COLLABORATIVE ASTEROID PHOTOMETRY OF THREE MAIN BELT ASTEROIDS

Robert A. Koff
1915 W. 101st Avenue
Thornton, CO 80260 USA
Bob.Koff@worldnet.att.net

Stephen M. Brincat
Fl.5 Ent.B, Silver Jubilee Apt.,
Ta' Zwejt, San Gwann SGN 09, Malta
sbrincat@orbit.net.mt

(Received: 15 June Revised: 20 June)

Overcoming the 24 hour commensurability of the Earth's rotation for mid-latitude observatories requires multiple sites widely separated in longitude. We report a collaborative lightcurve investigation between Thornton Observatory in the United States and Flarestar Observatory in Malta (separated in longitude by 119 degrees). Asteroid (565) Marbachia was determined to have a most likely period of 5.084 ± 0.005 hours and an amplitude of 0.22 mag. Asteroid (442) Eichsfeldia was found to have a period of 11.871 ± 0.004 hours with an amplitude of 0.38 mag. Asteroid (509) Iolanda exhibited a period of 12.306 ± 0.003 hours with an amplitude of 0.35 mag. Unraveling the near 24-hour commensurabilities for (442) and (509) demonstrates the value of the widely spaced longitude collaboration.

The Observatories and Equipment

Thornton Observatory is located in Thornton, Colorado, at an elevation of 5530'. Since 1997, the observatory, operating as Minor Planet Center observatory code 713, has been performing asteroid astrometry and the related photometry. Details of the observatory equipment may be found in Koff (2000).

Flarestar Observatory is located in San Gwann, Malta at an altitude of 300 feet. In 1999, Flarestar started operation as Minor Planet Center observatory code 171 and has been performing asteroid astrometry. The observatory employs a 25cm Meade Schmidt-Cassegrain telescope mounted on an LXD 650 German equatorial mount with a Computer Drive System. For photometry and astrometry the telescope is set to operate through an f/3.3 focal reducer, yielding an effective focal length of 660mm and an f-ratio of f/2.6. The imaging CCD camera is a Starlight Express HX516 and was used at full resolution of 660X500 square pixels of 7.4 microns each. This 16-bit camera uses the SONY ICX084AL interline chip. The resulting image scale is 2.33"/pixel, which fits well to the average seeing conditions at the site. All images were unguided and unfiltered. Peak response for the CCD stands at 550nm. That is situated very near the V band.

Procedure

Targets were selected based on their magnitude and position in the sky, to maximize the length of time they would be observable, particularly under the restricted sky visibility of Thornton Observatory. Targets were selected for which no lightcurve data had been previously reported (Harris, 1997).

The images were obtained in unfiltered light. The differential photometry was measured using the program "Canopus" by Brian Warner, which uses aperture photometry. Magnitudes were calculated using reference stars from the LONEOS catalog. The same reference stars were used for each individual asteroid, but comparison stars differed from night-to-night due to movement of the asteroid. This system does not permit calculation of absolute magnitudes, and has the potential for night-to-night variation in the calibration.

Lightcurves were prepared using "Canopus" based on the method developed by Dr. Alan Harris (Harris et al, 1989). This program allows compensation for night-to-night comparison star variation by manually shifting individual night's magnitude scales to obtain a best fit. Such adjustment is especially necessary when combing data from two observatories using cameras with different spectral sensitivities.

This investigation enjoyed the ongoing support and advice of Dr. Petr Pravec of the Ondrejov Observatory in the Czech Republic.

Observations and Results

(565) Marbachia

Marbachia was observed initially by Thornton Observatory on March 1, 2000. Initial results indicated a period near 6 hours, which would make a lightcurve difficult to obtain from one location. Assistance was requested from Flarestar Observatory, with which Thornton had an ongoing working relationship.

Observations from Thornton were made on 4 nights during the period from March 1, 2000 to March 9, 2000. A total of 94 images were taken, of which 83 were usable. Exposure times at Thornton these investigations were four minutes each. Images were taken at 10-minute intervals. Dark frames and flat fields were used to calibrate each image.

At Flarestar, observations were made on two nights, on March 3-4, 2000 and March 7-8, 2000. A total of 29 images were made, of which 24 were usable. Exposure times and intervals were variable. Images were not calibrated with dark frames or flat field frames.

Figure 1 shows the resulting lightcurve. The zero point of the curve is J.D. 2451604.6959. The period was determined to be 5.084 hours ± 0.005 hours, with an amplitude of 0.22 ± 0.03. The period was confirmed by Dr. Pravec as the most probable. However, Dr. Pravec notes that there is another solution at 4.59 hours which cannot be ruled out. Within the instrumental system, the mean measured magnitude was 12.94.

(442) Eichsfeldia

Building on the experience from the collaboration on (565), a lightcurve investigation was begun for (442) Eichsfeldia, as a collaborative effort from the outset. The asteroid was observed on 9 nights beginning on March 27, 2000 and ending on April 28, 2000. A total of 96 usable images were taken on three nights from Flarestar, followed by 153 usable images taken on 6 nights from Thornton. Images were obtained in unfiltered light. Exposure times at Thornton for this investigation were four minutes each. Images were taken at 10-minute intervals. Dark frames and flat fields were used to calibrate each image. At Flarestar, exposure times were 80 seconds at four-minute intervals. Images were dark subtracted.

Figure 2 shows the resulting lightcurve. The zero point of the curve is J.D. 2451631.4364. The period was determined to be 11.871 hours ± 0.004 hours, and Dr. Pravec found the solution to be unique. The amplitude of the curve is 0.38 ± 0.03. The mean measured instrumental magnitude was 12.40.

The period of the lightcurve is such that, from any one observatory, the curve shifts only 15.6 minutes per day. Thus, one observer would have to observe this object for 46 days to see one complete cycle, with no overlap. This effect is evident in Figure 2, by noting that each observatory examined roughly 70% of the asteroid, even though the observations covered a period of 32 days.

(509) Iolanda

With two successful collaborative lightcurves completed, a lightcurve investigation was begun at Flarestar Observatory of asteroid (509) Iolanda. Thornton Observatory stood by to assist as needed. The asteroid was observed from Flarestar on 3 nights beginning on May 4, 2000 and ending on June 6, 2000. A total of 118 usable images were taken. Observations were unfiltered. Exposure times were 80 seconds. Images were taken at 6-minute intervals. Dark frames were used to calibrate each image, and, in addition, flat fields were used for image calibration on the June 1 and June 6, 2000 observations.

It became apparent that the period of this object was near 12 hours, and Thornton Observatory took up observation of the object on June 8, 2000. 25 usable observations were made, each of four minutes exposure. The interval between observations was 10 minutes. All images were calibrated with dark frames and flat fields. Images were unfiltered.

Figure 3 shows the resulting lightcurve. The zero point of the curve is J.D. 2451669.3948. The period was determined to be 12.306 hours ± 0.003 hours, and Dr. Pravec found the solution to be unique. The amplitude of the curve is 0.35 ± 0.03. The mean measured instrumental magnitude was 12.86.

This lightcurve, as was the case with (442), would have been difficult to determine from one observatory, due to the proximity of the period to 12 hours. Again, the collaboration of two observatories made the determination practical.

Acknowledgments

Many thanks to Dr. Petr Pravec of Ondrejov Observatory for his help and support of the Thornton Observatory/Flarestar Observatory lightcurve project. Thanks also to Brian Warner for his continuing work on the program "Canopus", which has made it possible for amateurs to analyze and share lightcurve data.

References

Harris, A. W., Young, J. W. Bowell, E., Martin, L. J., Millis, R. L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H. J. , Debehogne, H., and Zeigler, K. W., (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." Icarus **77**, pp. 171-186.

Harris, Alan W. (1997). "Minor Planet Lightcurve Parameters", On the Minor Planet Center website: http://cfa-www.harvard.edu /iau/lists/LightcurveDat.html, or on the CALL website: http://www.MinorPlanetObserver.com/astlc/default.htm

Koff, R. A. (2000). "Rotation Period and Lightcurve of Mars-Crossing Asteroid 1999 US3." Minor Plan. Bull. **27**, 19-21.

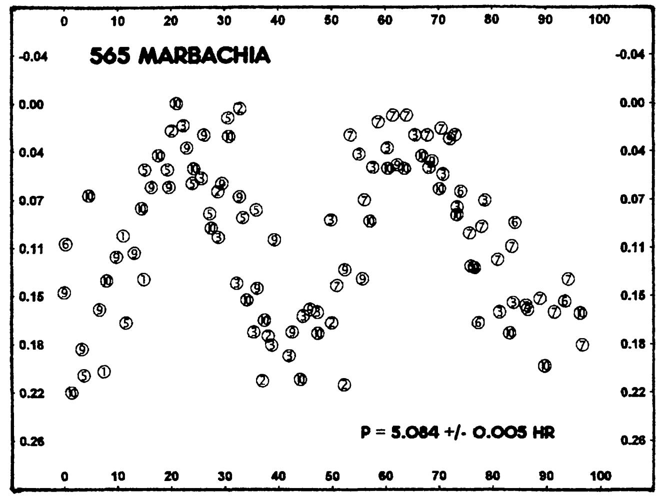

Figure 1. Lightcurve of (565) Marbachia, based on a period of 5.084 hours ± 0.005 Hours. Ordinate is relative magnitude. Curves 1 (3/3/2000), 2 (3/4/2000), 5 (3/8/2000), and 6 (3/7/2000) are Flarestar observations. Curves 3 (3/7/2000), 7 (3/9/2000), 9 (3/1/2000) and 10 (3/4/2000) are Thornton observations.

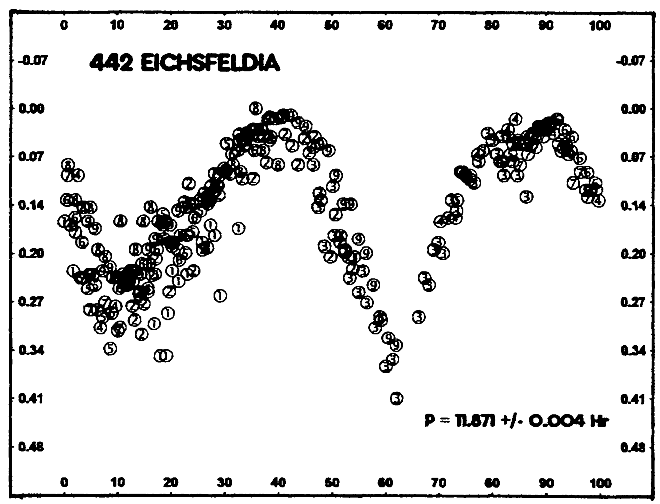

Figure 2. Lightcurve of (442) Eichsfeldia, based on a period of 11.871 hours ± 0.004 Hours. Ordinate is relative magnitude. Curves 1 (3/27-28/2000), 2 (4/6-7/2000) and 3 (4/22-23/2000) are Flarestar observations. Curves 4 (4/2/2000), 5 (4/8/2000), 6 (4/12/2000), 7 (4/14/2000), 8 (4/25/2000) and 9 (4/28/2000) are Thornton observations.

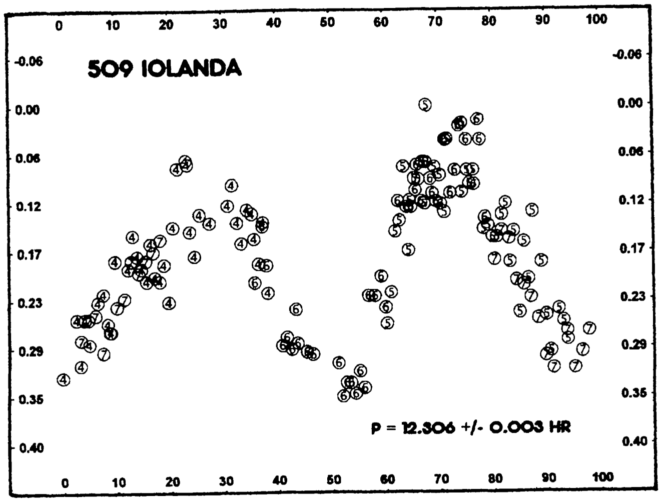

Figure 3. Lightcurve of (509) Iolanda, based on a period of 12.306 hours ± 0.003 hours. Ordinate is relative magnitude. Curves 4 (5/4-5/2000), 5(6/1-2/2000) and 6 (6/5-6/2000) are Flarestar observations. Curve 7 (6/8/2000) is Thornton observations.

EDITOR'S NOTE:

The authors and Dr. Pravec are to be especially congratulated for their international collaborative effort yielding otherwise unobtainable results. It is hoped that this will be the first of many such collaborations within the Minor Planets Section.

OPPORTUNITIES FOR OBSERVATIONS OF MINOR PLANETS HAVING CLOSE APPROACHES WITH (1) CERES, (2) PALLAS, (4) VESTA

Olga Kochetova
Institute of Applied Astronomy of RAS
nab. Kutuzova 10
St.Petersburg, 191187
Russia

(Received: 14 June Revised: 11 July)

It is proposed to observe some small minor planets having close approaches with (1) Ceres, (2) Pallas, (4) Vesta during the next two years. These observations can be of use for improving the mass values of these large asteroids.

Close approaches of minor planets with each other give important opportunities for determining the mass of the larger minor planet from its perturbing influence on the smaller body. In the paper (Hilton et al. 1996), the motion of minor planets with numbers from 1 to 4589 over the time interval from 1950 January 1 to 2017 July 16 has been analyzed. The authors have found 135 approaches for 21 of the most massive minor planets with other ones within distances less or equal to 0.05 au.

Since the time when the work of Hilton and his co-authors was completed the number of minor planets with well-determined orbits has tripled. Recently in the course of investigation of minor planets with numbers greater than 4583 I found a number of close approaches of these planets with Ceres, Pallas and Vesta. Some of these results are presented in Table I. Most entries included in the table are close to the present epoch. Among them one can see very interesting cascades of approaches by bodies (such as 7859 and 10325) with commensurable mean motions.

Readers are invited to take part in observations of perturbed minor planets during their next oppositions and later on. It should be taken in mind that due consideration must be given to the precision of observations. The required precision of positional observations is on the order of few tenth of arcsecond.

More detailed information and near-oppositional ephemerides can be obtained at e-mail addresses: 1136@ita.spb.su,kom@quasar .ipa.nw.ru

References

Hilton, J.L., Seidelmann, P.K., Middour, J. (1996). "Prospects for determining asteroid masses". Astron.J. 112, 2319-2329.

Perturbing asteroid	Perturbed asteroid	Date of close approach	Minimal distance (au)	Nearest oppositions	Brightness in opposition
1	7859	1992 4 11.0	.051		
1	7859	1996 11 17.0	.024		
1	7859	2001 6 24.0	.037	2001 07 09.1	17.2
1	7859	2006 1 30.0	.043	2006 08 20.6	16.7
1	8182	2001 5 6.0	.054	2001 07 09.6	16.3
1	9605	2001 4 23.0	.052	2001 07 08.7	18.3
1	9973	1968 12 25.0	.027		
1	9973	2001 3 18.0	.028	2001 07 10.1	17.4
1	9990	2001 1 10.0	.038	2001 07 13.2	16.6
1	11353	2001 2 25.0	.039	2001 07 11.2	16.8
1	13924	2000 7 27.0	.030	2001 07 18.4	16.4
1	13953	2000 5 11.0	.012	2001 06 24.1	17.7
1	14389	2001 1 6.0	.004	2001 07 18.3	16.3
1	14440	2001 1 11.0	.032	2001 07 13.1	17.2
1	14493	2000 9 15.0	.058	2001 09 01.5	15.6
2	4971	2000 7 18.0	.024	2001 05 31.3	16.7
2	13662	2000 7 6.0	.033	2001 07 19.2	17.2
2	13719	2000 6 19.0	.043	2001 08 01.2	16.6
4	343	2000 10 7.0	.039	2000 07 22.1	14.6
				2002 02 11.2	14.3
4	2190	2002 5 12.0	.030	2001 11 27.5	15.8
4	4789	1956 11 3.0	.029		
4	4789	2000 5 25.0	.024	2000 07 17.3	15.9
				2002 01 23.9	16.6
4	7023	2000 3 28.0	.052	2000 07 22.3	15.1
				2001 12 09.1	16.6
4	10325	1998 1 6.0	.051		
4	10325	2001 8 24.0	.029	2001 12 01.3	17.2
4	10325	2005 4 13.0	.023	2004 09 26.5	17.9
4	10325	2008 11 29.0	.042	2008 11 01.4	17.7