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LIGHTCURVE ANALYSIS OF ASTEROIDS FROM BLUE MOUNTAINS OBSERVATORY IN 2014

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Photometric observations of a number of asteroids were done from Blue Mountains Observatory in 2014. The observations were made in support of the binary asteroid and asteroid pairs campaigns by Petr Pravec, and to obtain new data at favorable apparitions for asteroids with poorly defined lightcurves.

CCD photometric observations were made throughout 2014 from Blue Mountains Observatory where three telescope systems were used. Table I lists the equipment used for the observations. Additional information can be found at the BMO website (BMO, 2014). Unless otherwise specified, all images were taken unfiltered with exposures per image of 300 sec to maximize SNR but at the same time to provide sufficient data point frequency for the more common rotational periods of 2-8 hours.

Data measurement and reduction were done using *MPO Canopus* v10. Period analysis used the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989). Calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins V magnitudes based on 2MASS J-K colors (Warner, 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit comparison stars to near solar color.

788 Hohensteina was observed by Oey *et al*. (2008) with a result of P = 37.176 h. The data were obtained from 20 sessions over a period of nearly two months with insignificant changes due to changing phase angle. Two observers from different longitudes were used for the campaign and both used an unlinked differential photometry method. In at least one case, a single 14-hour session was created by matching the end of one session with the start of the other, which helped determine the synodic period.

The asteroid was re-observed by the author in 2014 without realizing that Stephens *et al*. (2015) has also conducted an observation campaign and found a period of 29.94 h or 40.87 h with an amplitude of 0.10 mag or 0.15 mag, respectively. Oey's 2014 data were established using the *MPO Canopus* Comp Star Selector utility. Unfortunately no clear result was found.

The inability to find a unique period pointed to the possibility that the asteroid was tumbling. However, the objective was to constrain a primary (or dominant) period. To that end, the nightly zero points were adjusted to within the acceptable calibration error of the catalog, *i.e.*, about ± 0.05 mag, so that each session's slope matched reasonably well. From this, two distinct lightcurves were found, one with a period of 33.02 h and the other with a period of 43.48 h; both have an amplitude of about 0.18mag.

This result differs from that obtained by Stephens *et al.* (2015) and from Oey (2008). These divergent results reinforce the need for a more concerted observing campaign in the future. However, with a small amplitude, relatively long period, and suspected tumbling, the strategy will need to include high-precision linked data and successive long sessions covering widely spaced geographical locations.

749 Malzovia, 1706 Dieckvoss, 1796 Riga, and 2002 Euler were selected from CALL website (Warner, 2014) due to their favorable apparition.

1741 Giclas and 2110 Moore-Sitterly were part of the Photometric Search for Asynchronous Binary Asteroid (PSABA; Pravec, 2014) target selection; however, the selection criteria were also in support of NEO Source paired asteroid project (Pravec *et al*., 2010). 1741 Giclas was observed for one night with the data leading to a period of 3.107 ± 0.001 h. 2110 Moore-Sitterly was found to have a single period of 3.3445 ± 0.0001 h.

2478 Tokai, 2691 Sersic, and 10208 Germanicus. Observations of these previously discovered binary asteroids were made mainly to capture the mutual events (eclipses or occultation) due to the satellite. Complete data sets were obtained by other observers during the same apparitions and were pooled at the Photometric Search for Asynchronous Binary Asteroid (PSABA) web site (Pravec, 2014).

(4555) Josefaperez and (6944) 1979 MR3 were target asteroids that fit the PSABA selection criteria. When a lightcurve shows one or more attenuations but no definitive period for the events could be found, the given asteroid is considered a binary suspect.

4563 Kahnia, 4765 Wasserberg, (8107) 1995 BR4, (8091) 1992 BG, (10597) 1996 TR10, (25327) 1999 JB63, (388468) 2007 DB83, (27300) 2000 AA168, and (56437) 2000 GZ46 were observed as part of the PSABA campaign. They were all found to be singly periodic.

(5510) 1988 RF7 and (20470) 1999 NZ5 happened to be within the same field of view while observing other main targets. Both were in the primary target fields only one or two nights. The periods found were not conclusive and serve only as a guide for future observations.

(5647) 1990 TZ was observed as a routine favorable opposition target selection. During the observing campaign, six consecutive nights of observation were made when the asteroid was near the stationary point in its path across the sky. This provided an opportunity for differential photometry using the same comparison stars for all observing runs. There was a gradual brightening over the six nights that indicated the possibility of secondary period. The brightening due to opposition effect was ruled out since it was one month post-opposition.

6181 Bobweber showed a very small (0.03 mag) attenuation and was considered as binary non-detection. Such asteroids are designated for follow up at a future apparition.

(18082) 2000 GB136 was also selected from CALL website. After four nights of observations, it was clear that the rotation period of 11.94 ± 0.02 h was close to being commensurate with the rotation period of the Earth. In such cases, a complete lightcurve and secure period can often be found only with a collaboration among two or more observers at widely-spaced longitudes.

18787 Kathermann was another target meeting the PSABA selection criteria. It was found to have a period of 41.801 ± 0.004 h. So far, all slow-rotating asteroids have been found to be non-binary; the available data were insufficient to determine if the asteroid was a tumbler (Pravec *et al.* 2005).

(39796) 1997 TD had no previously reported period. Despite a sparse data set, analysis of the data from four nights suggested that the asteroid had an estimated rotation period of 40.7 ± 0.1 h and an amplitude of 0.38 ± 0.03 mag.

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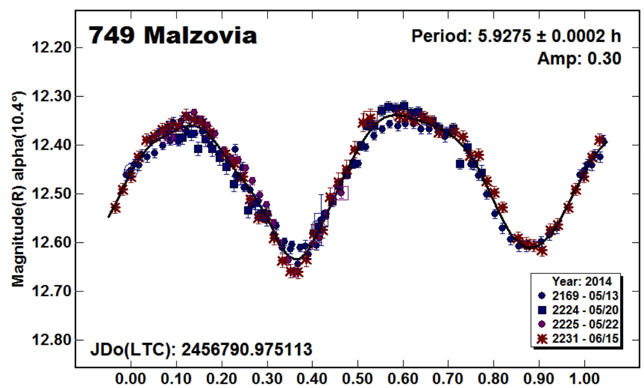
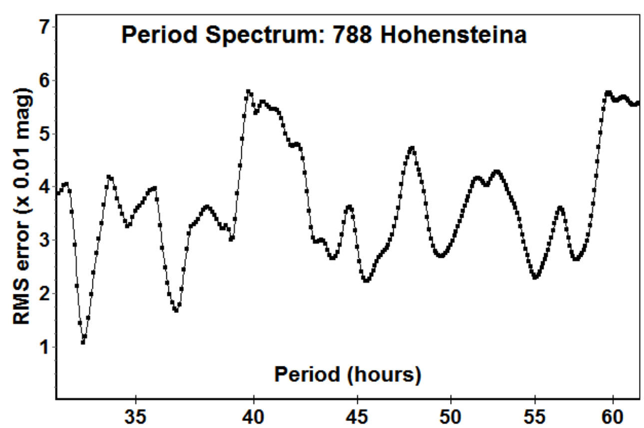
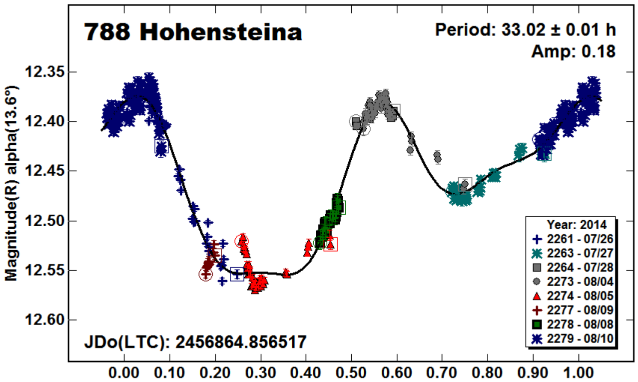
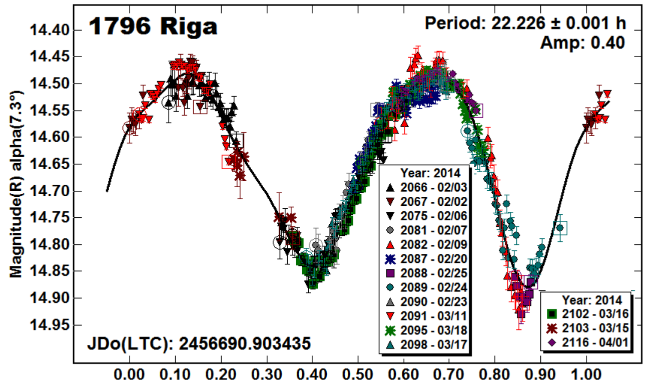


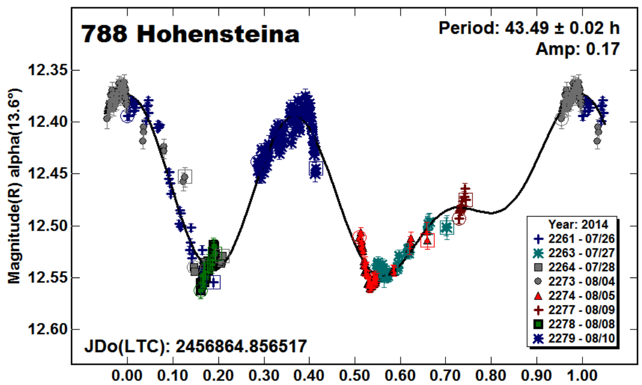


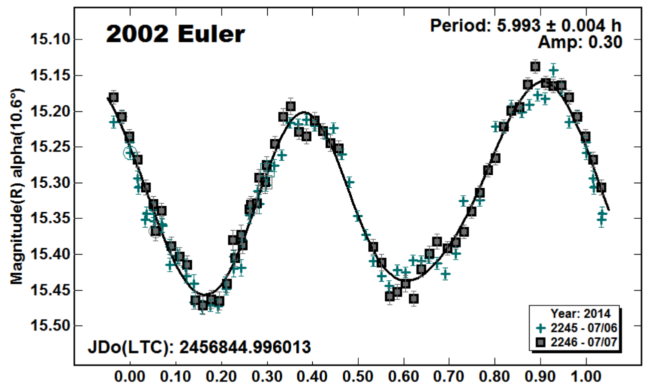
Observatory	Diameter (code)	f/ ratio	Camera	Pixels (microns)	Binning	Scale arcsec/pix
Kingsgrove (E19)	0.25m (10i)	11	ST-402ME (SBIG)	9	1x1	1.41
BMO (Q68)	0.35m (14i)	6	ST8-XME (SBIG)	9	1x1	0.88
BMO (Q68)	0.61m (24if)	6.8	U16M (Apogee)	27	3x3	1.40
BMO (Q68)	0.61m (24ib)	6.8	U42 (Apogee)	13.5	1x1	0.70

Table I. Observatory and telescope/camera systems used.


788 Hohensteina
Period: 33.02 ± 0.01 h
Amp: 0.18
Magnitude(R) alpha(13.6°)
JDo(LTC): 2456864.856517
Year: 2014
2261 - 07/26
2263 - 07/27
2264 - 07/28
2273 - 08/04
2274 - 08/05
2277 - 08/09
2278 - 08/08
2279 - 08/10


1796 Riga
Period: 22.226 ± 0.001 h
Amp: 0.40
Magnitude(R) alpha(7.3°)
JDo(LTC): 2456690.903435
Year: 2014
2066 - 02/03
2067 - 02/02
2075 - 02/06
2081 - 02/07
2082 - 02/09
2087 - 02/20
2088 - 02/25
2089 - 02/24
2090 - 02/23
2091 - 03/11
2095 - 03/18
2098 - 03/17
Year: 2014
2102 - 03/16
2103 - 03/15
2116 - 04/01


788 Hohensteina
Period: 43.49 ± 0.02 h
Amp: 0.17
Magnitude(R) alpha(13.6°)
JDo(LTC): 2456864.856517
Year: 2014
2261 - 07/26
2263 - 07/27
2264 - 07/28
2273 - 08/04
2274 - 08/05
2277 - 08/09
2278 - 08/08
2279 - 08/10


2002 Euler
Period: 5.993 ± 0.004 h
Amp: 0.30
Magnitude(R) alpha(10.6°)
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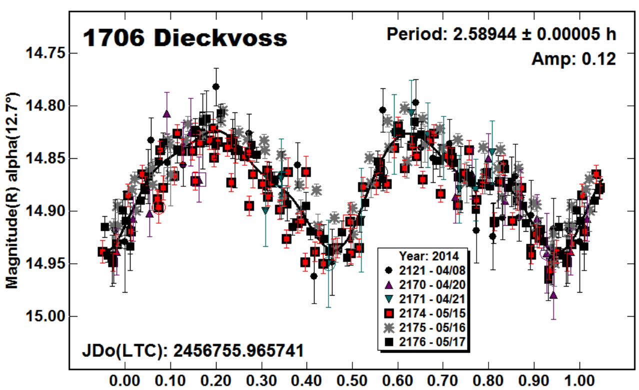
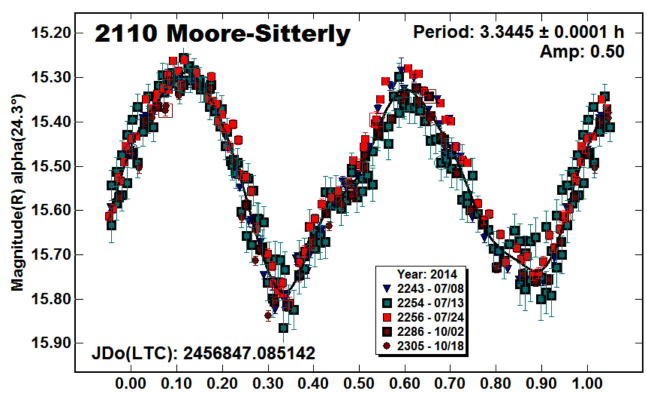
Year: 2014
2245 - 07/06
2246 - 07/07


1706 Dieckvoss
Period: 2.58944 ± 0.00005 h
Amp: 0.12
Magnitude(R) alpha(12.7°)
JDo(LTC): 2456755.965741
Year: 2014
2121 - 04/08
2170 - 04/20
2171 - 04/21
2174 - 05/15
2175 - 05/16
2176 - 05/17


2110 Moore-Sitterly
Period: 3.3445 ± 0.0001 h
Amp: 0.50
Magnitude(R) alpha(24.3°)
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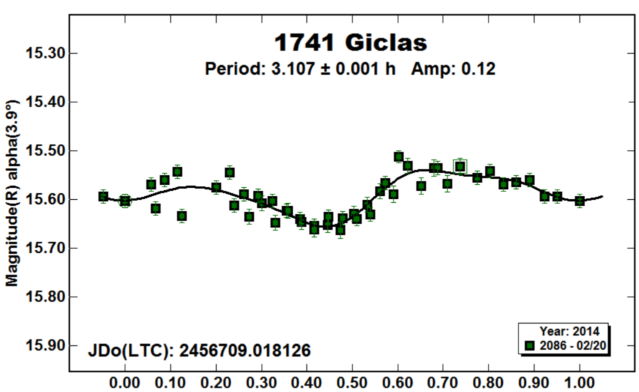
Year: 2014
2243 - 07/08
2254 - 07/13
2256 - 07/24
2286 - 10/02
2305 - 10/18


1741 Giclas
Period: 3.107 ± 0.001 h Amp: 0.12
Magnitude(R) alpha(3.9°)
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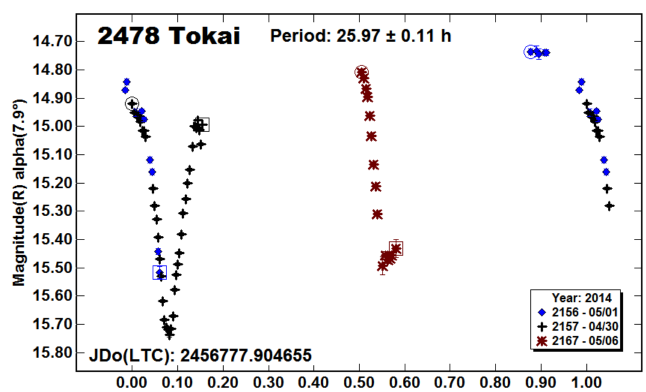
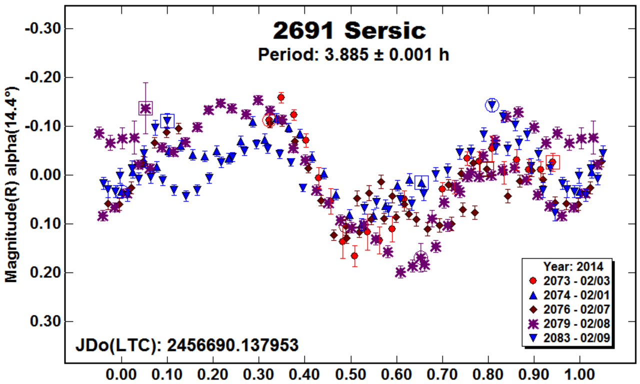
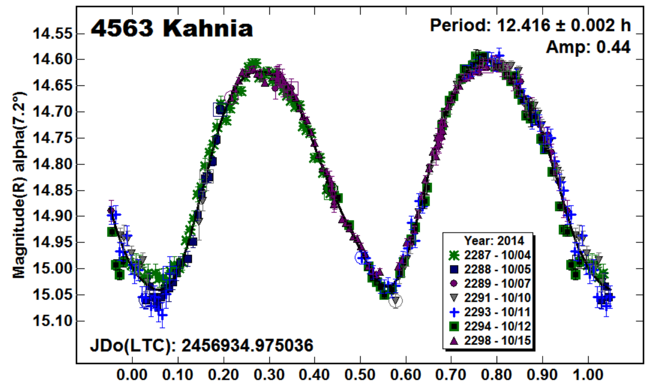
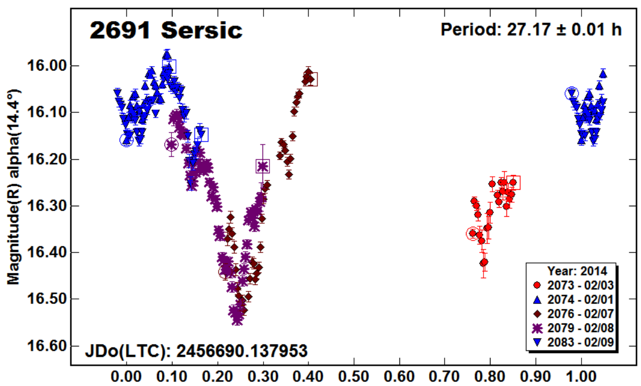
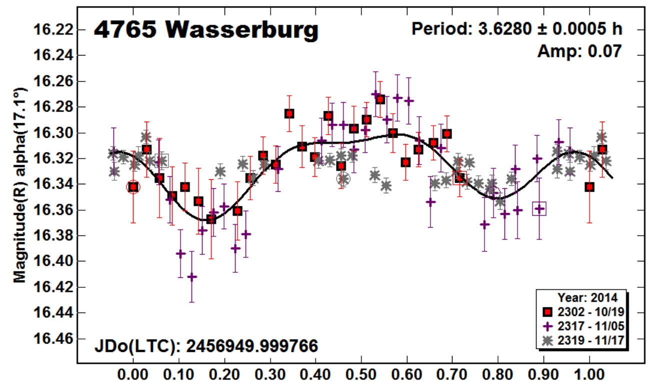
Year: 2014
2086 - 02/20


2478 Tokai
Period: 25.97 ± 0.11 h
Magnitude(R) alpha(7.9°)
JDo(LTC): 2456777.904655
Year: 2014
2156 - 05/01
2157 - 04/30
2167 - 05/06


2691 Sersic
Period: 3.885 ± 0.001 h
Magnitude(R) alpha(14.4°)
JDo(LTC): 2456690.137953
Year: 2014
2073 - 02/03
2074 - 02/01
2076 - 02/07
2079 - 02/08
2083 - 02/09


4563 Kahnia
Period: 12.416 ± 0.002 h
Amp: 0.44
Magnitude(R) alpha(7.2°)
JDo(LTC): 2456934.975036
Year: 2014
2287 - 10/04
2288 - 10/05
2289 - 10/07
2291 - 10/10
2293 - 10/11
2294 - 10/12
2298 - 10/15


2691 Sersic
Period: 27.17 ± 0.01 h
Magnitude(R) alpha(14.4°)
JDo(LTC): 2456690.137953
Year: 2014
2073 - 02/03
2074 - 02/01
2076 - 02/07
2079 - 02/08
2083 - 02/09


4765 Wasserburg
Period: 3.6280 ± 0.0005 h
Amp: 0.07
Magnitude(R) alpha(17.1°)
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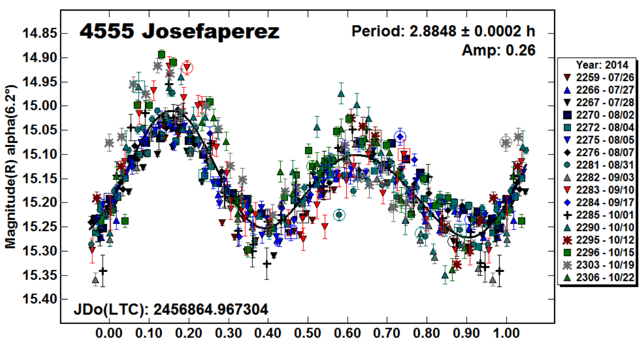
Year: 2014
2302 - 10/19
2317 - 11/05
2319 - 11/17


4555 Josefaperez
Period: 2.8848 ± 0.0002 h
Amp: 0.26
Magnitude(R) alpha(6.2°)
JDo(LTC): 2456864.967304
Year: 2014
2259 - 07/26
2266 - 07/27
2267 - 07/28
2270 - 08/02
2272 - 08/04
2275 - 08/05
2276 - 08/07
2281 - 08/31
2282 - 09/03
2283 - 09/10
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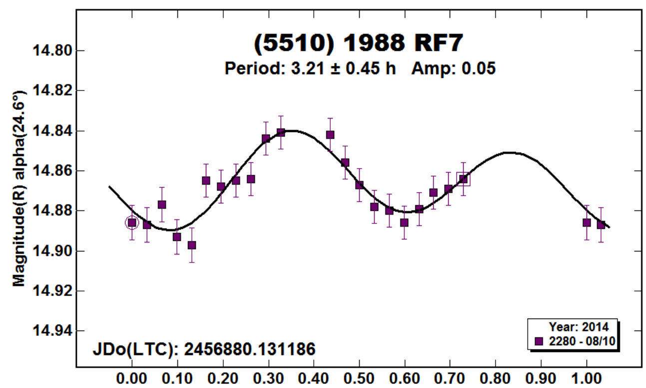
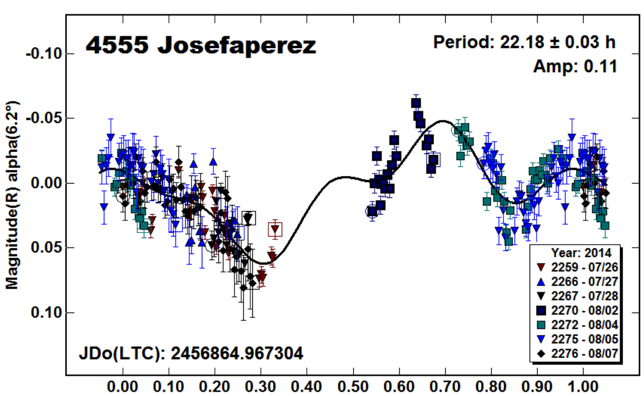
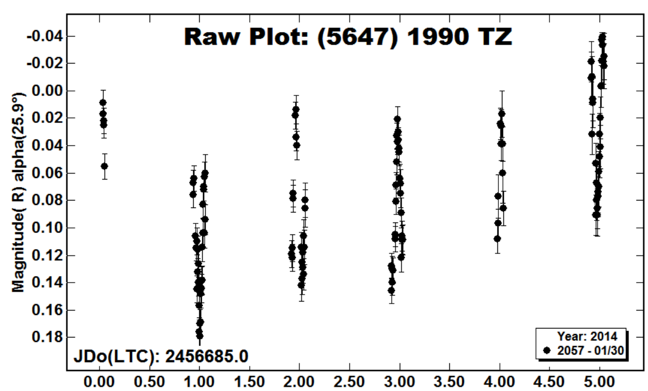
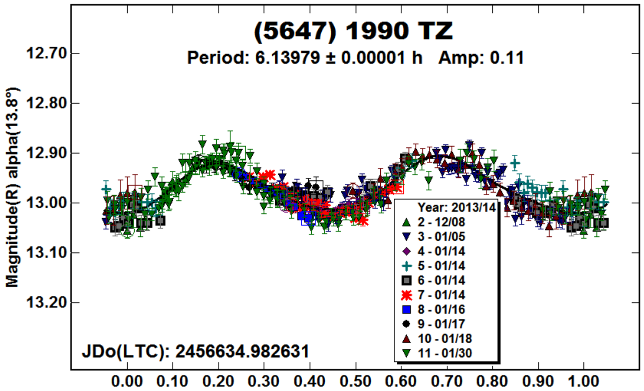
2303 - 10/19
2306 - 10/22


(5510) 1988 RF7
Period: 3.21 ± 0.45 h Amp: 0.05
Magnitude(R) alpha(24.6°)
JDo(LTC): 2456880.131186
Year: 2014
2280 - 08/10


4555 Josefaperez
Period: 22.18 ± 0.03 h
Amp: 0.11
Magnitude(R) alpha(6.2°)
JDo(LTC): 2456864.967304
Year: 2014
2259 - 07/26
2266 - 07/27
2267 - 07/28
2270 - 08/02
2272 - 08/04
2275 - 08/05
2276 - 08/07


Raw Plot: (5647) 1990 TZ
Magnitude(R) alpha(25.9°)
JDo(LTC): 2456685.0
Year: 2014
2057 - 01/30


(5647) 1990 TZ
Period: 6.13979 ± 0.00001 h Amp: 0.11
Magnitude(R) alpha(13.8°)
JDo(LTC): 2456634.982631
Year: 2013/14
2 - 12/08
3 - 01/05
4 - 01/14
5 - 01/14
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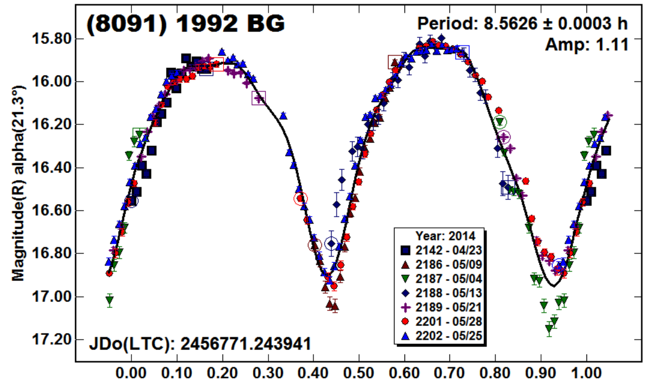
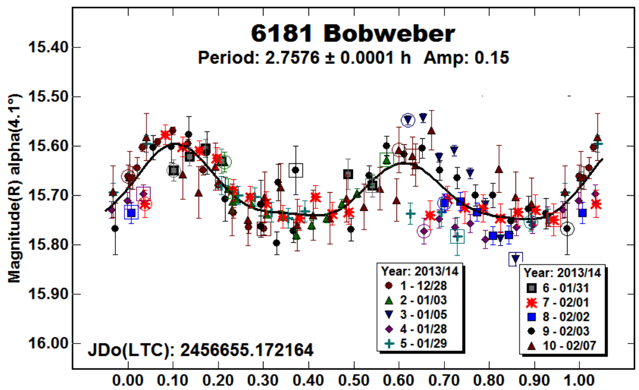
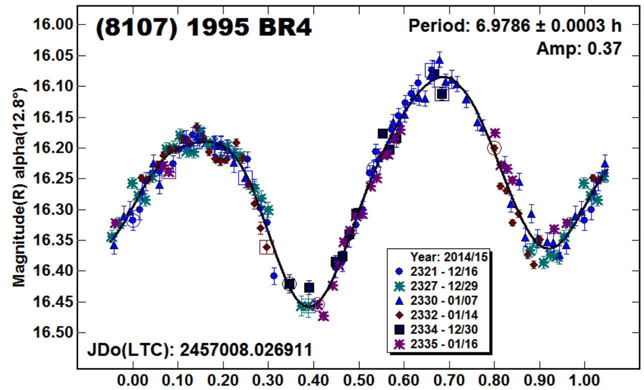
10 - 01/18
11 - 01/30


(8091) 1992 BG
Period: 8.5626 ± 0.0003 h
Amp: 1.11
Magnitude(R) alpha(21.3°)
JDo(LTC): 2456771.243941
Year: 2014
2142 - 04/23
2186 - 05/09
2187 - 05/04
2188 - 05/13
2189 - 05/21
2201 - 05/28
2202 - 05/25


6181 Bobweber
Period: 2.7576 ± 0.0001 h Amp: 0.15
Magnitude(R) alpha(4.1°)
JDo(LTC): 2456655.172164
Year: 2013/14
1 - 12/28
2 - 01/03
3 - 01/05
4 - 01/28
5 - 01/29
Year: 2013/14
6 - 01/31
7 - 02/01
8 - 02/02
9 - 02/03
10 - 02/07


(8107) 1995 BR4
Period: 6.9786 ± 0.0003 h
Amp: 0.37
Magnitude(R) alpha(12.8°)
JDo(LTC): 2457008.026911
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2321 - 12/16
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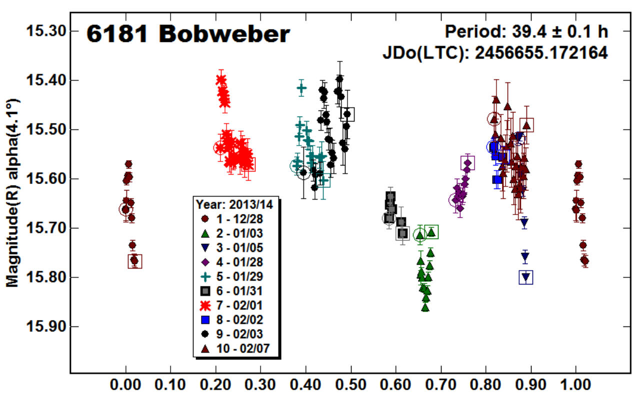
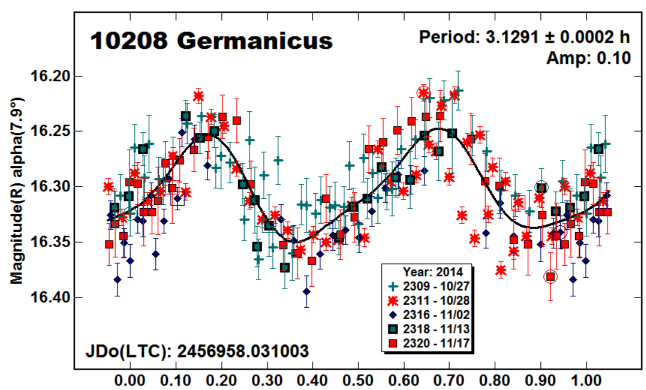
2332 - 01/14
2334 - 12/30
2335 - 01/16


6181 Bobweber
Period: 39.4 ± 0.1 h
JDo(LTC): 2456655.172164
Magnitude(R) alpha(4.1°)
Year: 2013/14
1 - 12/28
2 - 01/03
3 - 01/05
4 - 01/28
5 - 01/29
6 - 01/31
7 - 02/01
8 - 02/02
9 - 02/03
10 - 02/07


10208 Germanicus
Period: 3.1291 ± 0.0002 h
Amp: 0.10
Magnitude(R) alpha(7.9°)
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Year: 2014
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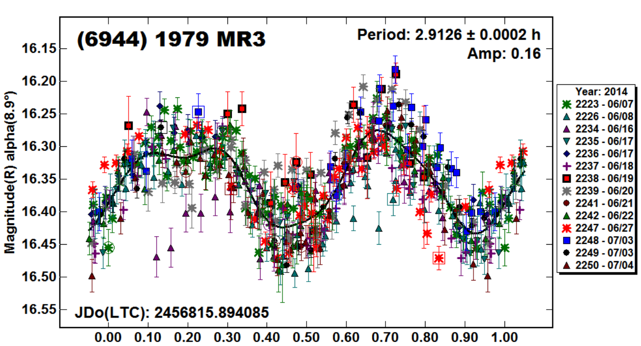
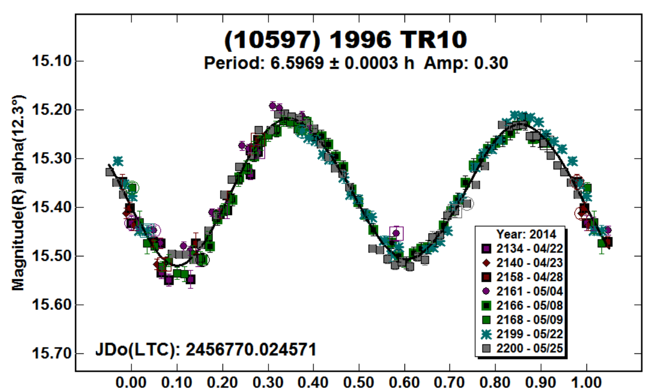
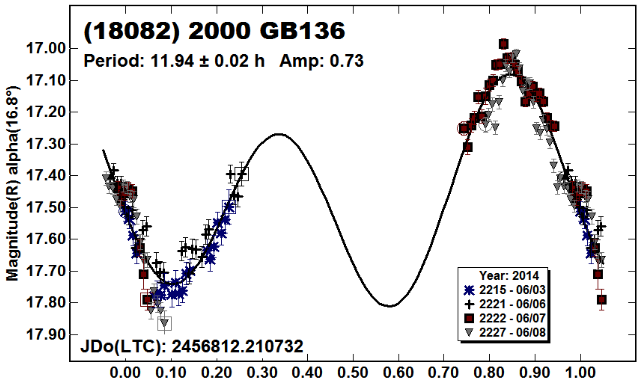
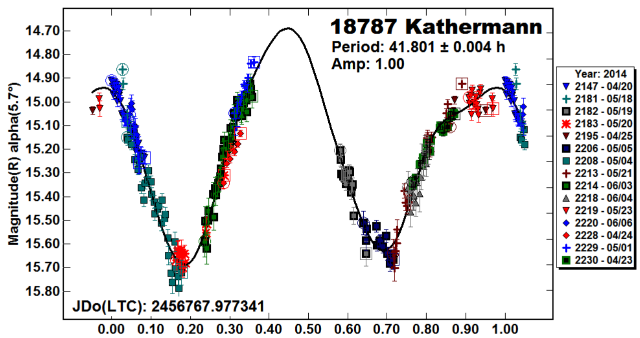
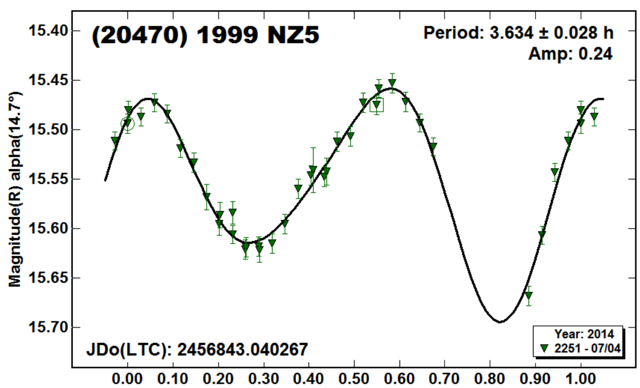
2316 - 11/02
2318 - 11/13
2320 - 11/17

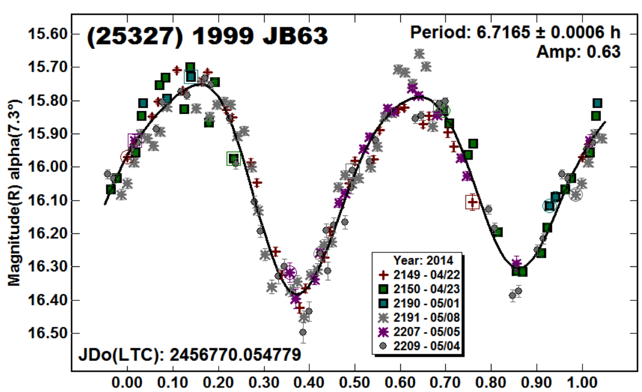

(6944) 1979 MR3
Period: 2.9126 ± 0.0002 h
Amp: 0.16
Magnitude(R) alpha(8.9°)
JDo(LTC): 2456815.894085
Year: 2014
2223 - 06/07
2226 - 06/08
2234 - 06/16
2235 - 06/17
2236 - 06/17
2237 - 06/18
2238 - 06/19
2239 - 06/20
2241 - 06/21
2242 - 06/22
2247 - 06/27
2248 - 07/03
2249 - 07/03
2250 - 07/04

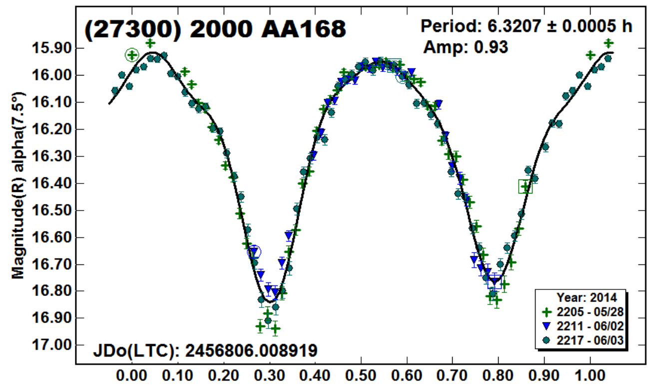

(10597) 1996 TR10
Period: 6.5969 ± 0.0003 h Amp: 0.30
Magnitude(R) alpha(12.3°)
JDo(LTC): 2456770.024571
Year: 2014
2134 - 04/22
2140 - 04/23
2158 - 04/28
2161 - 05/04
2166 - 05/08
2168 - 05/09
2199 - 05/22
2200 - 05/25

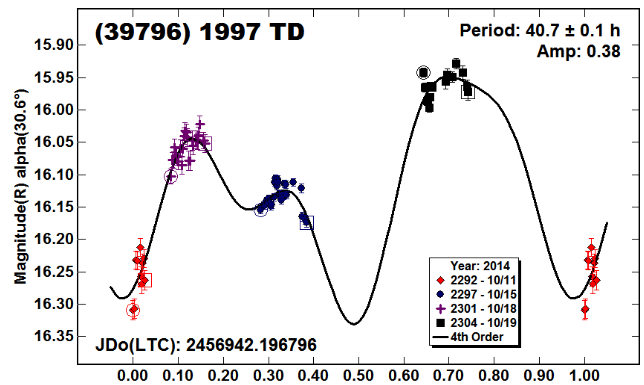

(18082) 2000 GB136
Period: 11.94 ± 0.02 h   Amp: 0.73
Magnitude(R) alpha(16.8°)
JDo(LTC): 2456812.210732
Year: 2014
2215 - 06/03
2221 - 06/06
2222 - 06/07
2227 - 06/08

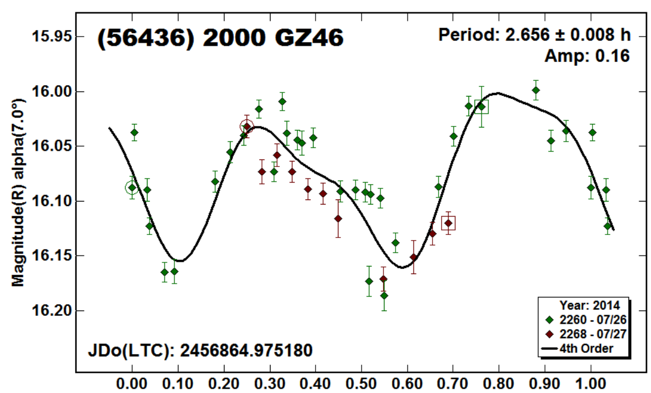

18787 Kathermann
Period: 41.801 ± 0.004 h
Amp: 1.00
Magnitude(R) alpha(5.7°)
JDo(LTC): 2456767.977341
Year: 2014

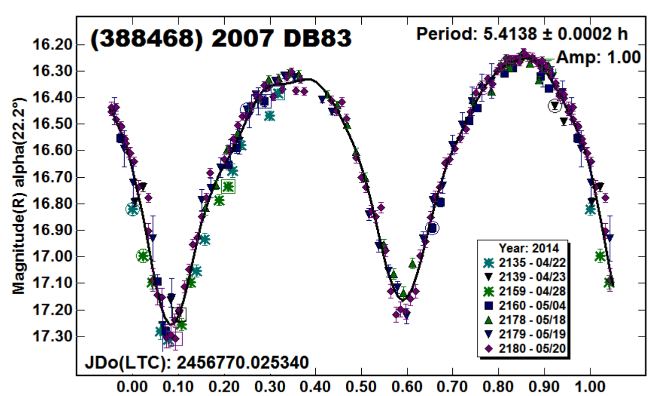

(20470) 1999 NZ5
Period: 3.634 ± 0.028 h
Amp: 0.24
Magnitude(R) alpha(14.7°)
JDo(LTC): 2456843.040267
Year: 2014
2251 - 07/04


(25327) 1999 JB63
Period: 6.7165 ± 0.0006 h
Amp: 0.63
Magnitude(R) alpha(7.3°)
JDo(LTC): 2456770.054779
Year: 2014
2149 - 04/22
2150 - 04/23
2190 - 05/01
2191 - 05/08
2207 - 05/05
2209 - 05/04


(27300) 2000 AA168
Period: 6.3207 ± 0.0005 h
Amp: 0.93
Magnitude(R) alpha(7.5°)
JDo(LTC): 2456806.008919
Year: 2014
2205 - 05/28
2211 - 06/02
2217 - 06/03


(39796) 1997 TD
Period: 40.7 ± 0.1 h
Amp: 0.38
Magnitude(R) alpha(30.6°)
JDo(LTC): 2456942.196796
Year: 2014
2292 - 10/11
2297 - 10/15
2301 - 10/18
2304 - 10/19
4th Order


(56436) 2000 GZ46
Period: 2.656 ± 0.008 h
Amp: 0.16
Magnitude(R) alpha(7.0°)
JDo(LTC): 2456864.975180
Year: 2014
2260 - 07/26
2268 - 07/27
4th Order


(388468) 2007 DB83
Period: 5.4138 ± 0.0002 h
Amp: 1.00
Magnitude(R) alpha(22.2°)
JDo(LTC): 2456770.025340
Year: 2014
2135 - 04/22
2139 - 04/23
2159 - 04/28
2160 - 05/04
2178 - 05/18
2179 - 05/19
2180 - 05/20

#	Name	mm/dd 2014 start-end	Inst	Period (h)	PE	Amp (mag)	AE	H	Dia (km)	Phase	L_{PAB}	B_{PAB}
788	Hohensteina	07/26 08/10	14i	33.02 43.49	0.01 0.02	0.18 0.17	0.05 0.05	8.6	105.15	13.4 16.5	274	17
749	Malzovia	05/13 06/15	10i	5.9275	0.0002	0.30	0.02	11.82	13.55	10.7	245	6.4
1706	Dieckvoss	04/08 05/17	14i	2.58944	0.00005	0.12	0.03	12.9	8.26	13.0 11.0	217.2 220.2	-2.6 -2.3
1741	Giclas	02/20	24if	3.107	0.001	0.12	0.02	11.4	28.96	4.1	160.9	3.4
1796	Riga	02/03 04/01	14i	22.226	0.001	0.40	0.05	9.84	59.4	7.3 15.0	142	-20 -15.8
2002	Euler	07/06 07/07	14i	5.993	0.004	0.30	0.02	12.3	10.86	20	298	10
2110	Moore- Sitterly	07/08	14i	3.3445	0.0001	0.50	0.02	13.2	7.18	24.5	321.6	0.3
2691	Sersic	02/03 02/09	24if	3.885 27.17*	0.001 0.01	0.20 0.50	0.05 0.05	13.1	7.51	26.5 24.5	198.2 204.6	-3.3
2478	Tokai	04/30 05/06	24if	25.97 *	0.11	1.0	0.1	12	12.47	7.0 10.0	206.9 207.2	-1.8 -1.6
4555	Josefaperez	07/26 10/22	14i	2.8848	0.0002	0.26	0.02	13.8	5.44	6.4 30.6	307.9 328.1	6.4 -0.8
4563	Kahnia	10/04 10/15	14i	12.416	0.002	0.44	0.02	13.2	7.18	7.4 4.9	18.6 19.5	-6.6 -6.8
4765	Wasserburg	10/19 11/17	14i	3.6280	0.0005	0.07	0.02	13.7	5.7	17.3 11.3, 11.7	45.7 45.8	-21 -16.8
5647	1990 TZ	13/12/08 14/01/30	10i	6.13979	0.00001	0.11	0.02	12	12.47	13.9 26.5	88.7 96.2	-14.3 -24
5510	1988 RF7	08/10	14i	3.21	0.45	0.05	0.01	13.4	6.54	24.8	347.4	-6.6
6181	Bobweber	13/12/28 14/02/07	14i	2.7576 39.4 *	0.0001 0.1	0.15 0.30	0.01 0.05	12.5	6.25	4.4 17.7	101.7 104.7	4.4 1.7
6944	1979 MR3	06/07 07/04	24if	2.9126	0.0002	0.16	0.04	14.2	4.53	8.6 20.2	245.6 248.4	8.9 7.3
8091	1992 BG	04/23 05/25	24if	8.5626	0.0003	1.11	0.03	13.7	5.7	21.4 10.1	246.7 250.4	13.6 14.2
8107	1995 BR4	12/16 01/16	24if	6.9786	0.0003	0.37	0.01	13.8	5.44	13.0 4.3, 7.2	104 105.6	-7.6 -6.4
10208	Germanicus	10/27 11/17	14i	3.1291	0.0002	0.10	0.02	14.4	4.13	8.2 4.9	45.6 46.6	0.2 -0.6
10597	1996 TR10	04/22 05/25	14i	6.5969	0.0003	0.30	0.01	13	7.87	12.5 8.9, 12.5	228.4 230.2	13.3 14.8
18082	2000 GB136	06/03 06/08	14i	11.94	0.02	0.73	0.01	14.2	4.53	17.0 14.8	278.7 279.4	-3.2 -3.6
18787	Kathermann	04/20 06/06	14i	41.801	0.004	1.00	0.05	14.6	3.77	5.9 22.1	213.6 219.5	7.6 2.9
25327	1999 JB63	04/22 05/08	24if	6.7165	0.0006	0.63	0.03	13.9	5.2	7.3 9.8	213.7 214.6	11.5 9.9
20470	1999 NZ5	07/04	14i	3.634	0.028	0.24	0.02	13.5	6.25	14.8	299.8	12.5
27300	2000 AA168	05/28 06/03	24if	6.3207	0.0005	0.93	0.03	13.7	5.7	7.5	247.1	12.8
39796	1997 TD	10/15 10/19	24ib	40.7	0.1	0.38	0.03	15.7	2.27	28.6	44.3	-19.7
56436	2000 GZ46	07/26	24if	2.656	0.008	0.16	0.04	14.7	3.6	7.1	307.3	8.1
388468	2007 DB83	04/22 05/20	14i	5.4138	0.0002	1.00	0.02	18.29	0.69	22.6 0.3, 3.8	223.6 236.5	11.5 -1.6

Table II. 24i: 0.61-m+U42, 14i: SCT 0.35-m, 10i: SCT 0.2-5m. *Orbital period of the satellite of the binary asteroid. The Phase column gives the solar phase angle on the first and last date. If there are three values, the phase angle reached a minimum value during the period. The phase angle bisector columns give the values for the first and last date of observation.