weak to raise more than speculation about the true nature of the system. Future observers should keep the possibility of dual periods in mind but remain highly skeptical.

(68547) 2001 XW29. While the period spectrum strongly favors a period of 36.7 h, there are indications that the asteroid is tumbling, at least to a small degree. The tumbling damping time (see Pravec et al. 2005) for a 37 period is ~ 1.6 Gyr, making it somewhat likely for the asteroid to be in an NPAR state.

70030 Margaretmiller. Images from 2003 were re-measured using the latest version of *MPO Canopus* software to verify a period of 3.98 h (Warner, 2005). Despite data with low SNR, the new analysis gave $P = 4.35$ h. The asteroid was observed in 2010 February with much higher SNR and a result of $P = 4.329$ h, confirming the revised period.

(85839) 1998 YO4. The amplitude of every data session was < 0.05 mag and the sessions showed no long-term variation. The period spectrum was as flat as the lightcurve shown below. The period to which the data were fit is not shown since it was no better (or worse) than dozens of others.

(188077) 2001 XW47. Based on only three sessions, it appears that this asteroid has a very long period. The plot is fit to $P = 525$ h, which based on the assumption that the ~ 0.3 mag amplitude of the session averages would indicate a bimodal solution.

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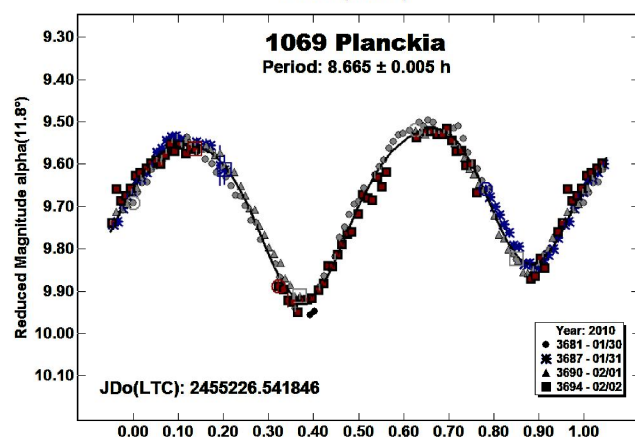
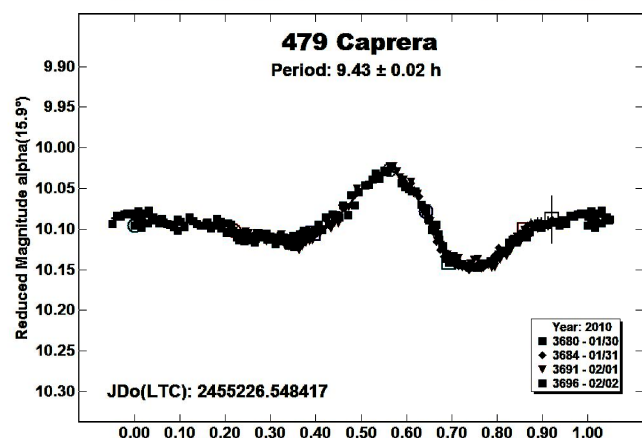
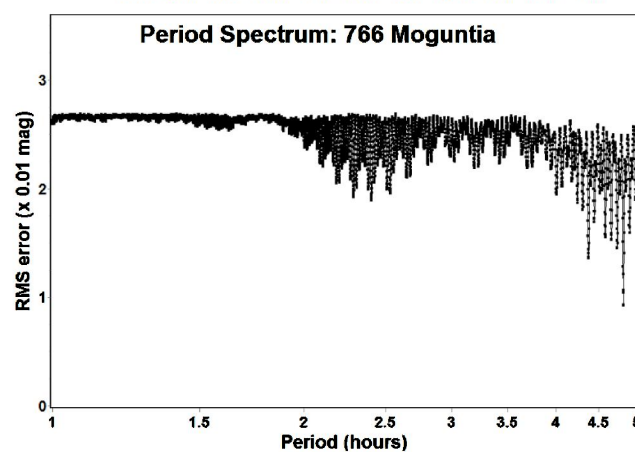
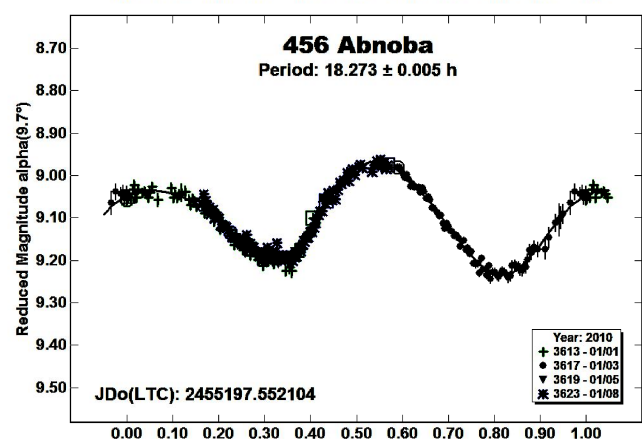
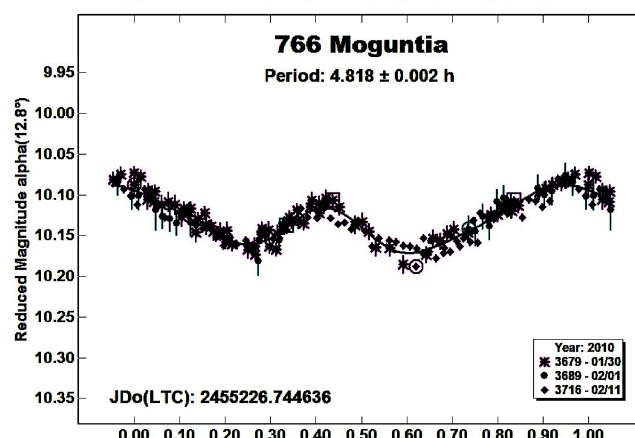
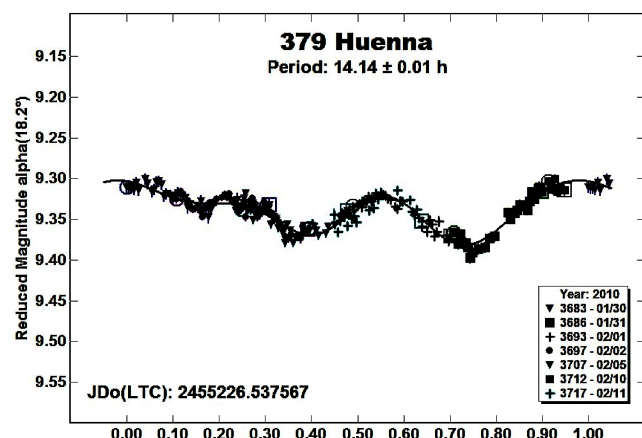
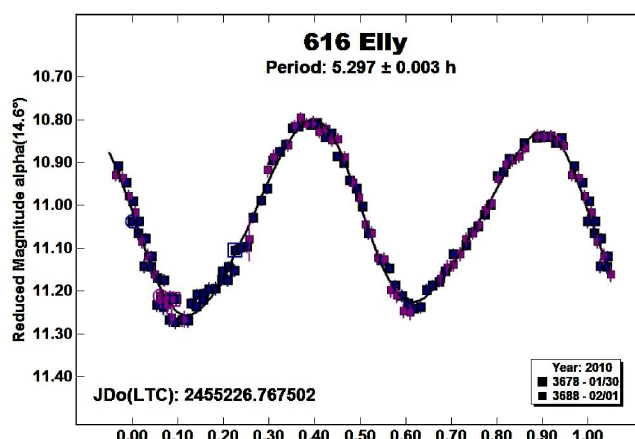
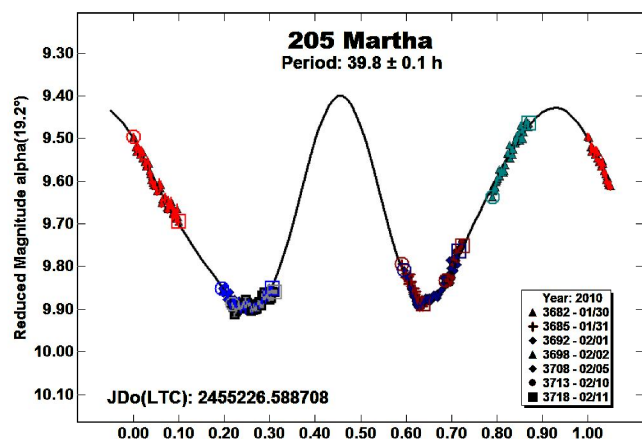
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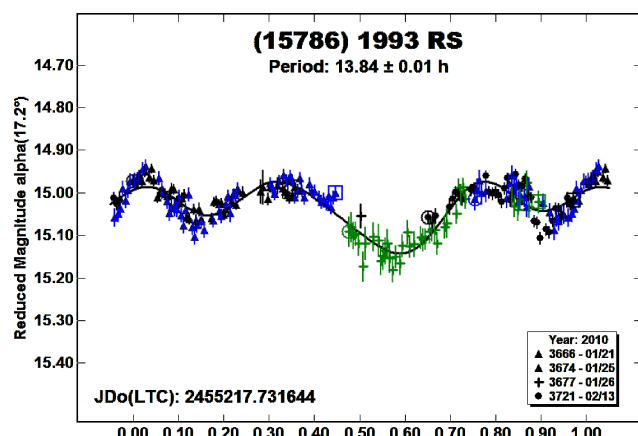
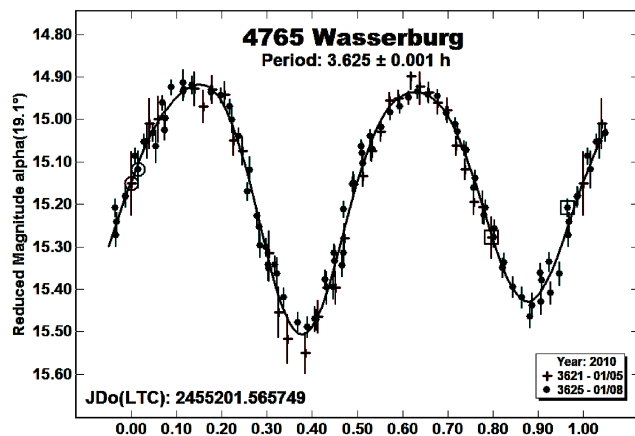
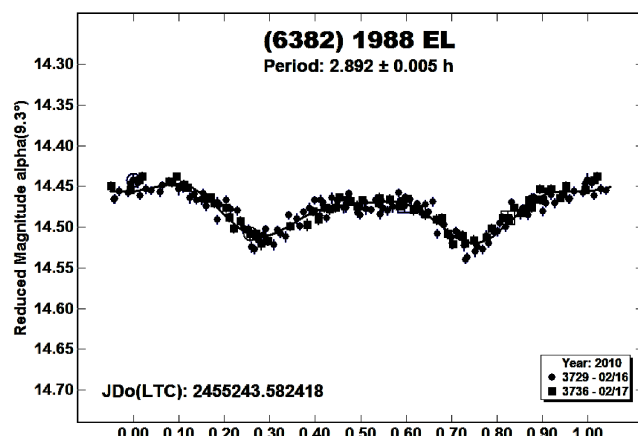
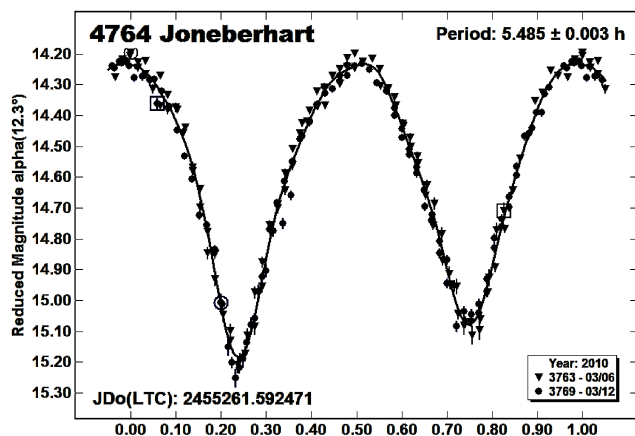
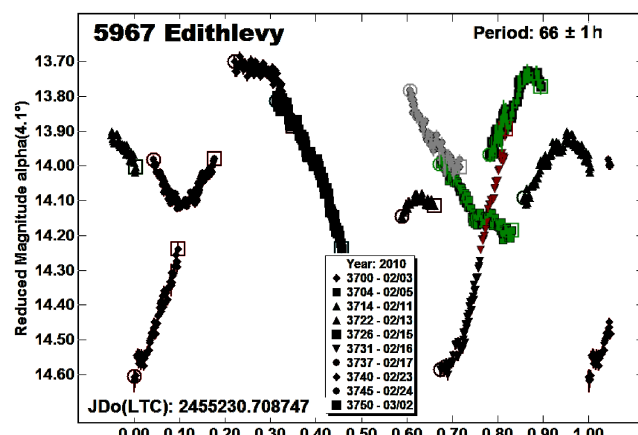
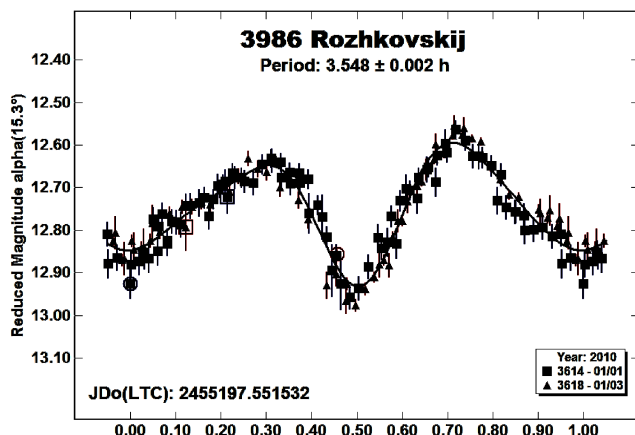
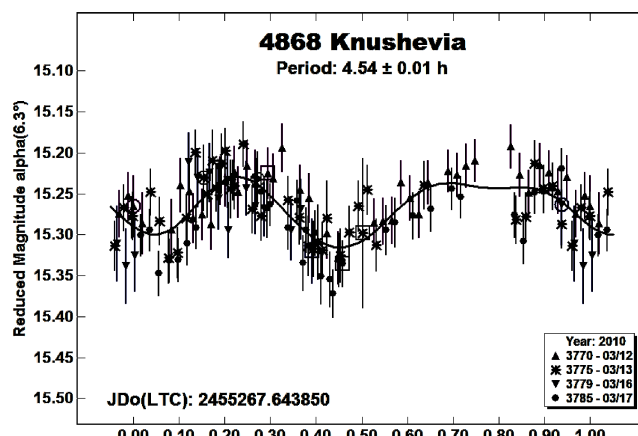
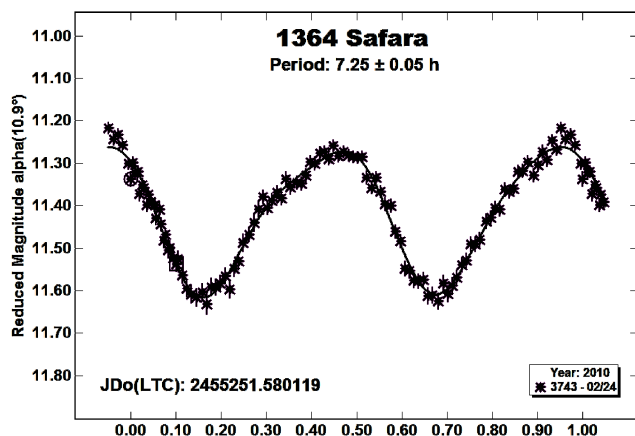
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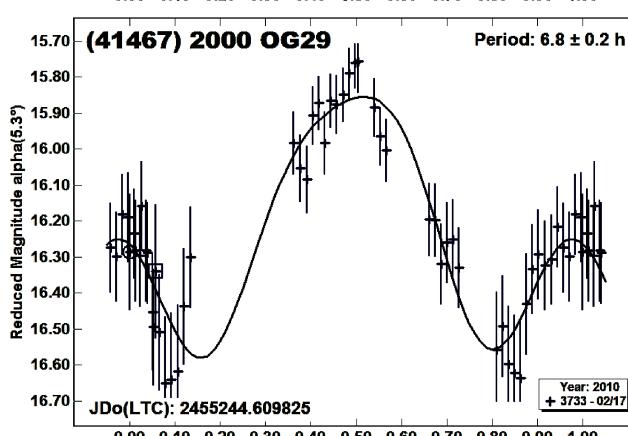
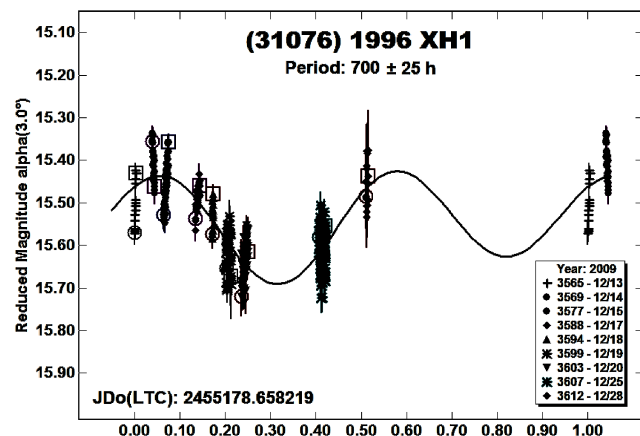
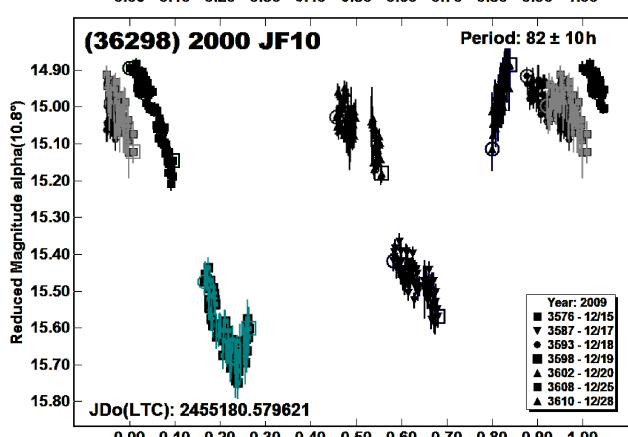
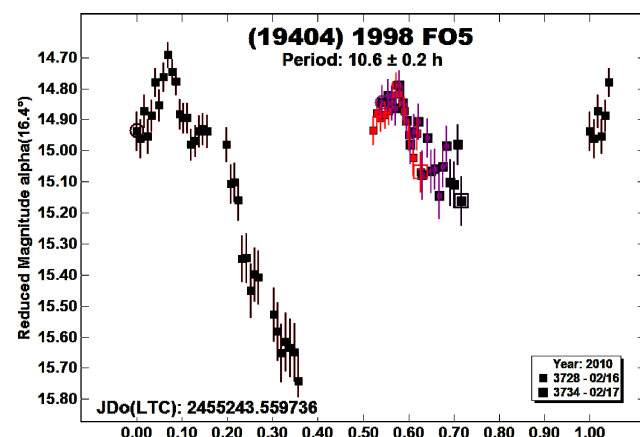
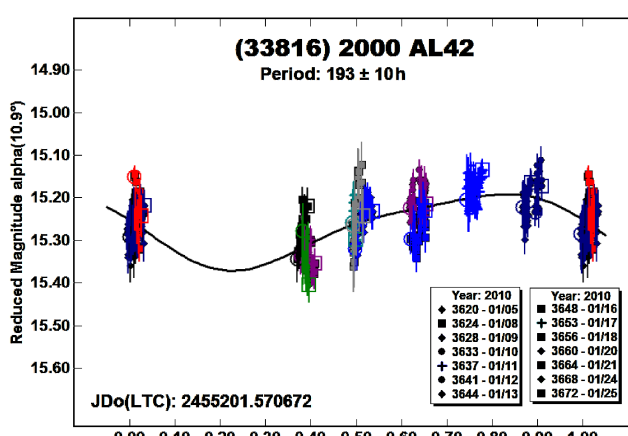
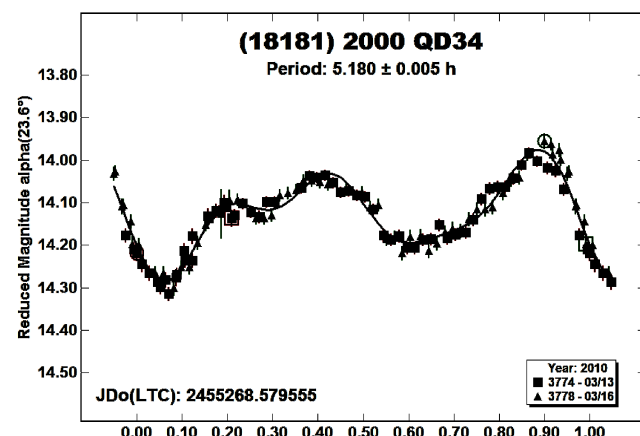
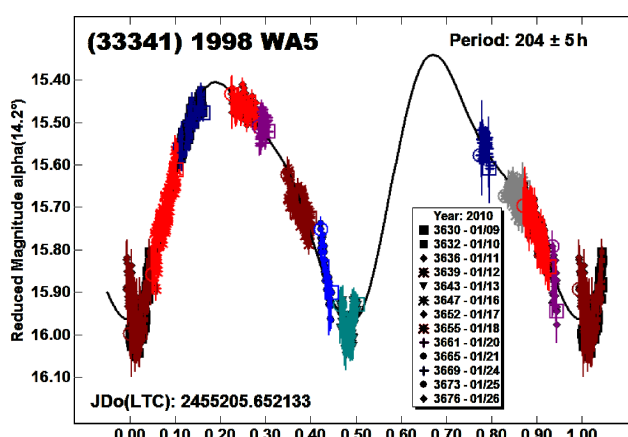
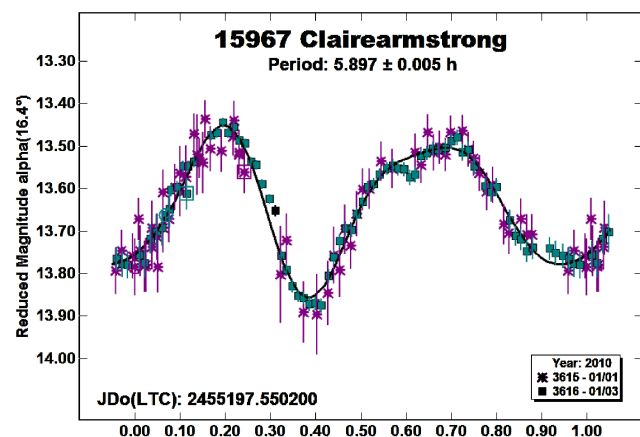
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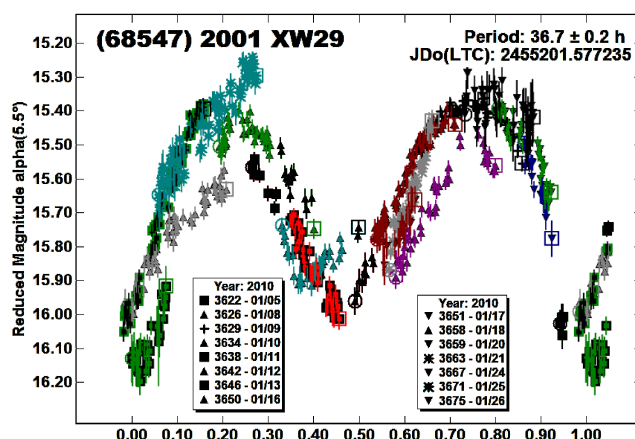
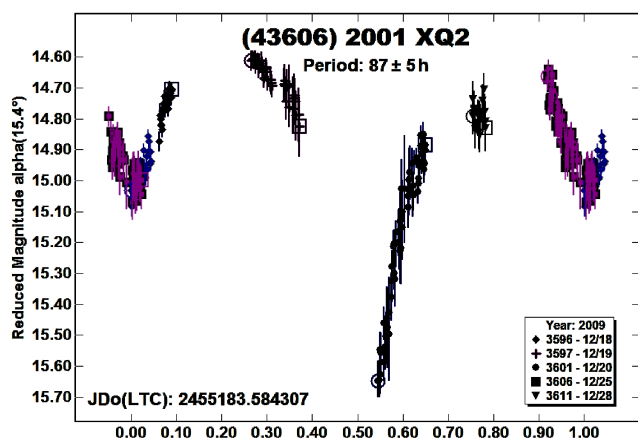
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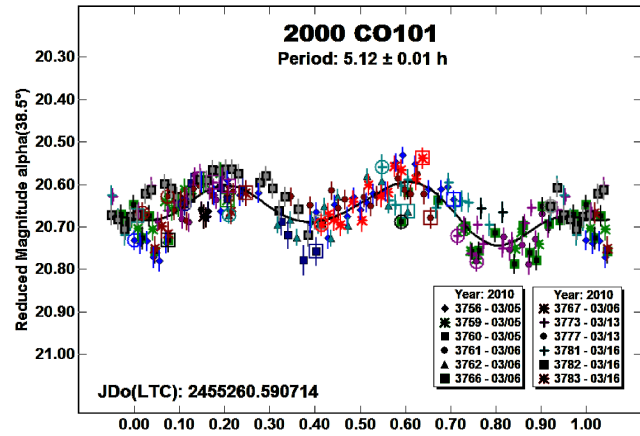
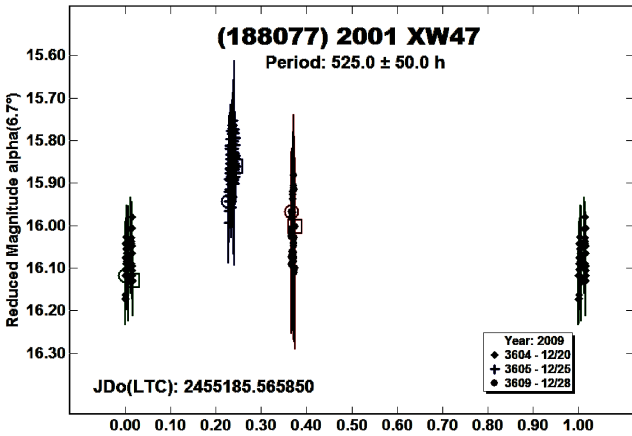
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#	Name	mm/dd 2010	Data Pts	α	L_{PAB}	B_{PAB}	Per (h)	PE	Amp (mag)	AE
205	Martha	01/30-02/11	313	19.0, 20.4	76	-10	39.8	0.1	0.50	0.03
379	Huenna	01/30-02/11	206	18.0, 18.8	80	-2	14.14	0.01	0.07	0.01
456	Abnoba	01/01-01/08	303	9.3, 11.2	74	-9	18.273	0.005	0.27	0.01
479	Caprera	01/30-02/02	266	15.4, 16.4	99	-5	9.43	0.02	0.12	0.01
616	Elly	01/30-02/01	135	15.0, 14.3	162	7	5.297	0.003	0.44	0.02
766	Moguntia	01/30-02/11	173	13.1, 9.4	166	6	4.818	0.002	0.08	0.01
1069	Planckia	01/30-02/02	219	11.4, 12.2	200	-10	8.665	0.005	0.42	0.02
1364	Safara	02/24	106	10.7	126	12	7.25	0.05	0.36	0.02
3986	Rozhkovskij	01/01-01/03	149	14.5, 15.6	78	2	3.548	0.002	0.34	0.02
4764	Joneberhart (H)	03/06-03/12	201	12.2, 13.5	164	20	5.485	0.003	0.96	0.02
4765	Wasserburg (H)	01/05-01/08	118	19.3, 18.8	124	24	3.625	0.001	0.60	0.02
4868	Knushevia (H)	03/12-03/17	134	6.3, 6.6	171	-9	4.54	0.01	0.08	0.01
5967	Edithlevy (H)	02/03-03/02	753	3.9, 18.5	135	9	66 (NPAR)		0.7	0.05
6382	1988 EL (H)	02/16-02/17	170	9.5, 9.3	148	12	2.892	0.005	0.07	0.01
15786	1996 RS (H)	01/21-02/13	241	17.6, 14.6	134	22	13.84	0.01	0.21	0.02
15967	Clairearmstrong	01/01-01/03	137	15.9, 16.6	76	-11	5.897	0.005	0.41	0.02
18181	2000 QD34	03/13-03/16	116	23.5, 24.5	129	5	5.180	0.005	0.32	0.02
19404	1998 FO5	02/16-02/17	76	15.9, 16.2	109	-2	10.6	0.2	0.80	0.05
31076	1996 XH1 (H)	12/13-12/28 ¹	329	3.3, 10.7	84	5	700/350	25	0.17	0.03
33341	1998 WA5 (H)	01/09-01/26	1016	14.4, 13.6, 15.1	121	18	204	5	0.57	0.05
33816	2000 AL42 (H)	01/05-01/25	391	10.3, 19.9	92	-6	193/390	10	0.12	0.01
36298	2000 JF10 (H)	12/15-12/28 ¹	427	10.4, 15.5	76	-11	82 (NPAR)	10	0.75	0.05
41467	2000 OG29	02/17	52	4.9	142	-8	6.8/10.0/14.5	0.2	0.8	0.05
43606	2001 XQ2 (H)	12/18-12/28 ¹	253	15.0, 17.8	74	20	87 (NPAR?)	5	1.3	0.2
48154	2001 GT3	03/17	70	7.7	161	11	5.56	0.05	0.79	0.02
53431	1999 UQ10 (H)	01/12-01/20	335	21.4, 22.9	94	32	2.650 + 38.4	0.002	0.15	0.02
68547	2001 XW29 (H)	01/05-01/26	630	5.5, 15.5	108	-8	36.7 (NPAR)	0.2	0.60	0.05
70030	Margaretmiller (H)	10/05-10/07 ²	157	13.3, 13.2	17	21	4.35	0.01	0.50	0.03
70030	Margaretmiller (H)	02/15-02/16	157	2.1, 2.5	146	-3	4.329	0.005	0.41	0.02
85839	1998 YO4	03/05-03/12	185	16.7, 19.7	158	14	-		<0.05	
188077	2001 XW47 (H)	12/20-12/28 ¹	145	5.7, 11.5	80	1	525	50	0.27	0.03
	2000 CO101	03/05-03/16	222	38.5, 37.2, 37.6	148	12	5.12	0.01	0.10	0.01

¹ 2009 observations
² 2003 observations

Table I. Observing circumstances. Asteroids with "(H)" after the name are members of the Hungaria group. 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. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).