LIGHTCURVE ANALYSIS OF ASTEROIDS FROM BLUE MOUNTAINS OBSERVATORY IN 2013

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Analysis of CCD photometric observations made in 2013 from Kingsgrove Observatory and Blue Mountains Observatory found the synodic rotation period for 30 asteroids.

Leura Observatory has undergone a reconstruction and an extension to accommodate additional telescopes. When it is in full operation, there will be five telescopes of assorted sizes and configurations, all of which will be dedicated to asteroid photometry and astrometry. They are: a 0.12-m refractor for wide field and NEA asteroid photometry, a 0.30-m reflector, a 0.35-m reflector for general photometry and astrometry, a 0.25-m or 0.35-m wide-field telescope for photometry, and a 0.61-m reflector. The objective will be full automation for research and education in astronomy, concentrating on minor planet work. To commemorate the observatory transformation, Leura has been renamed Blue Mountains Observatory with a new MPC code of Q68.

The instrument configurations used at Kingsgrove and Blue Mountains Observatory (BMO) for this work are given in Table I. At Kingsgrove, all exposures were 300 s and unfiltered, with the exception of 357 Ninina where an R filter was also used. Asteroid selection was mainly from the CALL website (Warner, 2013) with the selection criteria being an average magnitude during closest approach of V = 13-15 and a southerly declination facilitating maximum nightly observations due to local geographical restrictions. The telescopes in Blue Mountains Observatory were used mainly on fainter targets selected from Photometric Survey for Asynchronous Binary Asteroid (PSABA) for follow up and detection work coordinated by Pravec (2013).

MPO Canopus v.10.2.0.1 software, which incorporates the Fourier algorithm developed by Harris (Harris *et al.*, 1989), was used for period analysis. All lightcurve data were linked internally using the "Derived Mags" algorithm and the Comp Star Selector feature in *MPO Canopus* (see Stephens, 2008) where 2MASS to BVRI values were used (Warner, 2007). Although a clear filter is used in the observations, R catalog magnitudes were selected in order to match the CCD camera's greater sensitivity at the red end of the visible spectrum. Comparison stars were selected based on a near-solar color index of $0.5 \leq B\text{-}V \leq 0.9$.

357 Ninina was observed by Behrend *et al.* (2013) and found to have a synodic period of 35.98 h with a comment translated from French as "ill defined" amplitude. Observations of this asteroid were done in 2007 at Kingsgrove and in 2013 at BMO. The lightcurve from 2013 was reduced and plotted using the CSS method. The best period found was 36.0105 ± 0.0001 h with some adjustment done to the nightly zero points (the DeltaComp values in *MPO Canopus*). However, without the adjustments it was found to have a scatter of 0.1 magnitude; that is too high to be explained by catalog error alone. Due to the long period nature of this asteroid, such phenomena may be due to the asteroid being in non-principle axis rotation, or *tumbling* (Pravec, 2005). The data for 357 Ninina obtained in 2007 were never published since, without CSS method to link the nightly observations to standard magnitude, the period cannot be determined with confidence. The data were re-measured and a period of 35.9 ± 0.1 h was found, albeit with a low amplitude of 0.12 mag.

2077 Kiangsu has not, as best could be determined, been observed in the past. The sparse data obtained were not sufficient to get a unique solution for its period. One solution obtained was 48 h and this is commensurate with earth rotation period. To identify the correct period will require collaboration from different geographical locations.

6401 Roentgen was observed by Behrend (2013), who derived a period of 15.98 h using observations from only one night. Warner (2014) found the period to be 15.96 h. Analysis of the BMO data found a period of 15.9 h, which is consistent with both observations despite the short duration for each session.

13921 Sgarbini. Observations were done on two nights with the 0.61-m system. From the first night, the lightcurve did not remain on the same zero point throughout, suggesting a longer period lightcurve. The CSS feature in *MPO Canopus* was used but, even so, adjustments of the zero points by up to 0.2 mag were required to get the 7.3681 h period. This result was consistent with observations that were done previously. However, the error for CSS should be less than 0.05 mag. When the period was searched based on no vertical adjustment of the zero points, a longer period of 43 h was found. Pravec (private communication) found that the 43 h period was not unique and it may represent a second period of a two periodic binary component. Further observations of this asteroid are desirable.

Another asteroid with similar photometric behavior as 357 Ninina and 13921 Sgarbini was (43904) 1995 WO. It was a target selected from PSABA (2013). There had been no previous work reported for this asteroid. The short period was found to be 4.5894 h by adjusting the zero point of the lightcurves. Again with the amplitude of only 0.07 mag, this may be the result of a period search that latched on to an incorrect value. Once the period search was done without any zero point adjustments, a 99 h period was found, suggesting a slow rotating asteroid with the possibility non-principle axis rotation. This will be confirmed on future work with better linkages of data.

The long period asteroids (53008) 1998 VY5 and (12854) 1998 HA13 conform very nicely to the phased plots with the exception of the observation on 2013 August 4 for 1998 HA13, where a 0.11 magnitude adjustment was required.

References

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Observatory	Diameter (code)	f/	CCD Camera	Pixels (microns)	Bin	Scale ″/pix
Kingsgrove (E19)	0.25m (10)	11	ST-402ME (SBIG)	9	1x1	1.41
BMO (Q68)	0.35m (14)	6	ST8-XME (SBIG)	9	1x1	0.88
BMO (Q68)	0.61m (24)	6.8	U16M (Apogee)	27	3x3	1.40

Table I. Telescope/camera systems.

#	Name	mm/dd 2013 (*2014)	Scope	Period (h)	PE	Amp (mag)	AE	H	Dia (km)	PA	LPAB	BPAB
357	Ninina	07/24-11/06	10	36.0105	0.0001	0.24	0.05	8.72	99.5	14.7,3.3,17.9	344	-8
1367	Nongoma	04/25-08/09	14	94.8	0.1	0.83	0.05	12.00	12.47	26.9,1.4,9.4	271	-7
1387	Kama	07/28-09/30	14	52.5	0.1	0.57	0.05	13.30	6.85	20.2,5.1,16.2	335	6
1717	Arlon	04/17-06/09	14	5.148	0.001	0.09	0.05	12.20	11.37	4.1,3.7,20.9	212	-6
1830	Pogson	03/09-03/17	14	2.6036	0.0001	0.17	0.1	12.45	10.14	18.1,20.8	137	0
1979	Sakharov	02/06-02/08	14	7.5891	0.0001	0.22	0.02	13.60	5.97	5.4,4.7	144	-7
2055	Dvorak	07/24-07/27	24	4.4106	0.0001	0.17	0.01	12.60	9.46	16.9	294	-23
2077	Kiangsu	11/12-12/10	10,14	47.8	0.1	0.5	0.1	13.60	4.74	18.8,25.8	41,45	-21,-9
2897	Ole Romer	04/12-04/14	14	2.6024	0.0001	0.12	0.02	13.20	7.18	17.0,17.9	174	5
3060	Delcano	08/08-09/11	24	2.8027	0.0001	0.18	0.01	13.00	7.87	17.7,2.5,3.7	342	2
3951	Zichichi	10/11-11/07	14	3.4120	0.0001	0.35	0.05	12.60	9.46	8.5,	6	7
4905	Hiromi	09/29	24	5.62	0.01	0.40	0.01	12.10	11.91	10.4	23	0
6265	1985 TW3	04/12-05/19	14	2.70933	0.00001	0.27	0.05	13.40	6.54	7.8,0.5,12.3	216	1
6401	Roentgen	07/28-08/05	14	11.99	0.01	0.35	0.05	12.70	9.03	23.7, 24.5	248	13
10484	Hecht	04/01	14	2.5788	0.0001	0.17	0.01	13.8	5.44	4.8	185	-7.1
11901	1991 PV11	06/07-07/02	14	9.3759	0.0001	0.59	0.02	13.6	5.97	12.0, 17.8	254	17
12854	1998 HA13	07/26-08/08	24	50.59	0.01	0.34	0.05	14.9	3.28	11,7.7	314	9
13921	Sgarbini	12/02-01/05*	14,24	7.3681	0.0001	0.10	0.02	14.5	3.94	9, 22	67	12
13921	Sgarbini	12/02-01/05*	14,24	43.4	0.1	0.28	0.1					
26636	2000 HX57	04/06-04/07	14	4.2744	0.0001	0.25	0.02	12.9	8.24	5.6	197	11
26984	Fernand-Roland	08/08	24	20	1	0.30	0.01	12.20	20.04	5.7	310	14
29818	1999CM 117	05/01	14	14	1	0.41	0.02	14.5	3.94	2.5	216	0.6
34706	2001 OP83	04/06-04/18	14	2.5949	0.0001	0.15	0.05	14.8	3.43	7.3,9.3	197	10
43904	1995 WO	07/26-08/16	24	98	1	0.26	0.05	15.0	3.13	11.0,12.8	310	12
49636	1999 HJ1	07/28-08/10	24	2.8208	0.0001	0.26	0.05	13.9	5.2	33.9,35.2	258	28
53008	1998 VY5	12/06-01/03*	14	44.6	0.1	0.25	0.03	13.5	6.25	11.2 21.7	62.5 66.7	-13.4 -9.3
67747	2000 UF43	07/08	24	3.111	0.001	0.26	0.02	15.7	2.27	16.8	259	4.1
99942	Apophis	01/07-02/13	14	30.528	0.001	1.0	0.1	19.2	0.45	53.2 31.5 44.5	129 123 124	-22.2 -18.4 -12.2
163364	2002 OD20	06/17-06/19	24	2.4201	0.0001	0.11	0.01	18.8	0.55	20	253	1
285263	1998 QE2	05/20-0604	14	2.726	0.001	0.11	0.02	17.3	1.09	68.7 17.2 18.0	211 248	-27.4 8

Table II. Observing circumstances and analysis results.

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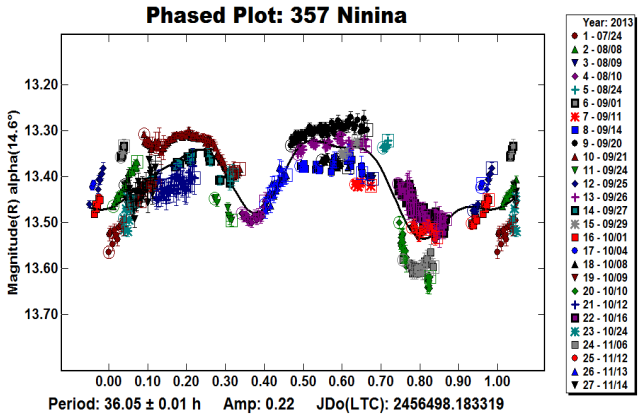
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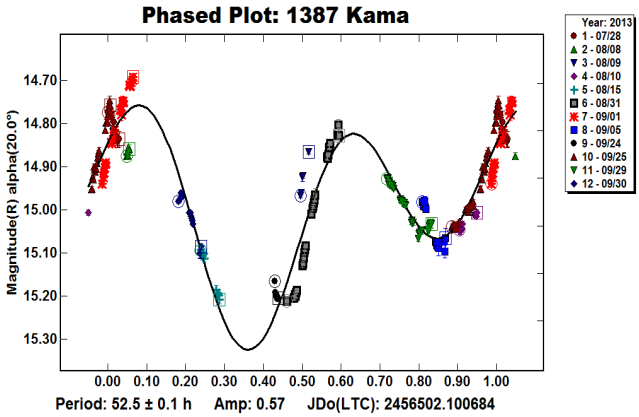
Phased Plot: 1387 Kama
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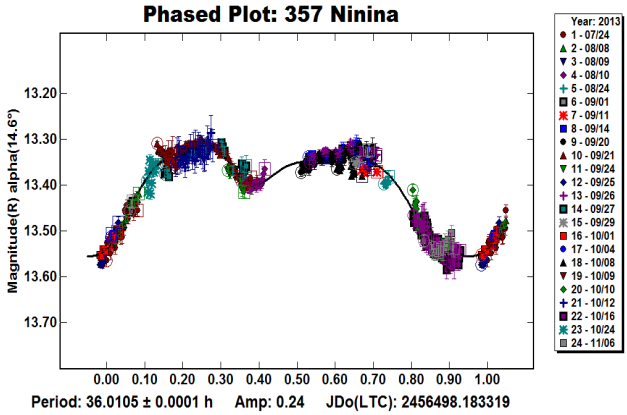
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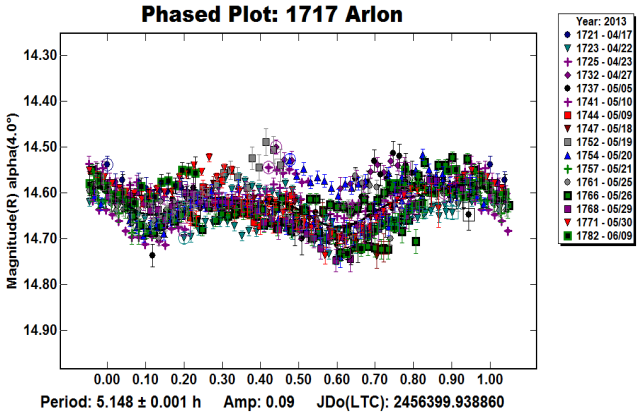
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Magnitude(R) alpha(4.0°)
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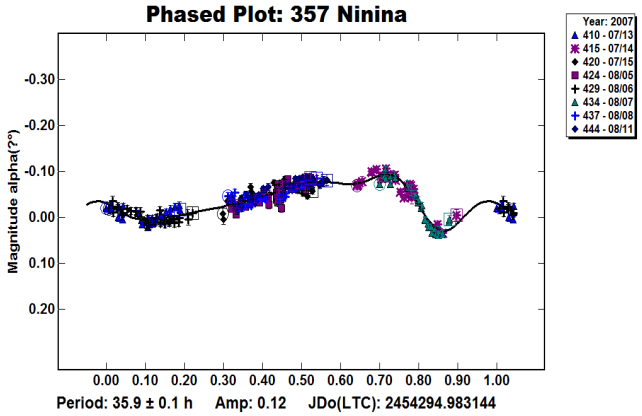
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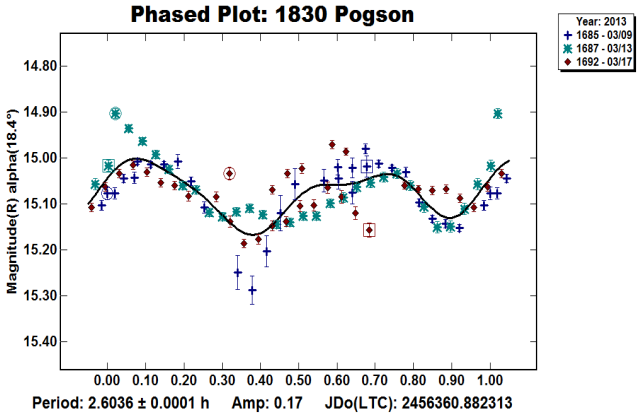
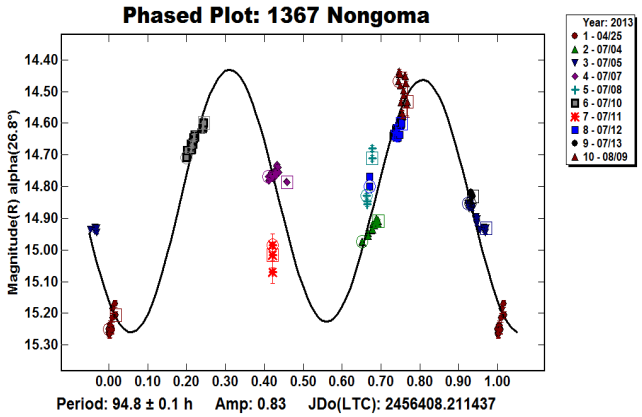

Phased Plot: 1830 Pogson
Magnitude(R) alpha(18.4°)
Year: 2013
Period: 2.6036 ± 0.0001 h Amp: 0.17 JDo(LTC): 2456360.882313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Magnitude(R) alpha(26.8°)
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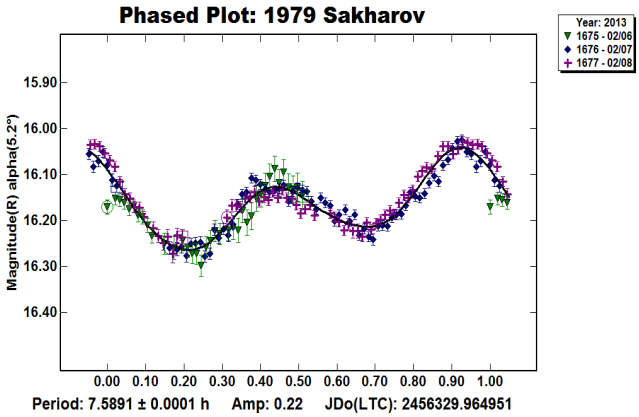
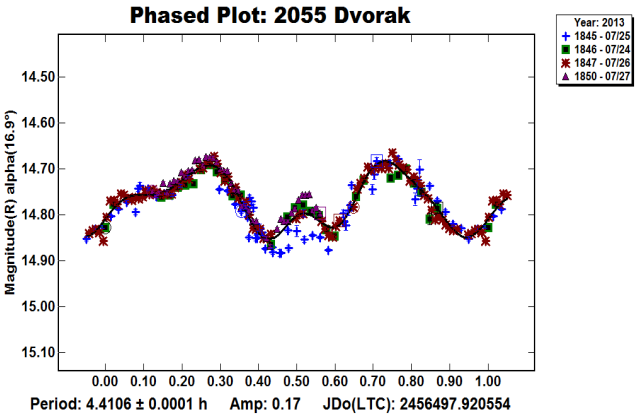
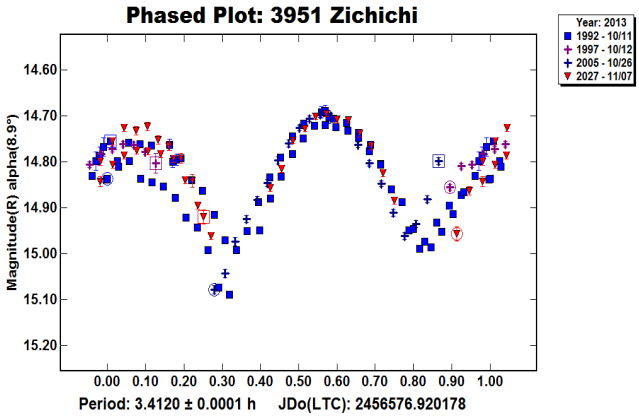
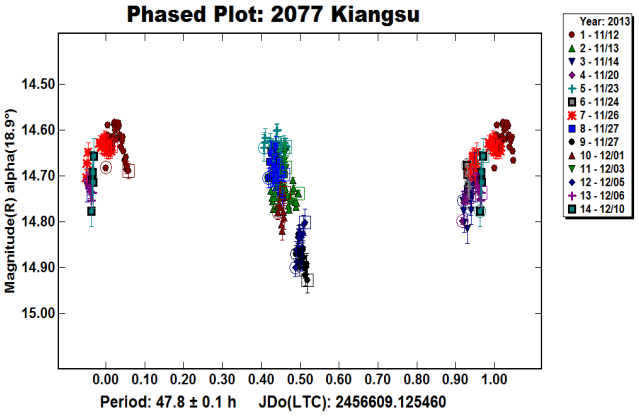
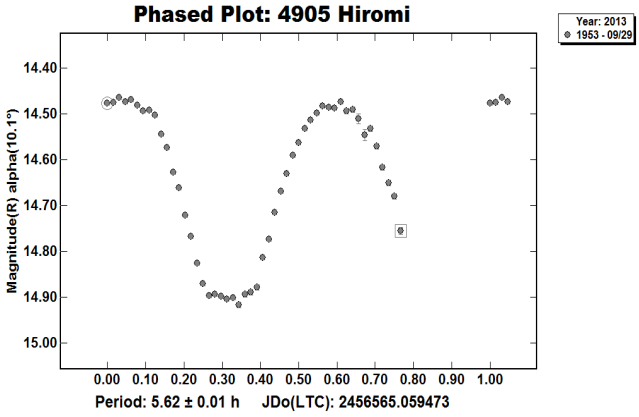
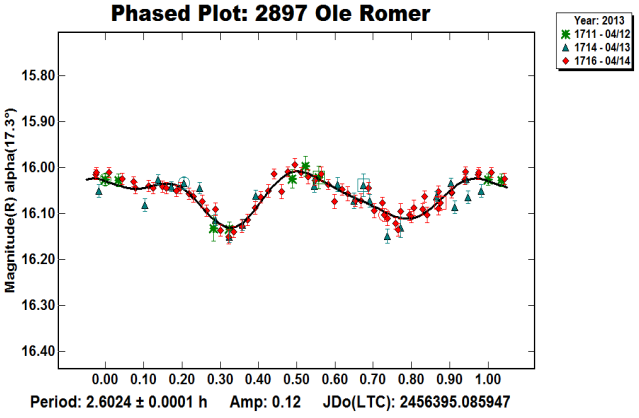

Phased Plot: 1979 Sakharov
Magnitude(R) alpha(5.2°)
Year: 2013
Period: 7.5891 ± 0.0001 h Amp: 0.22 JDo(LTC): 2456329.964951

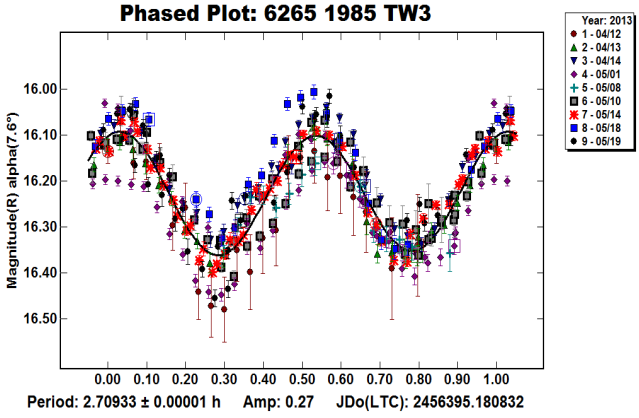

Phased Plot: 2055 Dvorak
Year: 2013
1845 - 07/25
1846 - 07/24
1847 - 07/26
1850 - 07/27
Magnitude(R) alpha(16.9°)
14.50
14.60
14.70
14.80
14.90
15.00
15.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 4.4106 ± 0.0001 h Amp: 0.17 JDo(LTC): 2456497.920554

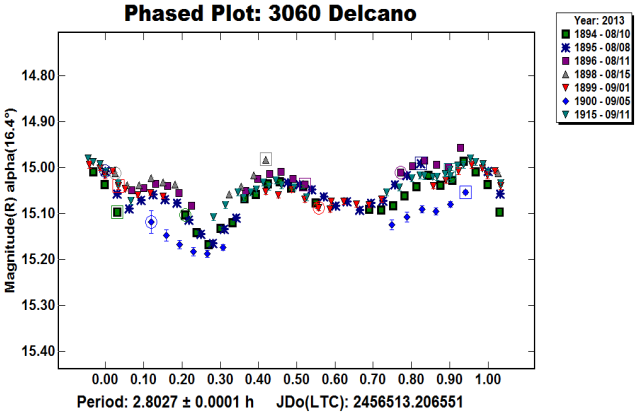

Phased Plot: 3951 Zichichi
Year: 2013
1992 - 10/11
1997 - 10/12
2005 - 10/26
2027 - 11/07
Magnitude(R) alpha(8.9°)
14.60
14.70
14.80
14.90
15.00
15.10
15.20
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 3.4120 ± 0.0001 h JDo(LTC): 2456576.920178

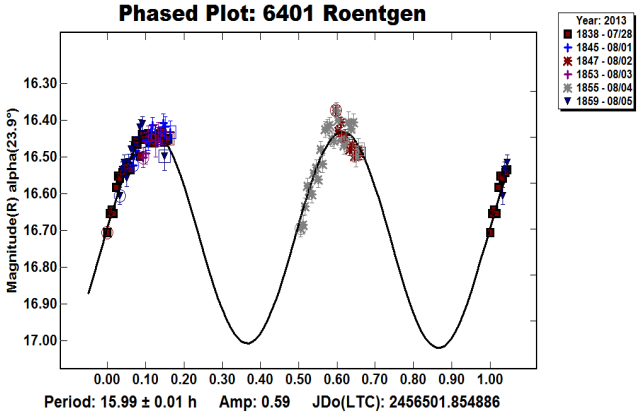

Phased Plot: 2077 Kiangsu
Year: 2013
1 - 11/12
2 - 11/13
3 - 11/14
4 - 11/20
5 - 11/23
6 - 11/24
7 - 11/26
8 - 11/27
9 - 11/27
10 - 12/01
11 - 12/03
12 - 12/05
13 - 12/06
14 - 12/10
Magnitude(R) alpha(18.9°)
14.50
14.60
14.70
14.80
14.90
15.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 47.8 ± 0.1 h JDo(LTC): 2456609.125460

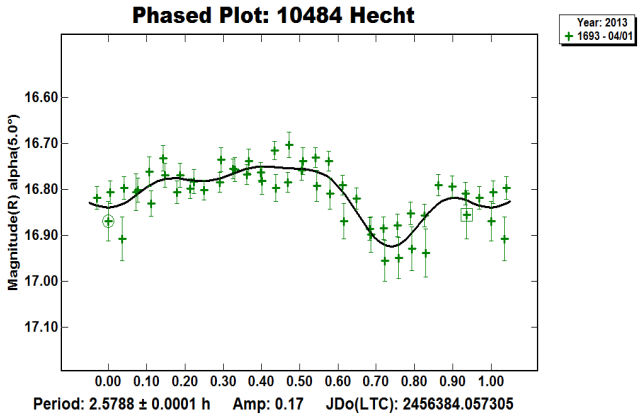

Phased Plot: 4905 Hiromi
Year: 2013
1953 - 09/29
Magnitude(R) alpha(10.1°)
14.40
14.50
14.60
14.70
14.80
14.90
15.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 5.62 ± 0.01 h JDo(LTC): 2456565.059473

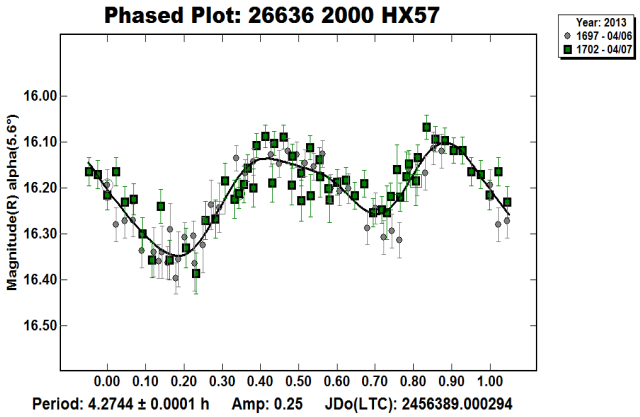

Phased Plot: 2897 Ole Romer
Year: 2013
1711 - 04/12
1714 - 04/13
1716 - 04/14
Magnitude(R) alpha(17.3°)
15.80
15.90
16.00
16.10
16.20
16.30
16.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.6024 ± 0.0001 h Amp: 0.12 JDo(LTC): 2456395.085947

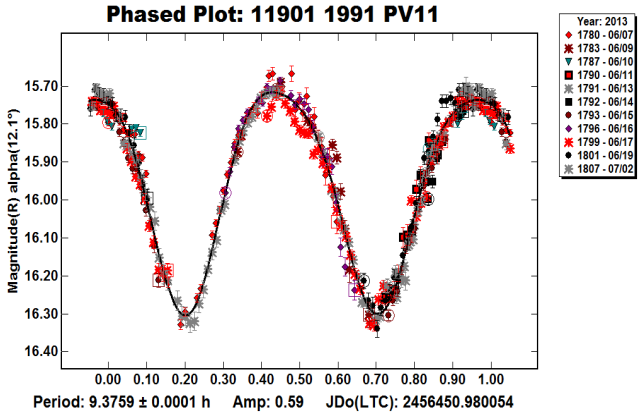

Phased Plot: 6265 1985 TW3
Year: 2013
1 - 04/12
2 - 04/13
3 - 04/14
4 - 05/01
5 - 05/08
6 - 05/10
7 - 05/14
8 - 05/18
9 - 05/19
Magnitude(R) alpha(7.6°)
16.00
16.10
16.20
16.30
16.40
16.50
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.70933 ± 0.00001 h Amp: 0.27 JDo(LTC): 2456395.180832

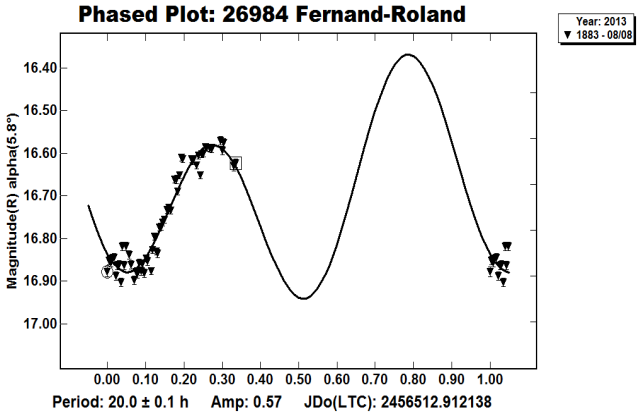

Phased Plot: 3060 Delcano
Year: 2013
1894 - 08/10
1895 - 08/08
1896 - 08/11
1898 - 08/15
1899 - 09/01
1900 - 09/05
1915 - 09/11
Magnitude(R) alpha(16.4°)
14.80
14.90
15.00
15.10
15.20
15.30
15.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.8027 ± 0.0001 h JDo(LTC): 2456513.206551

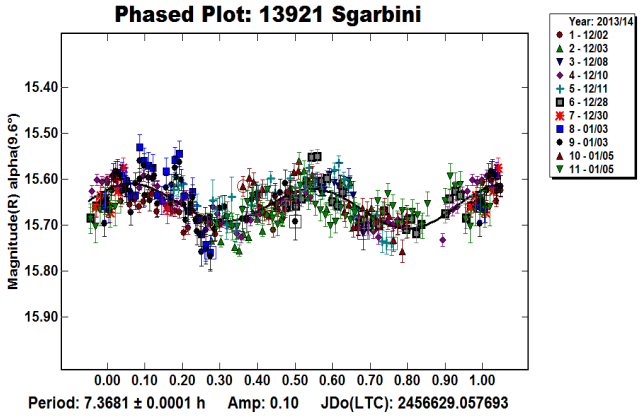

Phased Plot: 6401 Roentgen
Year: 2013
1838 - 07/28
1845 - 08/01
1847 - 08/02
1853 - 08/03
1855 - 08/04
1859 - 08/05
Magnitude(R) alpha(23.9°)
16.30
16.40
16.50
16.60
16.70
16.80
16.90
17.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 15.99 ± 0.01 h Amp: 0.59 JDo(LTC): 2456501.854886

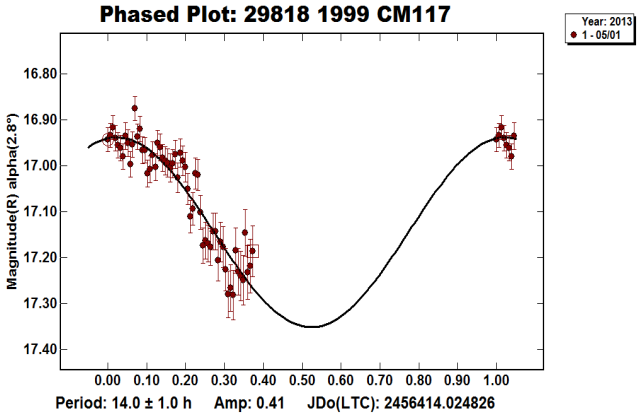

Phased Plot: 10484 Hecht
Year: 2013
1693 - 04/01
Magnitude(R) alpha(5.0°)
16.60
16.70
16.80
16.90
17.00
17.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.5788 ± 0.0001 h Amp: 0.17 JDo(LTC): 2456384.057305

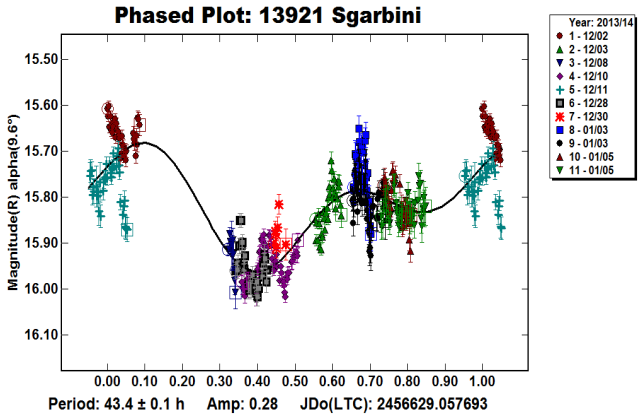

Phased Plot: 26636 2000 HX57
Year: 2013
1697 - 04/06
1702 - 04/07
Magnitude(R) alpha(5.6°)
16.00
16.10
16.20
16.30
16.40
16.50
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 4.2744 ± 0.0001 h Amp: 0.25 JDo(LTC): 2456389.000294

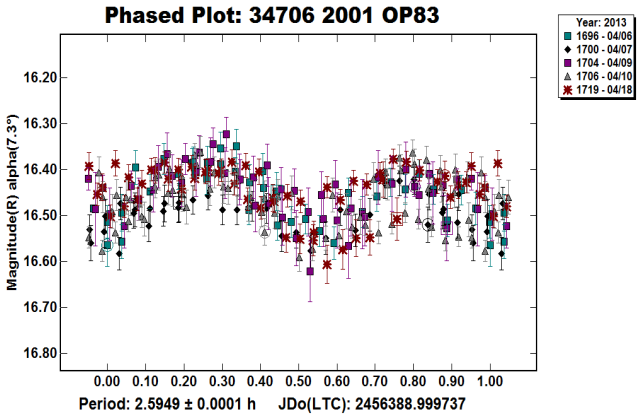

Phased Plot: 11901 1991 PV11
Year: 2013
1780 - 06/07
1783 - 06/09
1787 - 06/10
1790 - 06/11
1791 - 06/13
1792 - 06/14
1793 - 06/15
1796 - 06/16
1799 - 06/17
1801 - 06/19
1807 - 07/02
Magnitude(R) alpha(12.1°)
15.70
15.80
15.90
16.00
16.10
16.20
16.30
16.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 9.3759 ± 0.0001 h Amp: 0.59 JDo(LTC): 2456450.980054

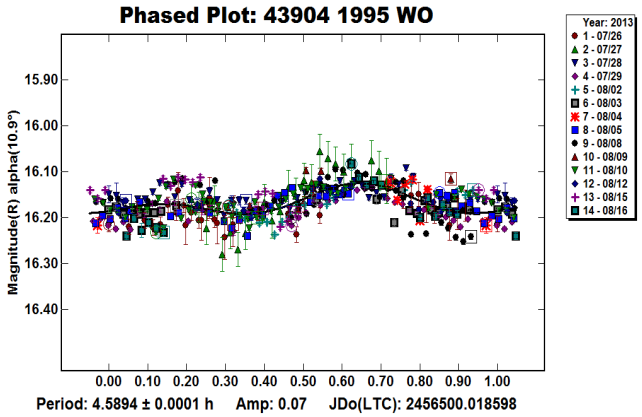

Phased Plot: 26984 Fernand-Roland
Year: 2013
1883 - 08/08
Magnitude(R) alpha(5.8°)
16.40
16.50
16.60
16.70
16.80
16.90
17.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 20.0 ± 0.1 h Amp: 0.57 JDo(LTC): 2456512.912138

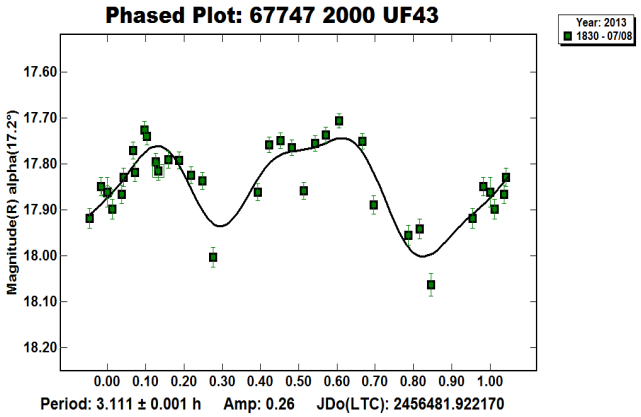

Phased Plot: 13921 Sgarbini
Year: 2013/14
1 - 12/02
2 - 12/03
3 - 12/08
4 - 12/10
5 - 12/11
6 - 12/28
7 - 12/30
8 - 01/03
9 - 01/03
10 - 01/05
11 - 01/05
Magnitude(R) alpha(9.6°)
15.40
15.50
15.60
15.70
15.80
15.90
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 7.3681 ± 0.0001 h Amp: 0.10 JDo(LTC): 2456629.057693

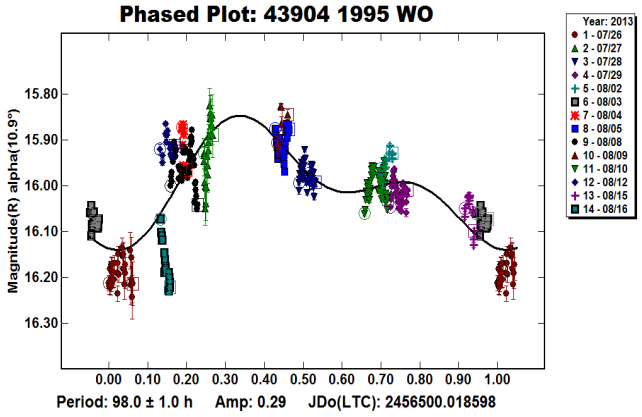

Phased Plot: 29818 1999 CM117
Year: 2013
1 - 06/01
Magnitude(R) alpha(2.8°)
16.80
16.90
17.00
17.10
17.20
17.30
17.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 14.0 ± 1.0 h Amp: 0.41 JDo(LTC): 2456414.024826

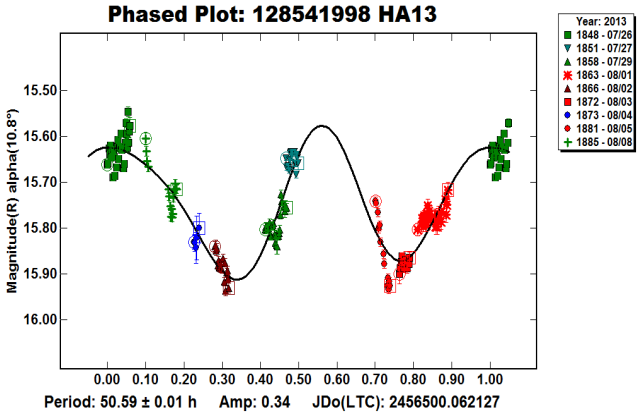

Phased Plot: 13921 Sgarbini
Year: 2013/14
1 - 12/02
2 - 12/03
3 - 12/08
4 - 12/10
5 - 12/11
6 - 12/28
7 - 12/30
8 - 01/03
9 - 01/03
10 - 01/05
11 - 01/05
Magnitude(R) alpha(9.6°)
15.50
15.60
15.70
15.80
15.90
16.00
16.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 43.4 ± 0.1 h Amp: 0.28 JDo(LTC): 2456629.057693

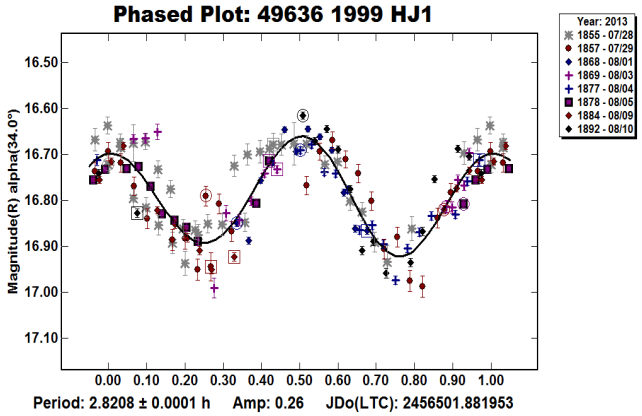

Phased Plot: 34706 2001 OP83
Year: 2013
1696 - 04/06
1700 - 04/07
1704 - 04/09
1706 - 04/10
1719 - 04/18
Magnitude(R) alpha(7.3°)
16.20
16.30
16.40
16.50
16.60
16.70
16.80
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.5949 ± 0.0001 h JDo(LTC): 2456388.999737

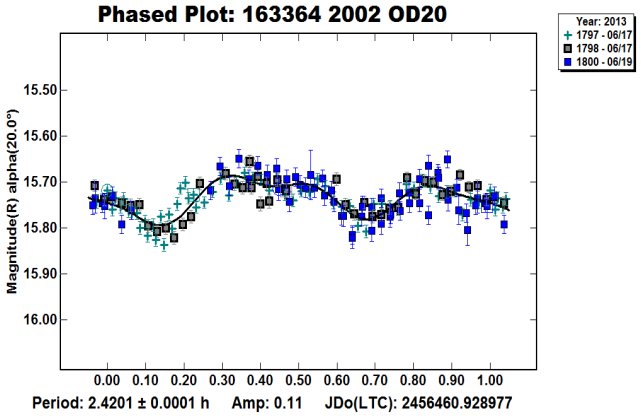

Phased Plot: 43904 1995 WO
Year: 2013
1 - 07/26
2 - 07/27
3 - 07/28
4 - 07/29
5 - 08/02
6 - 08/03
7 - 08/04
8 - 08/05
9 - 08/08
10 - 08/09
11 - 08/10
12 - 08/12
13 - 08/15
14 - 08/16
Magnitude(R) alpha(10.9°)
15.90
16.00
16.10
16.20
16.30
16.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 4.5894 ± 0.0001 h Amp: 0.07 JDo(LTC): 2456500.018598

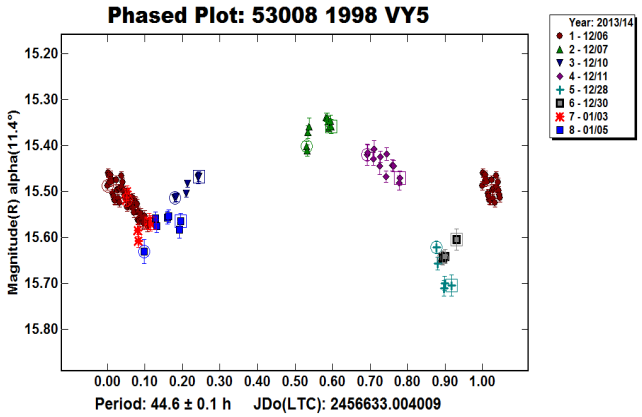

Phased Plot: 67747 2000 UF43
Year: 2013
1830 - 07/08
Magnitude(R) alpha(17.2°)
17.60
17.70
17.80
17.90
18.00
18.10
18.20
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 3.111 ± 0.001 h Amp: 0.26 JDo(LTC): 2456481.922170

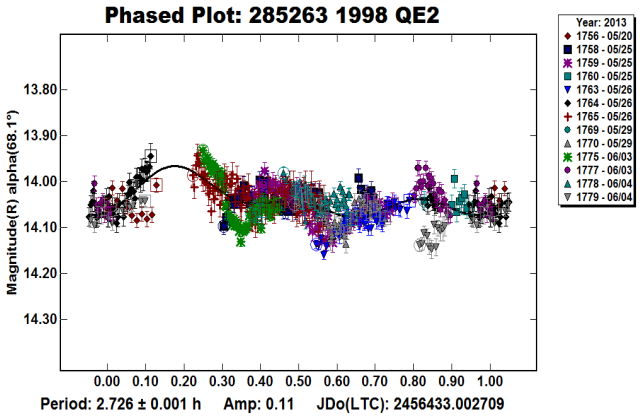

Phased Plot: 43904 1995 WO
Year: 2013
1 - 07/26
2 - 07/27
3 - 07/28
4 - 07/29
5 - 08/02
6 - 08/03
7 - 08/04
8 - 08/05
9 - 08/08
10 - 08/09
11 - 08/10
12 - 08/12
13 - 08/15
14 - 08/16
Magnitude(R) alpha(10.9°)
15.80
15.90
16.00
16.10
16.20
16.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 98.0 ± 1.0 h Amp: 0.29 JDo(LTC): 2456500.018598


Phased Plot: 128541998 HA13
Year: 2013
1848 - 07/26
1851 - 07/27
1858 - 07/29
1863 - 08/01
1866 - 08/02
1872 - 08/03
1873 - 08/04
1881 - 08/05
1885 - 08/08
Magnitude(R) alpha(10.8°)
15.50
15.60
15.70
15.80
15.90
16.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 50.59 ± 0.01 h Amp: 0.34 JDo(LTC): 2456500.062127


Phased Plot: 49636 1999 HJ1
Year: 2013
1855 - 07/28
1857 - 07/29
1868 - 08/01
1869 - 08/03
1877 - 08/04
1878 - 08/05
1884 - 08/09
1892 - 08/10
Magnitude(R) alpha(34.0°)
16.50
16.60
16.70
16.80
16.90
17.00
17.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.8208 ± 0.0001 h Amp: 0.26 JDo(LTC): 2456501.881953


Phased Plot: 163364 2002 OD20
Year: 2013
1797 - 06/17
1798 - 06/17
1800 - 06/19
Magnitude(R) alpha(20.0°)
15.50
15.60
15.70
15.80
15.90
16.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.4201 ± 0.0001 h Amp: 0.11 JDo(LTC): 2456460.928977


Phased Plot: 53008 1998 VY5
Year: 2013/14
1 - 12/06
2 - 12/07
3 - 12/10
4 - 12/11
5 - 12/28
6 - 12/30
7 - 01/03
8 - 01/05
Magnitude(R) alpha(11.4°)
15.20
15.30
15.40
15.50
15.60
15.70
15.80
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 44.6 ± 0.1 h JDo(LTC): 2456633.004009


Phased Plot: 285263 1998 QE2
Year: 2013
1756 - 05/20
1758 - 05/25
1759 - 05/25
1760 - 05/25
1763 - 05/26
1764 - 05/26
1765 - 05/26
1769 - 05/29
1770 - 05/29
1775 - 06/03
1777 - 06/03
1778 - 06/04
1779 - 06/04
Magnitude(R) alpha(68.1°)
13.80
13.90
14.00
14.10
14.20
14.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Period: 2.726 ± 0.001 h Amp: 0.11 JDo(LTC): 2456433.002709