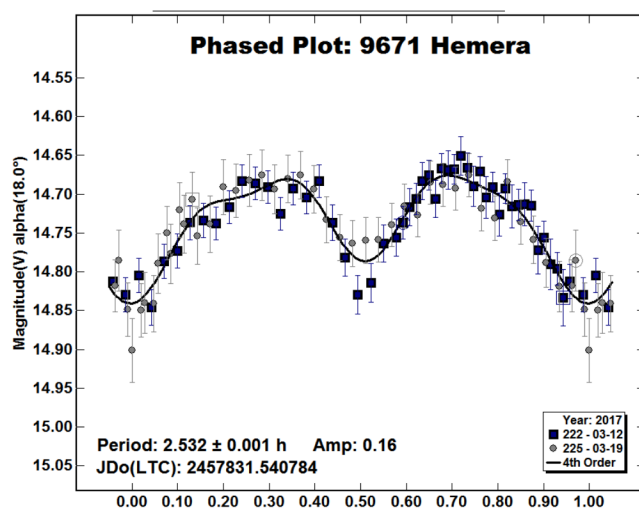




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LIGHTCURVE ANALYSIS OF ASTEROIDS FROM BMO AND DRO IN 2015

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Photometric observations of selected asteroids were done from Blue Mountains Observatory (BMO) and Darling Range Observatory (DRO) in 2015. The observations were made during a favorable apparition for each asteroid. Most of these objects had poorly defined lightcurves or were never worked in the past.

CCD photometric observations were made in 2015 from Blue Mountains Observatory by Oey and Williams while observations from Darling Range Observatory were by Groom. Five telescope systems were used for the observations (see Table I). Further information of the instruments used at BMO can be found at BMO website (BMO 2015). Table II shows the absolute magnitude (*H*) and the instruments used for each asteroid.

Obs	Scope	Ap (m)	<i>f</i>	Camera	Pixel	Bin	Scale
DRO	R12	0.30	7.4	ST-8XME	9.0	1x1	0.84
BMO	B14	0.35	6.0	ST-8XME	9.0	1x1	0.88
BMO	B5	0.12	7.5	ST-8300M	5.4	3x3	3.51
BMO	B24	0.61	6.8	U42	13.5	1x1	0.70
BMO	B12	0.30	5.5	ST-10XME	6.8	2x2	1.72

Table I. Equipment specifications. The Scope column gives the code used in Table II. Pixels sizes are in microns. The Scale is arcsec/pixel. BMO = Blue Mountains Observatory. DRO = Darling Range Observatory.

Unless otherwise specified, all images were taken unfiltered with exposures of 300s to maximize SNR but at the same time provide sufficient data point frequency for most common rotational periods. Data measurement and reduction was done using *MPO Canopus* V10. The reduction used Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989).

Calibration of the data was done using the *MPO Canopus* MPOSC3 catalog. The comparison stars used Johnson-Cousins R magnitudes that were converted from 2MASS J-K values. This resulted in internal consistency of < 0.05 mag however due to interstellar reddening, this result was inconsistent and required some adjustment in the zero point to compensate (Warner, 2007). The Comp Star Selector (CSS) feature in *MPO Canopus* was used to limit the comparison stars to near solar color to decrease errors caused by second order extinction.

176 Iduna was observed by Alton (2008) who derived a period of 11.2880 h from data covering several rotations. Despite a less reliable result from a single coverage, the result from BMO of 11.2928 h was in agreement.

Number	H	Group	Comment
176	8.30	MB-O	B5, B12
495	10.78	Nysa	B14, D12
908	10.69	MB-I	B24, B14, D12
910	10.50	MB-O	B5, B14
973	10.0	MB-O	B14
1264	9.60	MB-O	B24, B14, B12, B5
1566	16.90	Apollo	B24, B14
1685	18.60	Apollo	B14, D12
30776	15.10	MB	B14
44091	15.30	MB	B14
70799	15.50	MB	B24
77357	15.50	MB	B24
141527	18.90	Apollo	B24, B14, B12, B5
163696	16.50	Apollo	B24, B14, D12
413577	20.30	Aten	B14
2015 FS332	18.40	Apollo	B24

Table II. The H values are from the MPC. The orbital groups are from the LCDB (Warner et al., 2009a). MB = Main-belt, -I = inner, -O = outer.

495 Eulalia was observed for shape modelling and H-G determination. Each session was of short duration but sufficient to show the synodic period of 28.996 h consistent with previous work by Warner (2014) that showed a smaller amplitude of 0.15 mag compared to 0.40 mag due to the observations being at different phase angles.

908 Buda was observed on three separate times in 2015 and 2016 to get a large separation in phase angle during the apparition for shape modelling and H-G studies. The period found on the two occasions in 2015 September and December is consistent with result found previously by Warner (2009b).

973 Aralia was observed by Alkema (2013) and found to have a period of 7.291 h. Although the period obtained from BMO was consistent, our coverage over several rotations provided a more reliable result.

1264 Letaba. The previous work done by Stephens (2003) and Behrend (2006, 2016) derived the period of 32.16 h and >12 h, respectively. The observations from BMO were made from 2016 March 5 to July 9. The 23 nights of observations produced 873 data points. The best fit was to a bimodal lightcurve with a period of 63.74 h amplitude of 0.13 mag. Once the rotation period was found, some minor adjustments of the zero points to seven of the

sessions were done to within 0.05 mag limited by the MPOSC3 catalogue precision error for further refinement to the rotation period. Only data on Session 7 was not reduced with CSS method and the lightcurve was based on relative magnitude adjusted to fit into the main light curve. This asteroid may be a tumbler due to the inconsistent slope of its light curve segments.

When an attempting to match the period derived by Stephens (2003) using zero point adjustments, a 31.98 h period was found. Arbitrarily adjusting the zero-point based on relative magnitude may create a variety of low amplitude lightcurve periods; hence our latest period determination was more reliable. Due to the challenging nature of this asteroid, future observations including long sessions with more accurate data (± 0.03 mag) will be needed to find a more reliable period.

1566 Icarus was observed in 2015 June during its close approach. The lightcurve was derived from data from two nights of observations. The period of 2.2794 ± 0.0005 h is consistent with the period obtained by Warner (2015). The fast-moving NEA posed a challenge when it came to data reduction. During the close approach, the rapid sky motion of the asteroid required multiple sessions due to the small field-of-view. In turn, that meant different sets of comparison stars were required for the calibration. Due to the calibration errors described earlier, some adjustment of the zero points was necessary to get the best fit in the Fourier analysis.

1685 Toro was a Near Earth asteroid (NEA) observed in early 2016 July for the studies of the YORP effect. It had been observed previously by Warner (2013) and Higgins (2008) who derived the rotation period of 10.205 h and 10.1862 h, respectively. These values were consistent with the current 10.202 h.

(30776) 1987 QY, (70799) 1999 VY55, (77357) 2001 FW125 were all targets of opportunity. Only a single night data was obtained for each. There were no previously reported periods. The results here are only best estimates; they could vary up to ± 2 h.

(44091) 1998 FB106 was a target of opportunity. The derived rotation period was more reliable due to three overlapping multi-night sessions. There were no previous results found.

(141527) 2002 FG7 was observed during an exceptionally favourable close approach. Excellent data were obtained while it

Number	Name	2015 mm/dd	Pts	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
176	Iduna	01/07-01/29	345	10	116	-27	11.2928	0.0005	0.34	0.02
495	Eulalia	04/15-06/28	312	22, 6	3	289	28.998	0.002	0.37	0.02
908	Buda	08/29-10/30	197	20, 8, 10	21	-16	14.576	0.002	0.13	0.02
908	Buda	12/10-12/31	90	22, 25	28	-10	14.604	0.007	0.10	0.02
910	Anneliese	05/06-05/09	58	1	227	1	12.15	0.02	0.15	0.05
973	Aralia	05/05-05/07	183	8	188	-8	7.3662	0.0003	0.23	0.02
1264	Letaba	03/05-07/09	926	13, 22	188	-20	63.74	0.01	0.13	0.04
1566	Icarus	06/19-06/20	422	68, 61	234	15	2.2794	0.0005	0.10	0.03
1685	Toro	07/01-07/06	142	23, 27	251	-3	10.202	0.002	0.80	0.02
30776	1987 QY	09/14-09/14	43	2	350	2	5.8	0.4	0.21	0.03
44091	1998 FB106	06/04-06/06	145	7	241	0	5.20	0.01	0.28	0.05
70799	1999 VY55	10/06-10/06	35	6	3	4	3.4	0.3	0.23	0.03
77357	2001 FW125	01/23-01/23	24	4	125	-7	2.65	0.04	0.26	0.03
141527	2002 FG7	03/14-03/19	1292	67, 21	182	-23	6.3140	0.0003	1.00	0.01
163696	2003 EB50	11/24-12/04	854	94, 60	25	-20	62.02	0.02	1.64	0.03
413577	2005 UL5	11/18-11/18	111	61	84	-14	4.0	0.3	0.50	0.03
2015	FS332	10/24-11/06	144	47	25	-35	2.3998	0.0002	0.55	0.05

Table III. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. If there are three values, the middle value is for the minimum during the range. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

was located deep in the southern hemisphere.

(163696) 2003 EB50. This Apollo NEA was observed in early 2015 December during its close approach. Its period was found to be 62.02 h based on an incomplete bimodal light curve with 1.64 mag amplitude. This result is consistent with observations from Arecibo radar (2015) observations and that from Warner (2016).

(413577) 2005 UL5. This Aten NEA was very close to the plane of the Milky Way during its fly-by in 2015 November 2015. It was a difficult target and, unfortunately, it was not possible to find a reliable rotation period.

2015 FS332 was observed to support radar modelling. The rotation period of 2.3998 h was consistent with their result. This appears to be the first reported lightcurve period for the asteroid.

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