

LIGHTCURVES FOR SHAPE/SPIN MODELS

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We obtained lightcurves of 12 asteroids in 2015 for potential use in shape and spin axis modeling: 855 Newcombia, 929 Algunde, 1730 Marceline, 1967 Menzel, 2074 Shoemaker, 2323 Zverev, 3285 Ruth Wolfe, 3640 Gostin, 3682 Welther, 3873 Roddy, (6823) 1988 ED1, and (11424) 1999 LZ24.

In order to obtain an initial model for the shape of an asteroid, it is usually necessary to obtain lightcurves from at least 3 or 4 oppositions with different phase angle bisector longitudes (see Harris *et al.*, 1984). For main-belt asteroids, this usually means observations from several successive oppositions. In the last article in each *Minor Planet Bulletin*, Warner *et al.* (e.g., 2015) provide a list of possible shape/spin candidates. We chose to attempt to obtain lightcurves from their most recent article where the known periods were less than 4 hours. This gave us the chance to obtain at least one complete period cycle per night.

Our observations were obtained with the three Celestron 0.35-m telescopes and SBIG cameras at Etsorn Campus Observatory (Klinglesmith, 2015). The images were processed and calibrated using *MPO Canopus* 10.4.7.6 (Warner, 2015). The exposures were between 180 and 360 seconds through clear filters. The multi-night data sets for each asteroid were combined with the FALC routine (Harris *et al.*, 1989) within *MPO Canopus* to provide synodic periods for each asteroid.

The information about the discovery and names were obtained from the JPL Small Body Database Search Engine (JPL, 2015). The previously obtained periods and phase angle bisector longitudes and latitudes (L_{PAB} and B_{PAB}) were obtained from the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) and listed in Table I along with our results.

855 Newcombia is a main-belt asteroid discovered by S. Belyavskij at Simeis on 1916 Apr 3. An independent discovery was made by M. Wolf at Heidelberg on 1916 Apr 28. It is also known as 1916 ZP. Our results for the period and amplitude are $P = 3.004 \pm 0.001$ h, $A = 0.41$ mag.

929 Algunde is a Flora asteroid discovered by K. Reinmuth at Heidelberg on 1920 Mar 10. It is also known as 1920 GR. Our results for the period and amplitude are $P = 3.310 \pm 0.001$ h, $A = 0.14$ mag.

1730 Marceline is a main-belt asteroid discovered by M. Laugier at Nice on 1936 Oct 17. It is also known as 1936 UA, 1931 RE, 1950 WF, 1952 DR2, 1954 QA, and 1971 JC. Our results for the period and amplitude are $P = 3.837 \pm 0.001$ h, $A = 0.59$ mag.

1967 Menzel is a Flora asteroid discovered by M. Wolf at Heidelberg on 1905 Nov 1. It is also known as A905 VC, 1930 DS, 1965 SF, 1965 VH, 1970 EM, 1973 CE, 1975 UH, and

1975 VE. Our results for the period and amplitude are $P = 2.835 \pm 0.001$ h, $A = 0.29$ mag.

2074 Shoemaker is a Hungaria asteroid discovered by E.F. Helin at Palomar on 1974 Oct 17. It is also known as 1974 UA. Our results for the period and amplitude are $P = 2.534 \pm 0.001$ h, $A = 0.06$ mag.

2323 Zverev is a main-belt asteroid discovered by N. Chernykh on 1976 Sep 24 at Nauchnyj. It is also known as 1976 SF2, 1951 GP, 1960 WK, 1965 SW, and 1965 UF1. Our results for the period and amplitude are $P = 3.923 \pm 0.003$ h, $A = 0.37$ mag.

3285 Ruth Wolfe is a main-belt asteroid discovered by C. Shoemaker and E. Shoemaker on 1983 Nov 5 at Palomar. It is also known as 1983 VW1, 1952 BR, 1979 VP1, and 1979 YR1. Our results for the period and amplitude are $P = 3.939 \pm 0.001$ h, $A = 0.20$ mag.

3640 Gostin is a Flora asteroid discovered by C. Shoemaker and E. Shoemaker on 1985 Oct 11. It is also known as 1985 TR3, 1955 SS, 1960 CB, 1970 CS, and 1972 VJ1. Our results for the period and amplitude are $P = 3.263 \pm 0.003$ h, $A = 0.27$ mag.

3682 Welther is a main-belt asteroid discovered by K. Reinmuth at Heidelberg on 1923 Jul 12. It is also known as A923 NB, 1951 YO, 1978 NP3, and 1984 AA. Our results for the period and amplitude are $P = 3.599 \pm 0.003$ h and $A = 0.37$ mag.

3873 Roddy is a main belt asteroid discovered by C. Shoemaker at Palomar on 1984 Nov 21. It is also known as 1984 WB and 1953 XK1. Our results for the period and amplitude are $P = 2.479 \pm 0.001$ h, $A = 0.08$ mag.

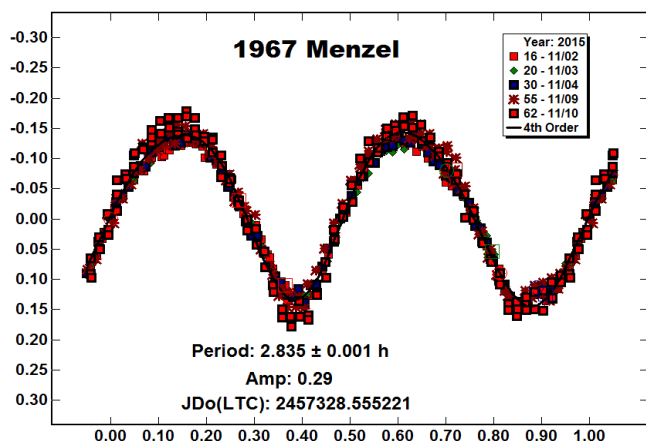
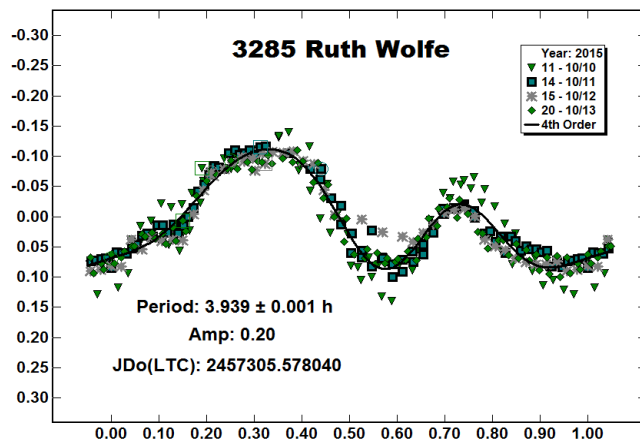
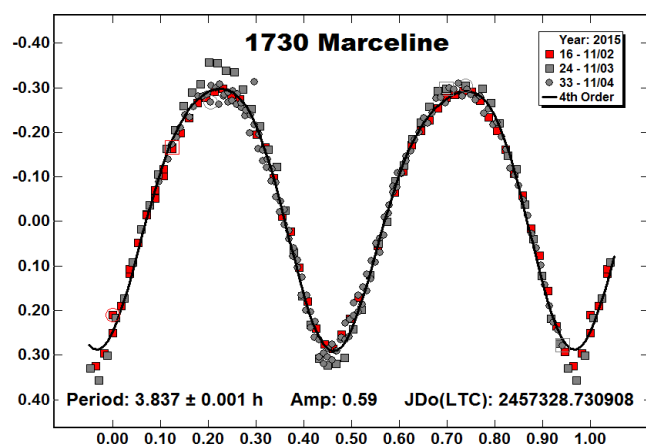
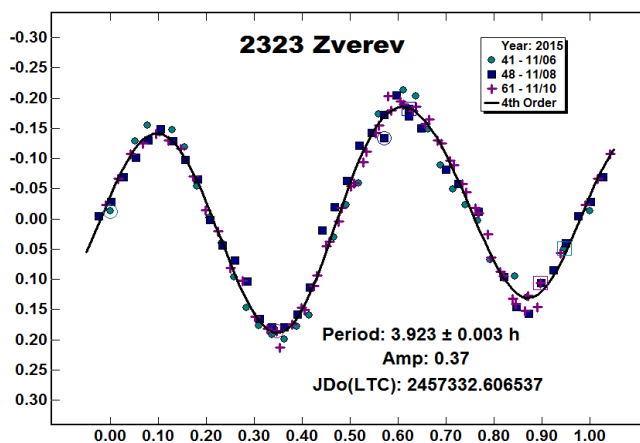
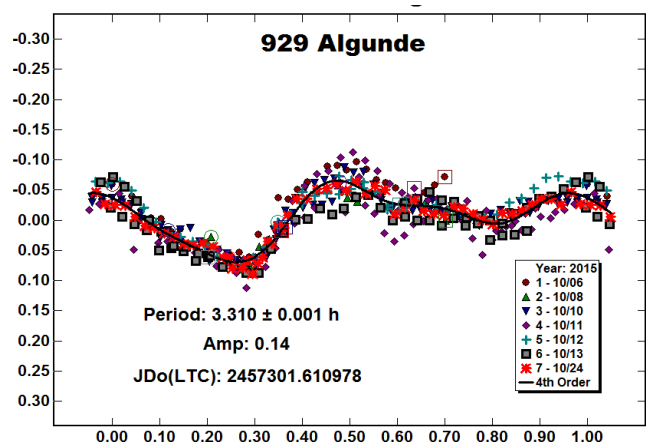
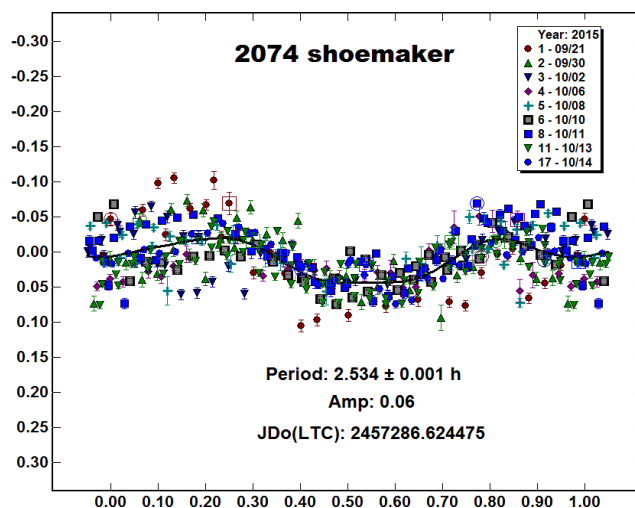
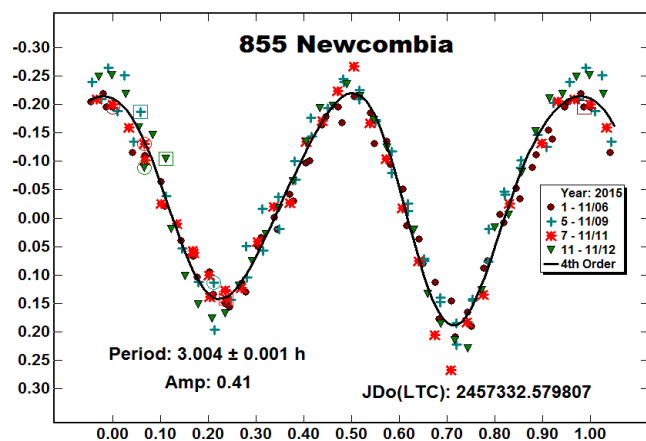
(6823) 1988 ED1 is main-belt asteroid discovered by M. Arai and H. Mori at Yorii on 1988 Mar 12. Our results for the period and amplitude are $P = 2.546 \pm 0.001$ h, $A = 0.13$ mag.

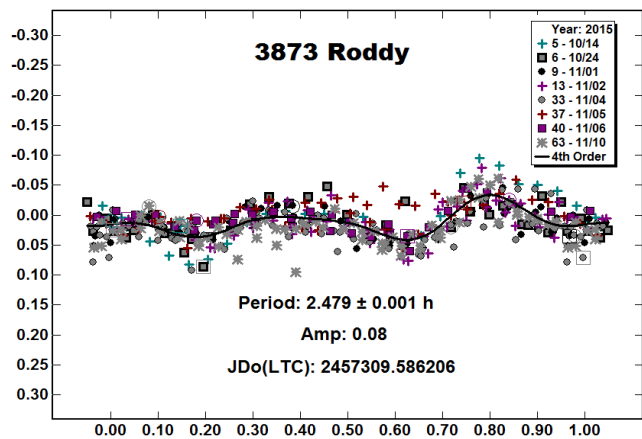
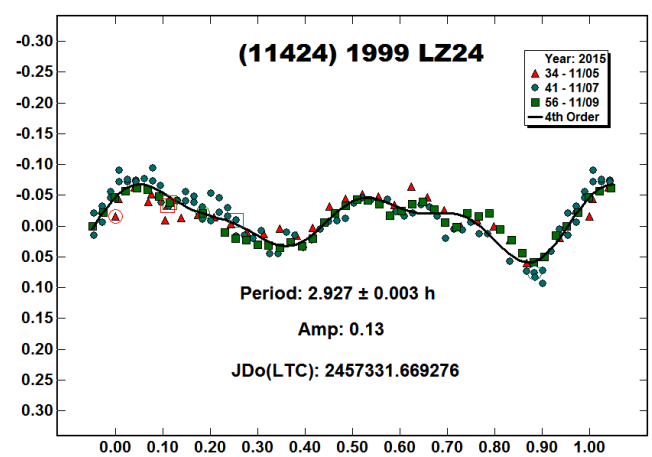
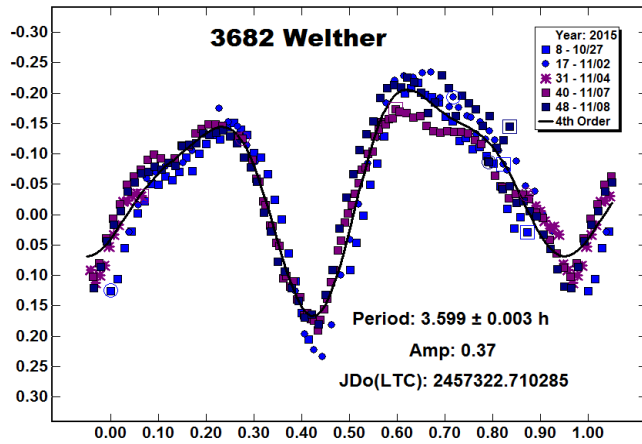
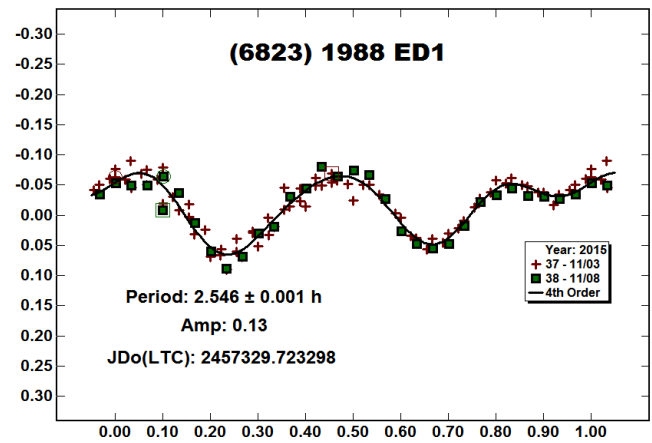
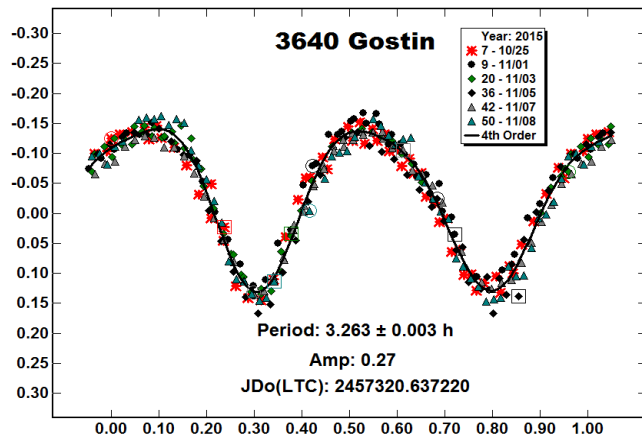
(11424) 1999 LZ24 is a main belt asteroid discovered by LINEAR at Socorro on 1999 Jun 09. It is also known 1955 XJ, 1970 YA, 1991 JH6, and 1998 GM2. Our results for the period and amplitude are $P = 2.927 \pm 0.003$ h, $A = 0.13$ mag.

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Number	Name	Reference	Date	L _{PAB}	B _{PAB}	Phase	Period	Amp
855	Newcombia	Cooney 2007	2004 Oct 14	9.0	-1.4	5.9	3.003	0.35
		Klinglesmith 2014	2014 Apr 01	197.8	1.8	12.9	3.003	0.33
		this paper	2015 Nov 10	20.8	2.3	11.6	3.004	0.41
929	Algunde	Galad 2008b	2008 Mar 18	143.1	-5.0	17.4	3.31016	0.00
		Pravec 2008web	2008 Mar 02	330.9	5.5	13	3.3107	0.02
		Behrend 2008web	2008 Aug 14	331.6	5.6	7.1	6.619	0.19
		Oey 2008e	2008 Aug 01	330.9	5.5	13.5	3.311	0.13
		this paper	2015 Oct 12	16.6	3.0	1.8	3.31	0.14
1730	Marceline	Aymami 2001a	2010 Sep 12	343.6	1.5	3.1	3.837	1.00
		Behrend 2010web	2010 Sep 26	344.2	0.5	10	2.8366	1.00
		Brinsfield 2011a	2010 Sep 03	343.3	2.1	2	3.836	0.94
		this paper	2015 Nov 03	45.7	-10.6	7.7	3.837	0.59
1967	Menzel	<i>Pray et al.</i> 2006	2005 Sep 24	19.4	-4.1	12.6	2.835	0.28
		<i>LeCrone et al.</i> 2006	2005 Nov 02	22.5	-2.9	11.6	2.834	0.38
		<i>Pravec et al.</i> 2007	2007 Apr 10	194.7	3.5	3.1	2.8344	0.24
		Higgins 2008	2007 Apr 10	194.7	3.5	3.1	2.8346	0.25
		Behrend 2005	2005 Oct 27	194.7	3.5	3.1	2.83481	0.27
		<i>Pravec et al.</i> 2010	2010 Jan 14	150.7	5.0	18.8	2.8343	0.27
		Clark 2015	2014 Jun 14	230.3	0.0	15.2	2.8346	0.25
		Liu 2016	2015 Oct 11	18.1	-3.8	2.7	2.84	0.39
		this paper	2015 Nov 05	20.2	-2.9	13.5	2.835	0.29
2074	Shoemaker	Warner 2009	2009 Oct 18	22.0	4.4	4.2	2.5328	0.06
		Warner 2011b	2010 Jul 24	312.1	43.4	28.3	2.5338	0.12
		Warner 2012	2012 Apr 05	219.7	3.7	16.2	2.82	0.08
		Warner 2016	2015 Jun 25	341.7	32.6	34.5	2.809	0.13
		this paper	2015 Oct 08	3.5	18.1	16.8	2.534	0.06
2323	Zverev	Behrend 2006	2006 Jan 08	140.5	4.5	13.4	3.9213	0.39
		Behrend 2011	2011 Jan 01	74.1	5.6	11.2	3.92114	0.36
		<i>Waszczak et al.</i> 2015	2011 Jan 13	74.8	5.5	15.9	3.9215	0.38
		this paper	2015 Nov 08	18.1	1.7	10.1	3.923	0.37
3285	Ruth Wolfe	Warner 2003	1999 Nov 03	41.2	13.6	8.8	6.722	0.21
		Warner 2005	1999 Nov 04	41.2	13.4	8.7	3.94	0.20
		Hummel <i>et al.</i> 2008	2007 Nov 02	32.9	16.2	11.1	3.919	0.20
		Warner 2011c	1999 Nov 04	41.2	13.4	8.7	3.937	0.20
		this paper	2015 Oct 10	25.1	21.1	14	3.939	0.20
3640	Gostin	<i>Albers et al.</i> 2010	2010 Mar 10	165.5	-5.2	4.1	3.2641	0.40
		<i>Chang et al.</i> 2014	2013 Feb 16	112.6	-1.3	19.6	3.26	0.47
		<i>Waszczak et al.</i> 2015	2013 Feb 11	119.9	-1.2	17.6	3.2632	0.37
		this paper	2015 Nov 05	47.0	5.6	4.7	3.263	0.27

Table 1, part 1: Previously published phase angle bisectors, synodic periods, and amplitudes from the Lightcurve Data Base (LCDB, Warner, 2015) plus results from this paper

Number	Name	Reference	Date	L _{PAB}	B _{PAB}	Phase	Period	Amp
3682	Welther	Stephens <i>et al.</i> 2002	2001 Sep 07	348.2	30.6	14.7	3.5973	0.21
		Behrend 2001	2001 Aug 25	345.0	20.2	16	3.603	0.33
		Stephens <i>et al.</i> 2002	2001 Oct 03	350.7	19.8	18.3		0.26
		Stephens <i>et al.</i> 2002	2001 Oct 06	351.3	19.6	19.3		0.28
		Stephens <i>et al.</i> 2002	2001 Oct 12	352.7	19.0	21		0.31
		Behrend 2001	2001 Oct 13	352.7	19.0	21.3	3.595	0.28
		Behrend 2010	2010 Aug 09	310.0	16.5	10.9	3.5973	0.22
		this paper	2015 Nov 04	60.9	7.1	13.3	3.599	0.37
3873	Roddy	Warner 2006	2005 Dec 05	113.3	-17.0	28.7	2.4782	0.09
		Warner 2008	2007 Aug 16	355.9	30.7	22.9	2.4792	0.10
		Warner 2009	2009 Jun 20	251.8	5.0	12.4	2.48	0.06
		Warner 2011d	2010 Nov 29	68.3	1.7	1.7	2.4782	0.05
		Warner 2013	2007 Aug 26	356.7	31.2	21	2.479	0.11
		Warner 2013	2012 Aug 30	11.5	32.4	19.1	2.479	0.08
		Warner 2016	2015 Jul 09	11.5	23.7	28.1	2.486	0.10
		this paper	2015 Nov 02	30.5	20.5	14.5	2.479	0.08
6823	1988 ED1	Stephens 2008	2007 dec 28	91.8	2.5	2.6	2.541	0.1
		Behrend 2011	2008 Jan 12	92.3	4.3	10.3	2.598	0.3
		Durkee 2012	2011 Dec 10	74.2	-4.8	3.3	2.546	0.19
		Waszczak <i>et al.</i> 2015	2013 Mar 12	200.6	19.5	13.7	2.546	0.19
		this paper	2015 Nov 05	54.6	-14.0	11.9	2.546	0.14
11424	1999 LZ24	Warner 2001	2000 Nov 25	60.0	-2.1	2.3	2.928	0.11
		Warner 2011b	2000 Nov 25	60.0	-2.1	2.3	2.925	0.08
		Waszczak <i>et al.</i> 2015	2013 Aug 24	198.3	7.9	13.8	2.9275	0.10
		this paper	2015 Nov 07	58.8	-4.3	9.7	2.927	0.13

Table 1, part 2: Previously published phase angle bisectors, synodic periods, and amplitudes from the Lightcurve Data Base (LCDB, Warner, 2015) plus results from this paper.