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LIGHTCURVES AND PERIODS FOR ASTEROIDS 105 ARTEMIS, 978 AIDAMINA, AND 1103 SEQUOIA

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CCD images recorded in July 2003 using a Celestron C-14 telescope yielded lightcurves and periods for three asteroids: 105 Artemis has a period of 17.80 ± 0.05 h and an amplitude of 0.09 mag; 978 Aidamina has a period of 10.099 ± 0.004 h and an amplitude of 0.1 mag; 1103 Sequoia has a period of 3.04 ± 0.01 h and an amplitude of 0.34 mag.

Introduction and Procedure

During the summer of 2003 one Rose-Hulman student (LeCrone) and a professor (Ditteon) obtained images at Oakley Observatory, which is located in Terre Haute, Indiana at an altitude of 178 m. The images were captured with a Celestron C-14 telescope operating at f/7 on a Paramount GT-1100 mount using an AP7 CCD camera. Exposures were 180 seconds.

Asteroids were selected for observation using *TheSky*, published by Software Bisque, to locate asteroids that were at an elevation angle of between 20° and 30° one hour after local sunset. In addition, *TheSky* was set to show only asteroids between 14 and 16 mag. The asteroids were cross checked with Alan Harris' list of lightcurve parameters (Harris, 2003). We tried to observe only asteroids that did not have previously reported measurements or had very uncertain published results.

Standard image processing was done using *MaxImDL*, published by Diffraction Limited. Photometric measurements and light curves were prepared using *MPO Canopus*, published by BDW Publishing.

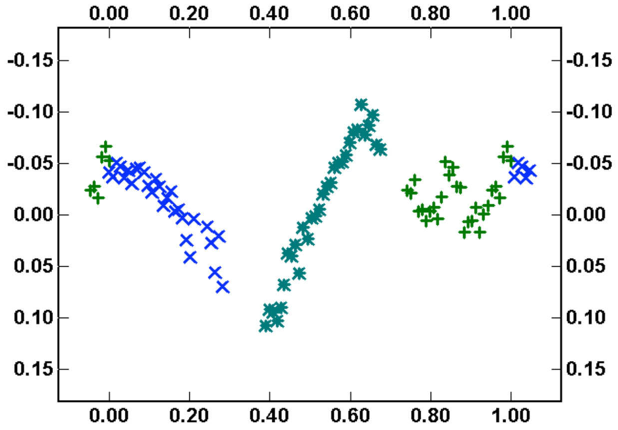
Observations and Results

A total of seven asteroids were observed during this campaign, but lightcurves were not found for all of these asteroids. If an asteroid had a very small variation in brightness, or if there was a large amount of noise, that asteroid was dropped from further observation. The data on 1499 Pori and 1775 Zimmerwald turned out to be little more than noise, while the images for 1428 Mombasa and 3484 Neugebauer were of poor quality. We report our successful results below. All of our data is available upon request.

105 Artemis

Asteroid 105 Artemis was discovered on 16 September 1868 by J. C. Watson at Ann Arbor. It was named after the Greek goddess, daughter of Zeus, and twin sister of Apollo (Schmadel, 1999). A total of 87 images were taken over three nights: 2003 July 17, 23, and 24. The data reveal a lightcurve with a 17.80 ± 0.05 h period and 0.09 mag amplitude.

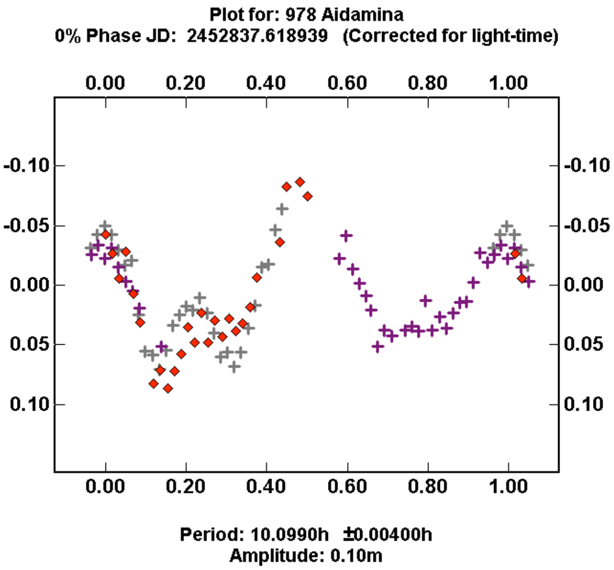
Plot for: 105 Artemis
0% Phase JD: 2452837.623430 (Corrected for light-time)



Period: 17.8300h ±0.05000h
Amplitude: 0.09m

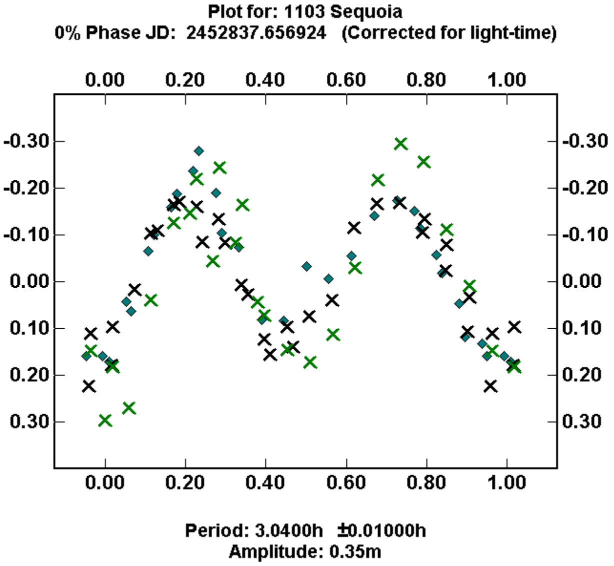
978 Aidamina

Asteroid 978 Aidamina was discovered on 18 May 1922 by S. I. Belyavskij at Simeïs and independently discovered on 30 May 1922 by M. Wolf and Heidelberg. It was named in honor of Aida Minaevna, a friend of the discoverer's family (Schmadel, 1999). A total of 86 images were taken over three nights: 2003 July 17, 23, and 24. The data reveal a lightcurve with a 10.099 ± 0.004 h period and 0.1 mag amplitude.



1103 Sequoia

Asteroid 1103 Sequoia was discovered on 9 November 1928 by W. Baade at Bergedorf. It was named after the Sequoia National Park (Schmadel, 1999). A total of 81 images were taken over five nights: 2003 July 17, 23, and 24. The data reveal a lightcurve with a 3.04 ± 0.01 h and 0.34 mag amplitude.



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2004 SPRING OBSERVING CAMPAIGN AT ROSE-HULMAN INSTITUTE: RESULTS FOR 955 ALSTEDE, 2417 MCVITTIE, 4266 WALTARI, AND 5036 TUTTLE

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CCD images recorded in February and April 2004 using the Tenagra 32 inch telescope yielded light curves and periods for four asteroids: 955 Alstede has a period of 5.19 ± 0.01 h and an amplitude of 0.25 mag; 2417 McVittie has a period of 4.934 ± 0.002 h and an amplitude of 0.31 mag; 4266 Waltari has a period of 11.200 ± 0.005 h and an amplitude of 0.11 mag; and 5036 Tuttle has a period of 3.775 ± 0.001 h and an amplitude of 0.33 mag.

Introduction and Procedure

During the winter and spring of 2004 two Rose-Hulman students (Duncan, LeCrone) and a professor (Ditteon) obtained images with the 32” Ritchey-Chretien telescope at Tenagra Observatory in Arizona. The Tenagra telescope operates at f/7 with a CCD camera using a 1024x1024x24u SITe chip (Schwartz, 2004). Exposure times were generally 90 seconds and our images were binned 2 by 2.

Asteroids were selected for observation using *TheSky*, published by Software Bisque, to locate asteroids that were at an elevation angle of between 20° and 30° one hour after local sunset. In addition, *TheSky* was set to show only asteroids between 14 and 16 mag. Bright asteroids were avoided because we pay for a minimum 60 second exposure while using this telescope. The asteroids were cross checked with Alan Harris’ list of lightcurve parameters (Harris, 2003). We tried to observe only asteroids that did not have previously reported measurements or had very uncertain published results.

Observation requests for the asteroids and Landolt reference stars were submitted by Ditteon using ASCII text files formatted for the TAO scheduling program (Schwartz, 2004). The resulting images were downloaded via ftp along with flat field, dark and bias frames. Standard image processing was done using *MaxImDL*, published by Diffraction Limited. Photometric measurements and light curves were prepared using *MPO Canopus*, published by BDW Publishing.

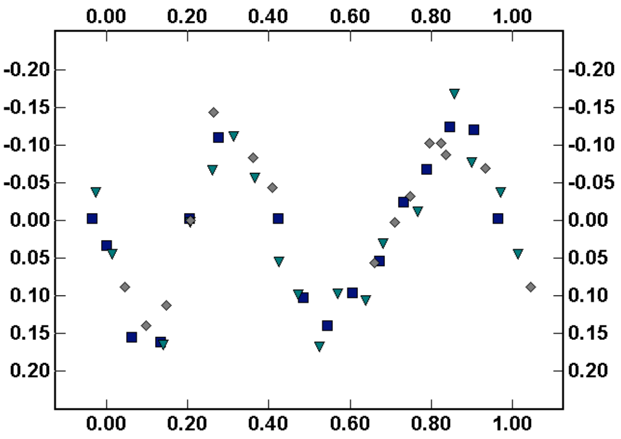
Observations and Results

A total of six asteroids were observed during this campaign, but lightcurves were not found for all of these asteroids. If an asteroid had a very small variation in brightness, or if there was a large amount of noise, that asteroid was dropped from further observation. This allowed the maximum number of quality observations with limited funds. The data on two asteroids (292 Algunde and 1511 Dalera) turned out to be little more than noise. We report our successful results below. All of our data is available upon request.

955 Alstede

Asteroid 955 Alstede was discovered on 5 August 1921 by K. Reinmuth at Heidelberg. It was named in honor of Mrs. Lina Alstede Reinmuth (Schmadel, 1999). A total of 45 images were taken over three nights: 2004 April 14, 16, and 17. The data reveal a lightcurve with a 5.19 ± 0.01 h period and 0.25 mag amplitude.

Plot for: 955 Alstede
0% Phase JD: 2453109.661882 (Corrected for light-time)

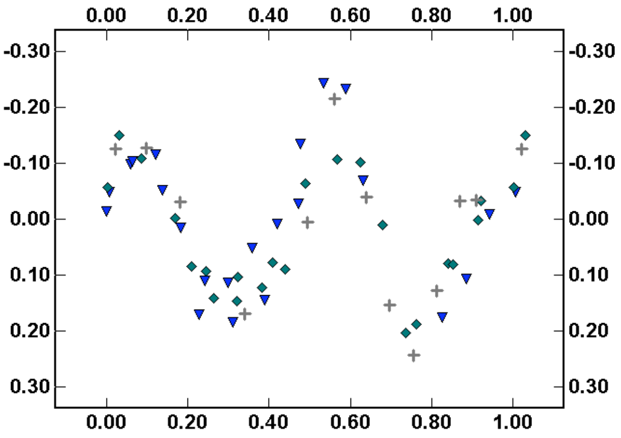


Period: 5.1900h ±0.01000h
Amplitude: 0.25m

2417 McVittie

Asteroid 2417 McVittie was discovered on 15 February 1964 at the Goethe Link Observatory at Brooklyn, Indiana. It was named in honor of George C. McVittie, astronomy department head at the University of Illinois from 1952 to 1972 and secretary of the American Astronomical Society from 1961 to 1970 (Schmadel, 1999). A total of 58 images were taken over three nights: 2004 February 13, 14, and 20. The data reveal a lightcurve with a 4.934 ± 0.02 h period and 0.31 mag amplitude.

Plot for: 2417 McVittie
0% Phase JD: 2453048.647333 (Corrected for light-time)

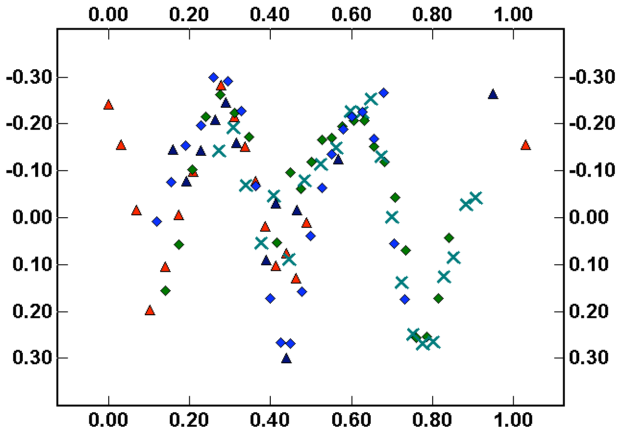


Period: 4.9340h ±0.00200h
Amplitude: 0.31m

4266 Waltari

Asteroid 4266 Waltari was discovered 28 December 1940 by Y. Väisälä at Turku. It was named in memory of Mika Waltari, a Finnish writer and member of the Academy of Finland (Schmadel, 1999). A total of 102 images were taken over five nights: 2004 February 17, 18, 19, 24, and 25. The data reveal a lightcurve with a 11.200 ± 0.005 h with 0.11 mag amplitude.

Plot for: 4266 Waltari
0% Phase JD: 2453052.617647 (Corrected for light-time)

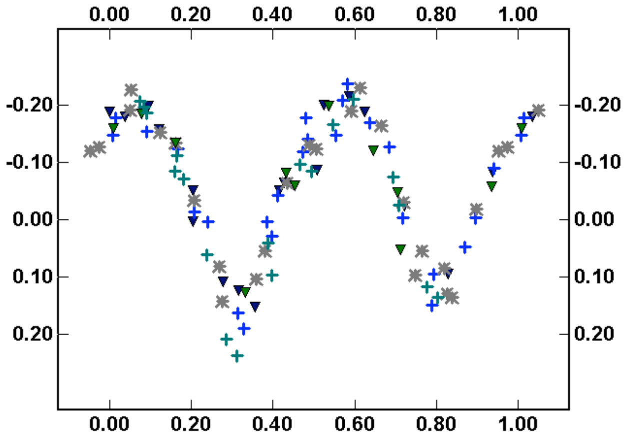


Period: 11.2000h ±0.00500h
Amplitude: 0.11m

5036 Tuttle

Asteroid 5036 Tuttle was discovered 31 October 1991 by S. Ueda and H. Kaneda at Kushiro. It was named for Horace P. Tuttle, astronomer at Harvard and the Naval Observatory in Washington (Schmadel, 1999). A total of 101 images were taken over five nights: 2004 February 17, 18, 19, 24, and 25. The data reveal a lightcurve with a 3.775 ± 0.001 h with 0.33 mag amplitude.

Plot for: 5036 Tuttle
0% Phase JD: 2453052.609139 (Corrected for light-time)



Period: 3.7550h ±0.00100h
Amplitude: 0.33m

Acknowledgments

This research was made possible by a grant from Sigma Xi to Crystal LeCrone. We also want to thank Michael Schwartz and Paulo Holvorcem for making remote observing with their telescope both possible and enjoyable.

References

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EDITORIAL: THE ELECTRONIC AGE IS COMING TO THE MPB

Beginning with the next issue (Volume 32, No. 1), the *Minor Planet Bulletin* will join the electronic age with each new issue becoming available online. Electronic access will be free of charge via:

http://www.minorplanetobserver.com/mpb/default.htm

But wait, don't panic. The *Minor Planet Bulletin* is continuing in printed form. Printed copies of the *MPB* will continue to be produced and mailed to paying subscribers, just as it has always been done for the past 31 years. The electronic age may be here, but this editor firmly believes that printed matter will continue for a long time into the future as a vitally important way to communicate and archive scientific results.

Choice and worldwide access are the tangible benefits of the electronic *MPB*. Some may choose to have an "electronic only" subscription to the *MPB* by simply checking the website every quarter, finding the latest issue, downloading it, and enjoying – all for free. We welcome voluntary contributions from those who are "electronic only" subscribers (suggesting $5 per year, but more is welcome; see the website) as there are still costs associated with producing the *MPB* regardless of print or electronic format. Most importantly, free worldwide access to the *Minor Planet Bulletin* means spreading our scientific results as widely as possible and broadly displaying the opportunities for new observers to join us.

Passion for astronomy and science will continue to be what fills the pages of the *Minor Planet Bulletin*, both literally and figuratively. For 20 years it has been the volunteer effort of Robert Werner to construct the actual pages that constitute the *Minor Planet Bulletin* and for 20+ years it has been the effort of Derald and Denise Nye to manage and distribute the print subscriptions. Now we offer thanks to Brian Warner for his voluntarily hosting the *MPB* electronic access website. But it is all about results – and without the passion and sweat of observers striving to obtain and communicate new results about these captivating little worlds we call asteroids, the *Minor Planet Bulletin* would not be here. Keep up the good work. Now the whole world will be with us on line.

ROTATION PERIOD AND LIGHTCURVE ANALYSIS OF ASTEROID 2653 PRINCIPIA

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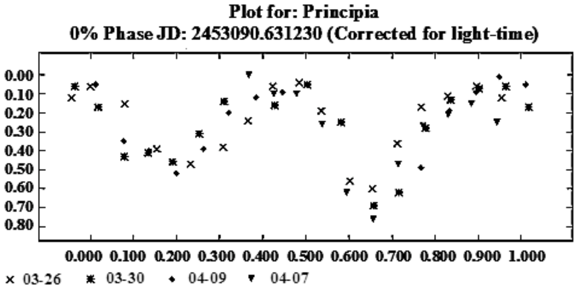
Asteroid 2653 Principia was observed during March and April of 2004. The synodic period was measured and determined to be 6.243 ± 0.002 hours with an amplitude of 0.47 magnitude.

Asteroid 2653 Principia was discovered at the Goethe Link Observatory on November 4, 1964 and was probably named after Sir Isaac Newton's work: *The Principia*. The asteroid was chosen from the list of suggested targets provided by the CALL website (Warner 2002).

Observations of Principia were made from Tenagra Observatory (Observatory code 926) in Nogales, Arizona. The observatory, located at an altitude 1312 meters, features a 0.81 m F7 Ritchey-Chrétien telescope and a 1024 x 1024x 24 micron pixel camera liquid cooled to -50º C yielding ~0.87" per pixel. Observations were conducted on 2004 UT dates March 26 and 30 and April 7 and 9. A total of 56 unfiltered images with exposure times of 100s were analyzed using Canopus. The lightcurve, shown in accompanying figure, exhibits a period of 6.243 ± 0.002 hours and amplitude of 0.47 magnitude



Acknowledgements

Thanks to Steven Slivan for his advice concerning the selection of this asteroid, and many thanks to Michael Schwartz and Paulo Halvorcem at Tenagra Observatory.

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LIGHTCURVE ANALYSIS FOR 6743 LIU

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The lightcurve for the Flora family asteroid 6743 Liu was determined using images taken by Yeung in 2004 April. The images were measured and the period analyzed by Warner. The lightcurve was found to have a synodic period of 7.364±0.005h and amplitude of 0.40±0.02m.

Forming a Collaboration

Asteroid 6743 Liu was discovered in 1994 April by K. Endate and K. Watanabe at Kitami. It is named in honor of Joseph H.C. Liu, who played a leading role in establishing the Hong Kong Space Museum and was its first director. Author Yeung hoped to inspire members of the Hong Kong Astronomy Club to take up asteroid lightcurve work by determining the lightcurve of the asteroid and having it published in the club's newsletter. "I picked Liu since it was named after a much respected retired amateur astronomer to whom they could relate, which should make it more interesting not only to HK amateurs but to me as well." (Yeung 2004). Unfortunately, timing was not good for Yeung to do both the imaging and analysis since he was involved in a site survey and moving his observatory to a new location when the asteroid came to opposition at the same time (2004 April). Yeung then contacted Warner to see if the latter would be interested in measuring and analyzing the data. Thus, a collaboration was formed.

Observations and Results

Using a 0.46m f/2.8 reflector and SBIG ST-10XME CCD camera, Yeung obtained images of the asteroid on the nights of 2004 April 12, 13, 14, and 16. Exposures were 240 seconds. Dark frames were applied to the images but no flats before they were copied to a CD and sent to Warner at the Palmer Divide Observatory. The images were measured using MPO Canopus, which uses aperture photometry and was developed by Warner. The period of the lightcurve data was then analyzed within Canopus, which implements the Fourier analysis routine developed by Harris (1989). The synodic period of the lightcurve was found to be 7.364±0.005h and its amplitude 0.40±0.02m. The plot in Figure 1 shows the data phased to this period. In all, 142 data points were used in the analysis. The table below shows the pertinent information about the asteroid's phase angle and phase angle bisector.

DATE	Phase	PAB	
2004	Angle	Long	Lat
04/12	6.8	208.4	8.4
04/13	6.4	208.4	8.3
04/14	6.1	208.5	8.3
04/16	5.7	208.6	8.2

The principal elements for Liu are: semi-major axis, 2.235AU; inclination, 8.121°; and eccentricity, 0.2060. Using a formula from Harris (2003), the approximate diameter of the asteroid is 6 km when assuming an albedo of 0.18.

Conclusion

It often happens that one observer cannot do all the work of image acquisition and reduction by himself. In others cases, such as this, one observer could get the images but other circumstances prevented him from measuring the images and analyzing the data. These are ideal situations for forming collaborations among amateurs and/or professionals since the alternative of having the raw data and/or results hidden away in the proverbial dusty filing cabinet should be avoided at all costs.

References

References Note: Asteroid names and discovery information are from Schmadel (1999).

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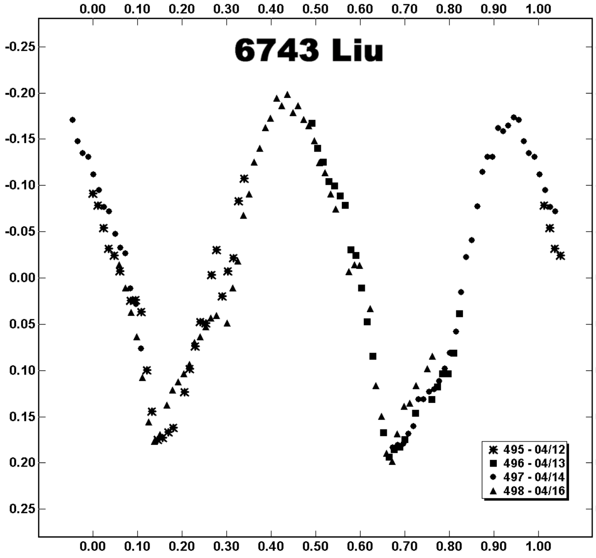

Figure 1. The lightcurve for 6743 Liu. The data is phased against a period of 7.364±0.005h. The amplitude is 0.40±0.02m.

CCD OBSERVATIONS AND PERIOD DETERMINATION OF SIX MINOR PLANETS

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I report new period determinations for five minor planets and a revised period for a sixth. The new results are: 1528 Conrada, 6.321 ± 0.001h; 1816 Liberia, 3.0861 ± 0.0001h; 2653 Principia, 5.5228 ± 0.0007h; 3455 Kristensen, 8.111 ± 0.002; and (5599) 1991 SG1, 3.620 ± 0.005. 206 Hersilia had a previously published period of 7.33 hours which was inconsistent with my data, showing a revised period of 11.11 ± 0.05 hours.

During the early spring of 2004 I observed six asteroids using the University of Iowa's Rigel Telescope (MPC Code 857; see http://phobos.physics.uiowa.edu/tech/rigel.html) at the Winer Observatory near Sonoita, Arizona (31° 39' N 110° 37' W). The Rigel Telescope is a 37cm f/14 classical Cassegrain with a 16-bit CCD camera—an FLI IMG-1024 with a backside illuminated CCD sensor. The camera has a pixel scale of 1 arcsecond per pixel, and through the course of these observations the typical seeing per night was approximately 2.8 arcseconds.

The observational goal was to determine periods for unknown asteroids and to contribute to long term synoptic projects, e.g. pole determinations. Each asteroid observed was chosen because it entered opposition midway through the spring semester. I also limited the candidates to asteroids that had a visible magnitude of 15 or brighter for good signal-to-noise ratio, as investigated for the Rigel Telescope by Ivarsen et al. (2004).

One of the asteroids, 206 Hersilia, was listed with a period of 7.33 hours in the December 15, 2003 Harris list, a period clearly inconsistent with my data. Shevchenko et. al. (1992) presented a combined lightcurve from two nights of data that did not display a typical two-maxima two-minima shape. The combined lightcurve from my six nights of observation exhibits two-maxima two-minima behavior with a period of 11.11 hours.

Information about each epoch of observation is given in Table I. Table II contains information about the period determination for each asteroid, and the Appendix contains the composite lightcurves for the six minor planets. Further information about the observations can also be obtained by visiting the website, http://phobos.physics.uiowa.edu/research/asteroids-sew/

References

Harris, A. W. (2003). http://cfa-www.harvard.edu/iau/lists/LightcurveDat.html

Shevchenko et. al. (1992). "Photometry of Seventeen Asteroids" *Icarus* **100**, 295-306

Table I – Observation details

Ast#	Epoch	Filter	Exposure	#Images	Mag
206	12 Feb 04	C	30	46	13.8
206	13 Feb 04	C	30	89	13.5
206	14 Feb 04	C	30	38	13.7
206	17 Feb 04	C	30	47	13.3
206	18 Feb 04	C	30	56	13.8
206	10 Mar 04	C	30	80	12.0
206	24 Mar 04	C	30	58	12.5
1528	14 Feb 04	C	30	18	14.1
1528	17 Feb 04	C	30	99	14.3
1528	18 Feb 04	C	30	39	14.2
1528	10 Mar 04	C	30	102	14.3
1528	24 Mar 04	C	30	94	13.4
1528	27 Mar 04	C	30	64	13.4
1528	28 Mar 04	C	30	97	13.8
1528	29 Mar 04	C	30	93	13.5
1816	07 Feb 04	R	30	20	14.3
1816	08 Feb 04	R	30	44	13.6
1816	09 Feb 04	R	30	89	13.5
1816	10 Feb 04	R	30	91	13.8
1816	11 Feb 04	R	30	32	13.3
1816	12 Feb 04	R	30	31	13.5
1816	13 Feb 04	R	30	44	13.5
1816	14 Feb 04	R	30	80	13.4
1816	17 Feb 04	C	30	53	13.3
1816	10 Mar 04	C	30	99	14.1
1816	27 Mar 04	C	30	97	14.4
1816	28 Mar 04	C	30	149	14.6
1816	29 Mar 04	C	30	141	14.6
2653	07 Feb 04	R	30	12	14.9
2653	10 Feb 04	R	30	98	15.4
2653	11 Feb 04	C	30	96	15.0
2653	12 Feb 04	C	30	115	15.2
2653	13 Feb 04	C	30	104	16.0
2653	14 Feb 04	C	30	105	15.6
2653	16 Feb 04	C	30	102	15.5
2653	17 Feb 04	C	30	112	15.2
2653	10 Mar 04	C	30	95	14.9
2653	27 Mar 04	C	30	52	15.8
2653	28 Mar 04	C	30	84	15.7
2653	29 Mar 04	C	30	82	15.6
3455	10 Feb 04	R	30	103	15.5
3455	12 Feb 04	C	30	115	15.7
3455	13 Feb 04	C	30	89	15.5
3455	14 Feb 04	C	30	38	15.6
3455	16 Feb 04	C	30	121	15.6
3455	17 Feb 04	C	30	114	15.8
3455	24 Mar 04	C	30	77	15.7
5599	07 Feb 04	C	30	39	16.4
5599	08 Feb 04	C	30	21	17.1
5599	09 Feb 04	C	30	103	16.1
5599	10 Feb 04	C	30	100	16.1
5599	11 Feb 04	C	30	106	16.5
5599	14 Feb 04	C	30	48	16.0
5599	18 Feb 04	C	30	66	15.8
5599	20 Feb 04	C	30	17	16.0

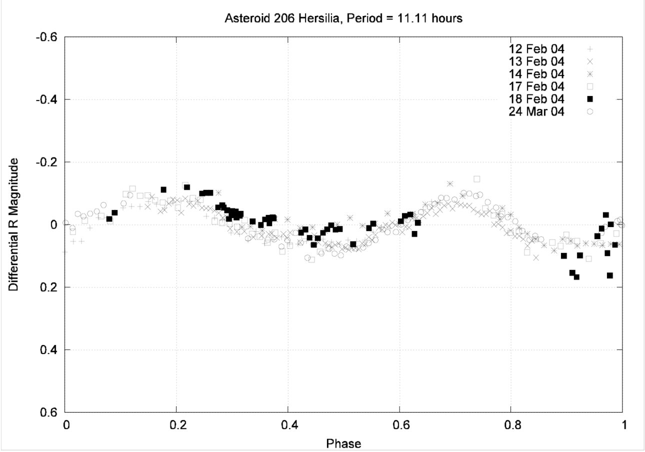
Table II – Asteroid rotation results

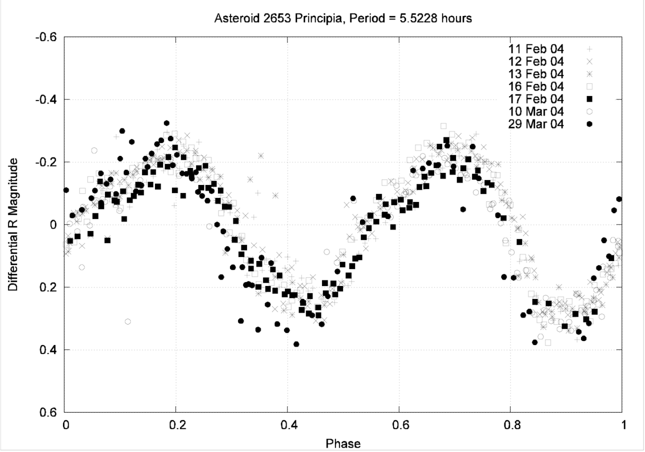
	P.A.B.					
Ast.	Long.	Lat.	P.A. Range	Period	(H)	Amp
206*	11	-4	6.8 - 27.6	11.11	±0.05	0.13
1528	13	+3	6.7 - 16.0	6.321	±0.0005	0.49
1816	10	-1	6.7 - 23.4	3.0861	±0.00005	0.40
2653	11	-2	9.9 - 22.1	5.5228	±0.0007	0.50
3455	12	+2	7.5 - 20.5	8.111	±0.002	0.38
5599	9	-5	8.9 - 14.0	3.62	±0.01	0.26

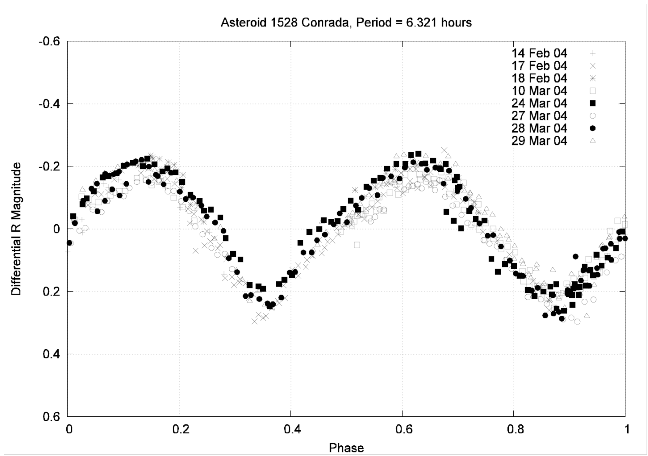
* = Existing entry in Harris List as of Dec 2003

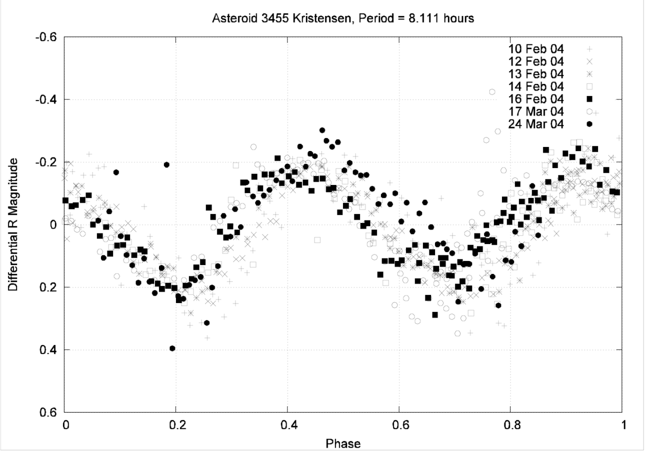
APPENDIX:

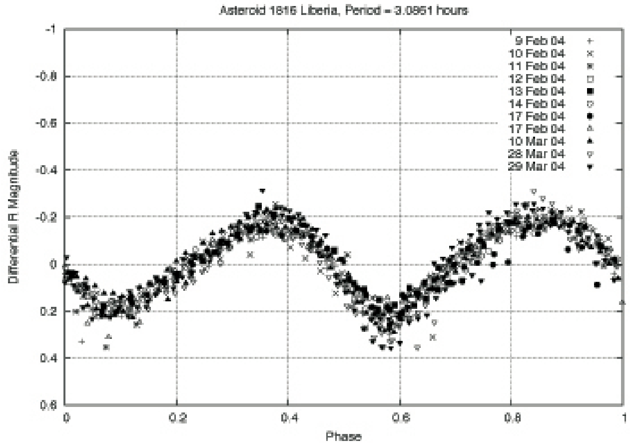
Composite lightcurves for 6 asteroids observed at the Winer Observatory, February – March 2004.

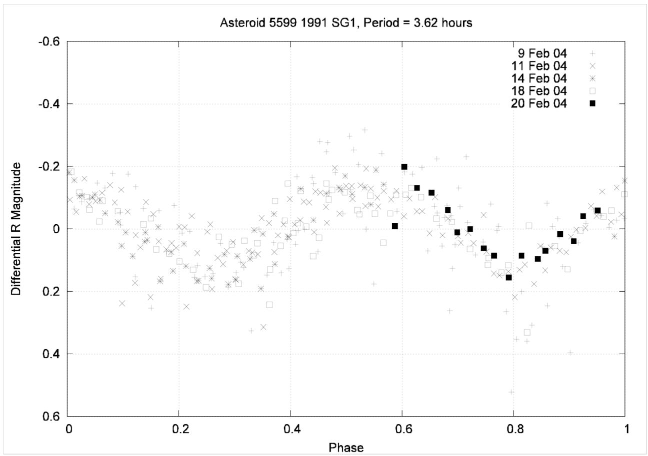












LIGHTCURVE OF ASTEROID (21652) 1999 OQ2

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594 CCD images were taken of the main-belt asteroid (21652) 1999 OQ2 through a Bessel R-band filter over the course of four nights. Differential photometric reduction and Fourier transformation of the relative magnitudes show a period of 16.207 ± 0.002h with a mean R magnitude of 14.05 and a lightcurve amplitude of 0.9 magnitudes. Compared on average with similar-sized asteroids, 1999 OQ2 rotates more slowly and has a larger amplitude, suggesting a highly elongated shape.

Observations

Observations of asteroid (21652) 1999 OQ2 were conducted at the John J. McCarthy Observatory (IAU 932) in New Milford CT. Data were collected on August 20, 21, 22 and 24 2003. No data were collected on August 23 due to clouds. The imaging telescope was a 0.41 meter Meade LX200 Schmidt-Cassegrain. The main imaging CCD used was an SBIG ST-7E. 594 one-minute images were taken through a Bessel R-band filter and binned 3x3. The guide scope was a 106mm Takahashi Refractor with an SBIG STV CCD. Standards star fields were imaged on August 24th. In addition, the fields of view where the asteroid had been on the previous nights were also imaged. The standard magnitudes were obtained from the European Southern Observatory's webpage. From this the standard magnitude of stars within the field of view of the asteroid could be calculated.

Results and Discussion

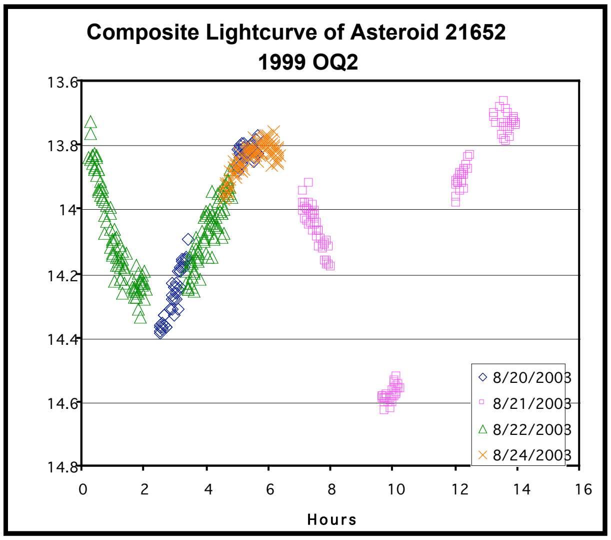
445 images were calibrated and used for the final rotation periodicity determination of 21652. Calibration included the subtraction of 10 median averaged dark, flat and bias frames. Flats were obtained each night by imagining evenly illuminated white boards on the inside of the observatory dome after observations were complete. All calibration was done using Mira AP. MIRA AP was used to find the total counts above background for the standard stars and stars in the field of view of the asteroid. An instrumental magnitude (m_1) for each standard star was calculated:

$$m_1 = -2.5 \log_{10} (\text{counts per second}) \tag{1}$$

The difference between the instrumental magnitude and reported magnitude was plotted as a function of airmass. The linear regression of this plot produced:

$$y = 2.2781x + 16.24 \tag{2}$$

Next the standard magnitudes of the stars in the field of view of the asteroid were calculated. Equation 2 was used to calculate the scalar to be added to a calculated instrumental magnitude for all stars in the field of view of the asteroid. From this, absolute photometry was performed using Mira AP and a Fast Fourier Analysis yielded a rotation period of 16.207 ± 0.002h. The resulting R-band lightcurve appears in the accompanying figure.



Asteroid (21652) 1999 OQ2 shows a mean R magnitude of 14.05 and a lightcurve range from R13.7 to R14.6, making the lightcurve amplitude 0.9 magnitudes. The large amplitude suggests that from an equatorial view 21652 has a two-dimensional size ratio of about 2.3:1. Using the mean R magnitude with an estimated albedo of 0.10 and correcting for solar phase angle we estimate that the average diameter of the asteroid is 14 km. From this we estimate equatorial dimensions of order 10 km by 20 km. Compared on average to other main-belt asteroids of similar size, 21652 is more highly elongated and rotates more slowly.

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LIGHTCURVE ANALYSIS FOR NUMBERED ASTEROIDS 863, 903, 907, 928, 977, 1386, 2841, AND 75747

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The lightcurves of eight asteroids were obtained in early to mid-2004 and analyzed. The following synodic periods and amplitudes were determined. 863 Benkoela: 7.03±0.02h, 0.05±0.01m; 903 Nealley: 21.60±0.05h, 0.13±0.02m; 907 Rhoda: 22.44±0.02h, 0.16±0.02m; 928 Hildrun: 14.12±0.03h, 0.34±0.02m; 977 Philippa: 15.405±0.005h, 0.16±0.02m; 1386 Storeria: 8.67±0.02h, 1.40±0.03.m; 2841 Puijo, 3.545±0.005h, 0.03±0.01m; and (75747) 2000 AX_{153}: 6.38±0.02h, 0.30±0.02m. There is a possibility that 2841 Puijo is a binary.

Equipment and Procedures

The asteroid lightcurve program at the Palmer Divide Observatory has been previously described in detail (Warner 2003) so only a summary is provided now. The main instrument at the Observatory is a 0.5m f/8.1 Ritchey-Chretien telescope using a Finger Lakes Instruments IMG camera with either a Kodak KAF-1001E or SITe TK-1024 chip. For the accompanying curves, none of the other instruments, a 0.25 and 0.35m f/10 SCT, was used.

Initial targets are determined by referring to the list of lightcurves maintained by Dr. Alan Harris (Harris 2003), with additions made by the author to include findings posted in subsequent issues of the *Minor Planet Bulletin*. In addition, reference is made to the Collaborative Asteroid Lightcurve Link (CALL) web site maintained by the author (http://www.MinorPlanetObserver.com/astlc/default.htm) where researchers can post their findings pending publication. MPO Canopus, a custom software package written by the author, is used to measure the images. It uses aperture photometry with derived magnitudes determined by calibrating images against field or, preferably, standard stars. Raw instrumental magnitudes are used for period analysis, which is included in the program. The routine is a conversion of the original FORTRAN code developed by Alan Harris (Harris et al., 1989).

Note: in the following, the orbital elements are taken from the IAU MPCORB data file available at the Minor Planet Center web site (ftp://cfa-ftp.harvard.edu/pub/MPCORB/). The date of osculation for the elements was 2453200.5. The Phase Angle Bisector (PAB) was previously described (Warner 2004).

Results

863 Benkoela

This main-belt IIIb asteroid was discovered by M. Wolf at Heidelberg on 1917 Feb. 9. The naming is uncertain but it may be for the city of Benkoelen on the island of Sumatra. It was originally designated 1927 WD. Benkoela was classified by Tholen (1989) as being taxonomic type A. The IRAS study (Tedesco 1989) gives a diameter of 27.06±1.5 km with an albedo 0.5952±0.07. The principal orbital elements are: semi-major axis, 3.1995AU; inclination, 25.397°; and eccentricity, 0.0366.

Benkoela has been reported at least twice before. The first time was in 1989 by Harris et al. (1989). That study had only a few data points obtained on a single night. The second study was by Jean-Gabriel Bosch (Behrend 2003). That study also consisted of data from a single night. Both studies stated the possibility of a long period, i.e., probably 24 hours or more. Benkoela was also one of the targets of interest in a study of olivine rich asteroids for their iron content (Sunshine 1997). Observations of Benkoela were obtained at the Palmer Divide Observatory on three nights, 2004 May 5-7, using the 0.5m telescope. A total of 418 data points was used in the final analysis, which found a synodic period of 7.03±0.02h and an amplitude of 0.05±0.01m. Figure 1 shows the data phased against this period.

903 Nealley

This asteroid has carried 13 designations over time, among them being 1927 DB and 1960 WU. It was discovered by J. Palisa at Vienna on 1918 Sept. 13 and named for a New York amateur who supported the edition of the Wolf-Palisa photographic star charts. Nealley is a member of the main-belt group IIIb. Tedesco (1989) reported a diameter of 63.43±2.0 km and albedo of 0.0528±0.004 and orbital elements: semi-major axis, 3.2391AU; inclination, 11.7517°; and eccentricity, 0.0379.

Nealley was observed with the 0.5m telescope at PDO on the nights of 2004 June 3-7 and 11-14. 280 data points were used in the final analysis that gave a synodic period of 21.60±0.05h and amplitude of 0.13±0.02m. Figure 2 shows the data phased against this period. While inspection of the period "spectrum" revealed no other likely periods, the lack of overlap and gap in coverage makes the period less certain than would be preferred.

907 Rhoda

Formerly carrying the designations of A901 BA and A913 SC, 907 Rhoda was discovered by M. Wolf at Heidelberg on 1918 Nov. 12. It's a type IIb main belt asteroid. Tholen (1989) puts it in his C taxonomic class. The IRAS study (Tedesco 1989) gives a diameter of 62.73±1.7 km and albedo of 0.056±0.003. The 2004 apparition was the fourth brightest between 1995 and 2050. The next time it reaches brighter than 14th magnitude is not until 2007. The principal orbital elements are: semi-major axis, 2.7992AU; inclination, 19.568°; eccentricity, 0.1640.

The 0.5m telescope was used to acquire the 609 data points used in the final analysis. Observations were made on 2004 April 1, 13-16, 21, and 25. The derived synodic period of the lightcurve was found to be 22.44±0.02h and the amplitude to be 0.16±0.02m. Figure 3 shows the data phased against the period.

928 Hildurn

Hildrun is a main belt IIIb asteroid that was discovered on 1920 Feb. 23 by K. Reinmuth at Heidelberg. Kozai (1979) puts the asteroid in his group 54, which has 25 asteroids including 137 Meliboea as its lowest numbered member. Tedesco (1989) gives a diameter of 66.83±1.7 km and albedo of 0.0687±0.004. The principal orbital elements are: semi-major axis, 3.1316AU; inclination, 17.6495°; and eccentricity, 0.1524. These would apparently make the asteroid a member of the main belt IIIb group. The 2004 apparition was above average, being 14.4m at brightest. That's about 0.5m fainter than the best possible but almost two magnitudes better than the worst case. The next apparition that's brighter is in 2009.

The 0.5m telescope and SITe chip camera were used for runs on 2004 April 28 and May 2-4. 407 data points were merged into the final analysis of the lightcurve, which found a synodic period of 14.12±0.03h and an amplitude of 0.34±0.02m. Figure 4 shows the data phased against this period.

<u>977 Philippa</u>

Discovered on 1922 Apr. 6 at Algiers by B. Jekhovsky, Philippa has carried the designations A914 YA and A919 XA. It is named in honor of financier Philipp von Rothschild. This is a main belt IIIb asteroid, of taxonomic class C (Tholen 1989). Kozai (1979) puts the asteroid in his group 57, which has 22 members, including 250 Bettina as the lowest numbered asteroid. The IRAS study (Tedesco 1989) gives a diameter of 65.67±5.3 km and albedo of 0.0555±0.010. The principal orbital elements are: semi-major axis, 3.1187; inclination, 15.1891°; and eccentricity, 0.0301.

Using the 0.5m telescope and SITe chip camera, 502 data points were obtained for analysis on 2004 Apr. 17-19 and 26-27. The phased plot in Figure 5 is against a synodic period of 15.405±0.005h and has an amplitude of 0.49±0.02m.

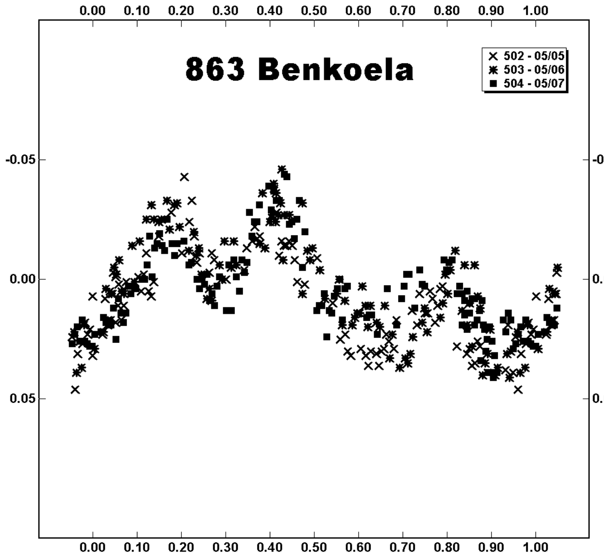

Figure 1. Phased lightcurve of 863 Benkoela against a synodic period of 7.03±0.02h. The amplitude is 0.05±0.01m

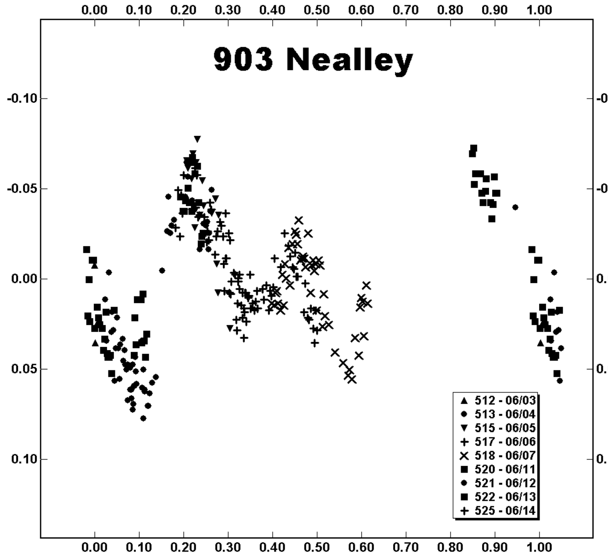

Figure 2. Phased lightcurve of 903 Nealley against a synodic period of 21.60±0.05h. The amplitude is 0.13±0.02m.

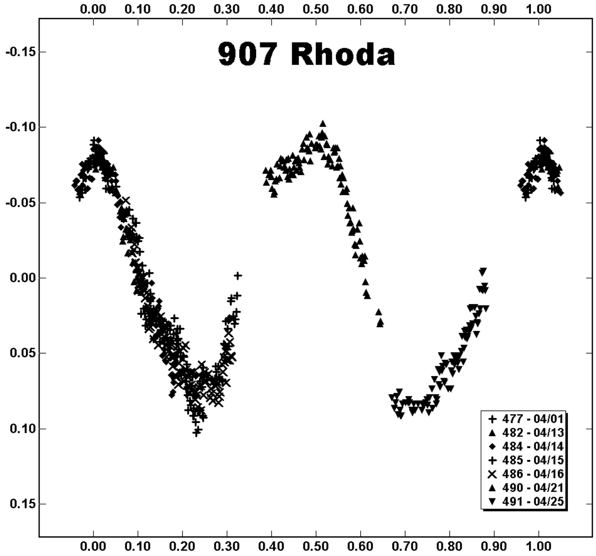

Figure 3. The data for 907 Rhoda is shown in this lightcurve that is phased against a synodic period of 22.44±0.02h. The amplitude is 0.16±0.02m.

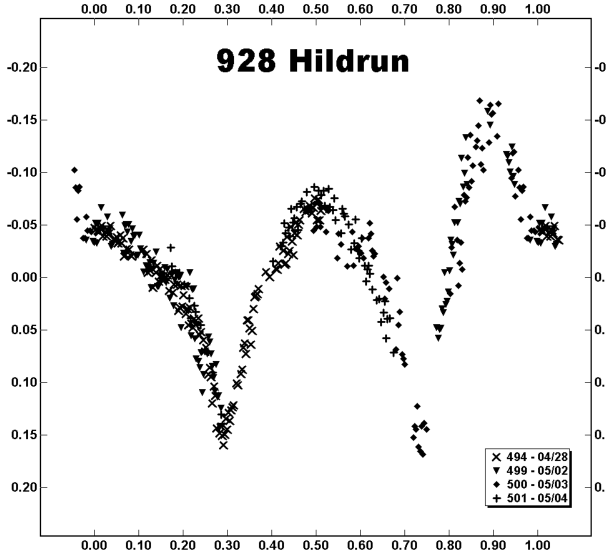

Figure 4. Phased lightcurve for 928 Hildrun. The data were phased against a synodic period of 14.12±0.03h. The maximum amplitude is 0.34±0.02m.

1386 Storeria

Official discovery of Storeria is given to G. Neujmin at Simeis (1935 Jul. 28). However, an independent discovery by E. Delporte at Uccle on 1935 Aug. 2 was reported first. The name is after Dr. N. Wyman Storer, who was the professor of the student at the University of Kansas who first computed the orbit. Its previous designations were 1935 PA and 1975 RF. Using the method explained by Harris (2003), a diameter of about 9 km can be assumed. The principal orbital elements are: semi-major axis, 2.3655AU; inclination, 11.8104°; and eccentricity, 0.2852. The 2004 apparition was one of the few that put the asteroid in range of amateur equipment. From 2005-2007 it will be in the 16s at its brightest and the next time it reaches at least 14.5 is not until 2015.

A total of 262 data points was obtained for final analysis using the 0.5m telescope. Observations were made on three successive nights, 2004 June 22-24. The derived lightcurve has a synodic period of 8.67±0.02h and amplitude of 1.40±0.03m. This implies a projected a/b ratio for an ellipsoid of 3:1, making for a very elongated object. See Figure 6 for a phased plot.

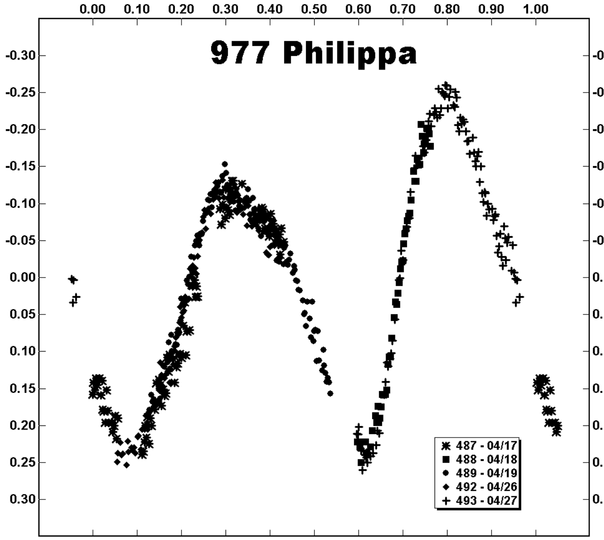

Figure 5. Phased lightcurve for 977 Philippa. The data were phased against a synodic period of 15.405±0.005h. The amplitude is 0.49±0.02m.

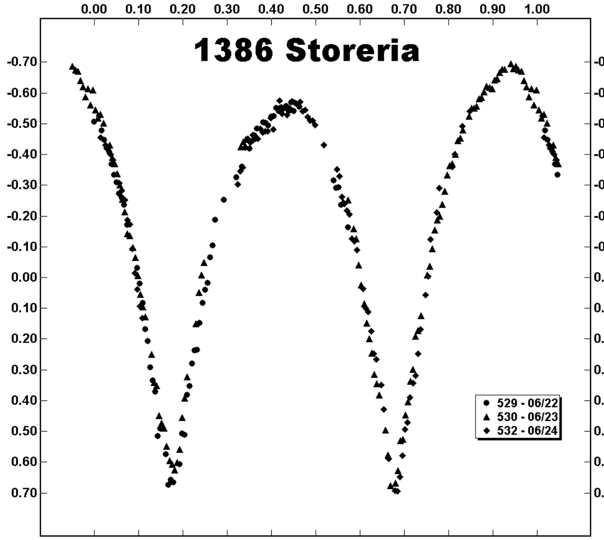

Figure 6. Phased lightcurve for 1386 Storeria. The assumed synodic period is 8.67±0.02h. The amplitude of 1.40±0.03m implies a 3:1 a/b ratio for an ellipsoid.

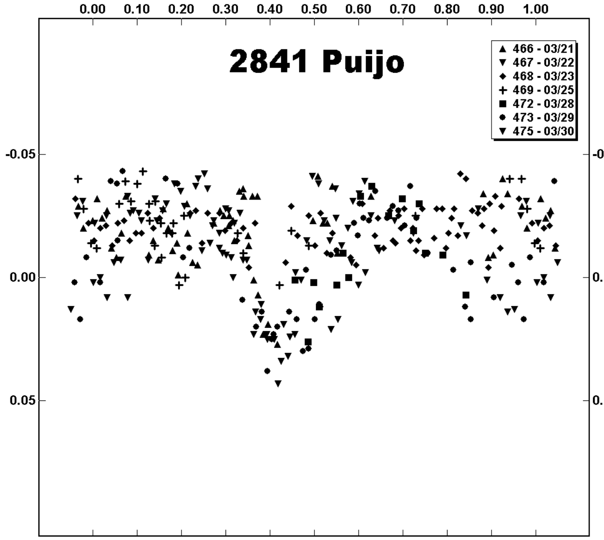

Figure 7. Phased lightcurve for 2841 Puijo. The main synodic period of the curve is 3.545±0.005h and the amplitude is 0.03±0.01m. A satellite with a period of 24.6±0.1h *might* explain the minimum near 0.4.

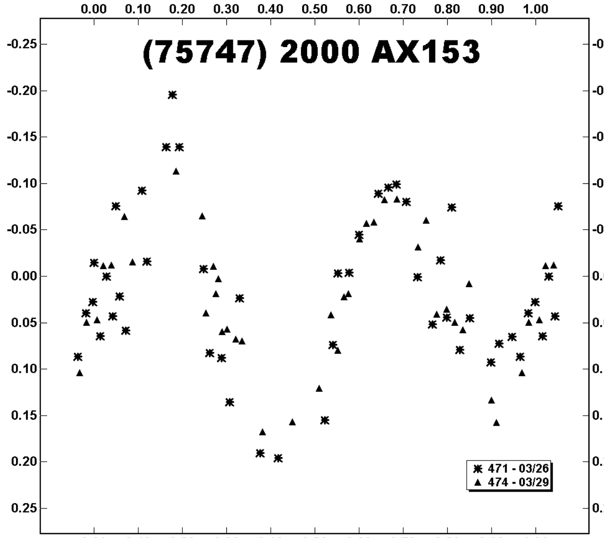

Figure 8. The phased lightcurve for the Flora asteroid (75747) 2000 AX$_{153}$ shows the data against a period of 6.38±0.02h and amplitude of 0.30±0.02m. The original data were binned by averaging two consecutive data points. This reduced the noise caused mostly by a very low S/N ratio.

2841 Puijo

Named for a large hill on Lake Kallavesi in Finland, this member of the Flora group was discovered on 1943 Feb. 26 at Turku by L. Oterma. The estimated diameter (Harris 2003) is about 9 km. The principal orbital elements are: semi-major axis, 2.2524AU; inclination, 4.9155°; and eccentricity, 0.0844.

Most of the observations using the 0.5m telescope and FLI 1001E camera showed a curve with a very small amplitude. However, observations on 2004 March 21, 22, and 29 also show a 0.04m decline that lasted approximately 0.75h (see Figure 7). Subtracting this effect allowed finding a period of 3.545 ±0.005h for the main lightcurve and an amplitude of 0.03±0.01m. I contacted Dr. Petr Pravec of the Ondrejov Observatory, Czech Republic, for an independent analysis. After his examination, he replied in part:

> "If you rule out observational cause, it might be either a rapidly evolving feature of the lightcurve (even though this possibility doesn't look too plausible for me as there are some points not supporting it) or an attenuation event due to a satellite. If its orbital period were 24.6±0.1h, it would fit all the data well."

Attempts were made to observe the asteroid in 2004 May, but it had faded too much to get observations with sufficient S/N. Future observers should be aware of the possibility of short term events in the lightcurve that may indicate a satellite. The next time Puijo is brighter than 15th magnitude is not until 2011.

(75747) 2000 AX_{153}

Discovered by LINEAR at Socorro on 2000 Jan. 2, this tiny asteroid of 3 km (Harris 2003) is a member of the Flora group. Its principal orbital elements are: semi-major axis, 2.1769AU; inclination, 7.0602°; and eccentricity, 0.1302. The 2004 apparition was 17.8 at brightest, which made for a difficult target even with the 0.5m telescope. It's best appearance is in 2014 when it reaches 16.8. It is often no brighter during some years than mid-19th magnitude.

Observations were made on 2004 Mar. 26 and 29. The raw data were binned 2x3, meaning two adjacent points separated by no more than three minutes were averaged to create a single data point. This resulted in 79 points used in the final analysis of the lightcurve, which was found to have a synodic period of 6.38±0.02h and amplitude of 0.30±0.02m. Figure 8 shows the binned data points phased against this period.

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PERIOD DETERMINATION OF ASTEROIDS 1508 KEMI AND 5036 TUTTLE

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Asteroids 1508 Kemi and 5036 Tuttle were observed during February and March 2004. Their lightcurve periods and amplitudes are: 7.510 ± 0.004h, and 0.30 mag.; 9.19 ± 0.05h, and 0.25 mag.

Observing Procedures

We report observations of asteroid 1508 Kemi and 5036 Tuttle observed at the Frank T. Etscorn New Mexico Tech Campus Observatory in Socorro, NM with a 14" Celestron Schmidt-Cassegrain using a SBIG ST-8E CCD. Exposures were taken through a Bessel-R filter. During one month of observation, two sets of master flat fields were prepared. A series of 11 one-half second flat fields is imaged looking at an evenly illuminated view screen in our observatory. A series of 11 one-half second dark frames are also imaged. A median combine of these 11 one-half second darks is then subtracted from each of our 11 one-half second flat fields. Then, we do a median combine of these 11 dark-subtracted flat fields to produce our final master flat. We then find the median value for the master flat and divide by this mean, giving us a normalized master flat.

On a typical night, we expose a series of 9 120-second light frames (180-second for some nights) through a Bessel-R filter followed by a single dark frame at the same temperature and exposure time. This process was repeated throughout the night as long as favorable conditions existed. At the end of the night, we median combine all of our dark frames to produce a master dark for the night. During reduction, we subtract the master dark from each of the raw images. We then take the result of this dark-subtraction and divide by the current normalized master flat. At this point, we line up all of our processed images so that the background stars appear motionless while our asteroid moves across the field of view. Then, we use IDL "daophot" procedures from the IDLAstro package created at Goddard Space Flight Center (URL: http://idlastro.gsfc.nasa.gov) to do aperture photometry for both the asteroid and comparison stars. We define a comparison star as one whose instrumental magnitude is always within 1 magnitude of the asteroid's instrumental magnitude. We then subtract the comparison magnitude from the asteroid magnitude and plot this differential magnitude as a function of light-time corrected Julian date. The median of all the differential magnitudes is subtracted from each image's differential magnitude so that they all share a common zero-point magnitude. Since each differential magnitude calculation has some noise associated with it, we then take the median of all of these zero-point differential magnitudes to arrive at a final zeroed differential magnitude.

Results

5036 Tuttle

This asteroid was discovered by S. Ueda and J. Kaneda at Kushiro, Japan on October 31, 1991. Tuttle is a main-belt asteroid. This asteroid was chosen for observation due to its high declination angle at the observing site, a lack of reported periods, and by suggestion from the CALL website. We observed 5036 Tuttle for 8 nights between 02/10/04 UTC and 03/17/04 UTC. 5036 Tuttle's period of 7.510 ± 0.004hr was determined from a series of 826 2-3 minute exposures with a Bessel-R filter. Of the 826 observations made, 155 images were discarded because of interfering clouds or stars entering our asteroid's photometric aperture. 5036 Tuttle's period was determined both by fitting a double sine wave to the data as well as a method which phased the data by an increment of time, given an initial period. We chose the period which gave the best data overlap. Both were in fair agreement and showed the period to be 7.510 ± 0.004h. Over the 115 rotations during which 5036 Tuttle was observed, the magnitude varied 0.30mag.

1508 Kemi

Asteroid Kemi was discovered in 1938 by H. Alikoski at the Observatory of Turku Academy, Finland. We observed 1508 Kemi for 4 nights between 03/18/2004 UTC and 03/22/2004 UTC. We determined a period of 9.19 ± 0.05hr for 1508 Kemi from a total of 347 images through a Bessel-R filter using the same period determination methods as mentioned for 5036 Tuttle. Kemi went through roughly 13 rotations during this observation period, varying 0.25mag.

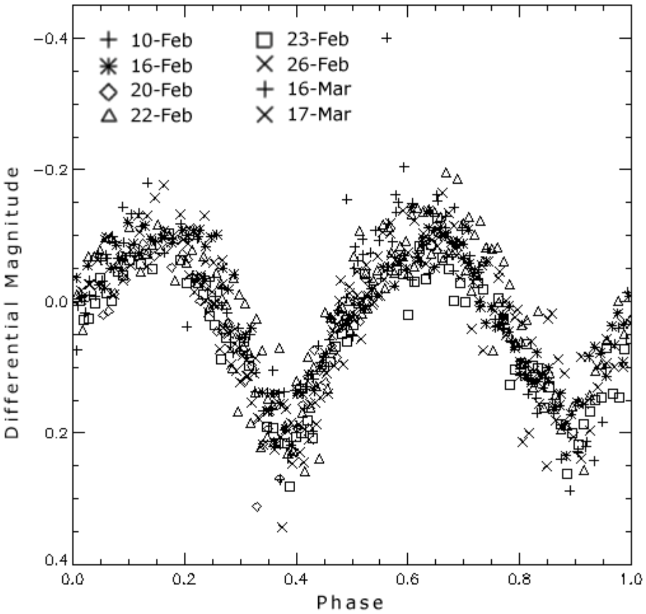

Figure 1. Lightcurve, 5036 Tuttle, Period = 7.510hr

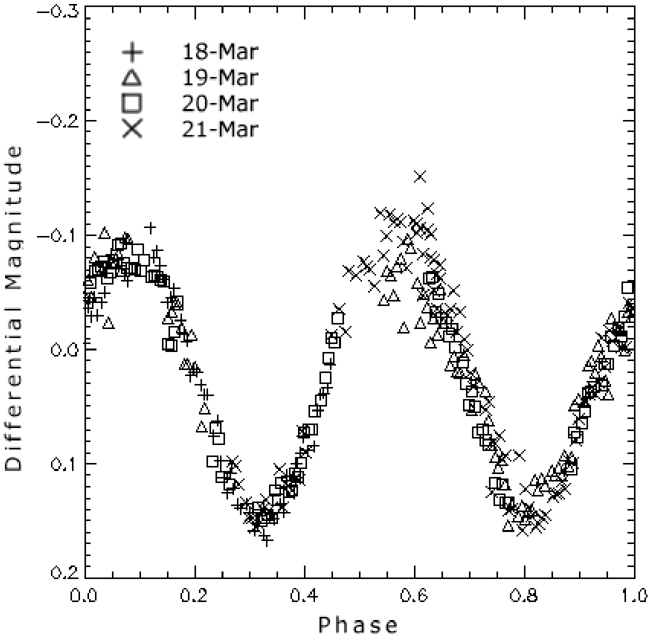

Figure 2. Lightcurve, 1508 Kemi, Period = 9.19hr

A PHOTOMETRIC STUDY OF 371 BOHEMIA

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The lightcurve of asteroid 371 Bohemia indicates a rotation period of 10.7391 ± 0.0002 hours, with an amplitude of 0.15 mag. The measured color indices of the asteroid are (B-V)= 0.84 ± 0.06 and (V-R)= 0.49 ± 0.03. A detailed search for changes in V-R color with rotation angle was negative within ± 0.03 mag.

Introduction and Observing Procedures

Observations of 371 Bohemia were made during the 2003/4 apparition at Altimira Observatory (V-band) and Blauvac Observatory (unfiltered). This study also used unfiltered observations from amateur observatories at Cabris and Harfleur, France, taken respectively in 2001 and 2002.

Altimira Observatory, located in southern California, used a 0.28-m Schmidt-Cassegrain (Celestron NexStar-11), operating at f/6.3, with an SBIG ST-8XE NABG CCD and Johnson-Cousins B, V and R filters. Blauvac Observatory is located in France (5°13' East longitude, 44°3' North latitude), and used a 310mm f/3.4 Newtonian telescope, with an Audine CCD camera equipped with a KAF-402ME chip. M Conjat made measurements from Cabris, France (6°56' East longitude, 43°38' north latitude) using a 200mm f/4 Newtonian telescope, and a ST4 CCD camera. Ph. Baudoin used a 200mm f/4.0 Newtonian telescope, and an Audine CCD camera equipped with a KAF-400 CCD chip to make measurements from Harfleur, France (0°12' East longitude, 49°31' North latitude).

Observational Results

Previous studies have reported quite a wide range of lightcurve periods for this object. Mohamed et al. (1995) observed it during the 1993 apparition and reported a period of 3.792 hours, with an ~0.15 mag. amplitude. However, their published lightcurve shows wide scatter in the data after it is wrapped to the indicated period, and their result depends very heavily on a single night's observations. Also during the 1993 apparition, Riccioli et al (1995) observed on three nights, and inferred a period of 12.48 hours, with amplitude > 0.16 magnitude. However, their data is very sparse, and they observed only a single maximum, leaving open the possibility that a more-complete lightcurve would show significantly different features.

We obtained 9 nights of data from 2003-12-27 to 2004-03-09 UT. All lightcurves were corrected for light-travel time to the asteroid. This data set provides a dense and complete coverage of the lightcurve. The data set consisting of Altimira filtered observations and Blauvac unfiltered observations, was analyzed with methods based on Fourier polynomials, using both Brian Warner's MPO Canopus and CourbRot (Behrend, 2001), with very similar results: 10.7391 ± 0.0002 hour rotation period. A photometric slope parameter G=0.15 was used in these computations, as described see below. The resulting lightcurve is shown in Figure 1.

Note the presence of a tertiary maximum at rotational phase ≈ 0.15 in Figure 1. This feature appears in several nights' data, and so is almost certainly a real feature of this asteroid's shape. This feature may have been a contributing factor in the previously reported, discordant lightcurve periods. We searched for consistent periodic lightcurves with periods in the range 1 hour to 1 day, giving special attention to previously reported periods; we found nothing except the 10.7391h periodicity. This value is also consistent with the observations taken during the 2001 and 2002 apparitions. Figures 2 and 3 present lightcurves from these apparitions constructed with the 10.7391h period. The variability of Bohemia was around 0.10-0.15 mag for all studied oppositions, and all lightcurves presented similar shapes. Thus, Bohemia's equator is probably not very far from the ecliptic, rendering future work to model its 3D shape difficult.

The Planetary Data System Small Bodies Node reports a color index of B-V = 0.822 for this asteroid. Ricciolo et al (1995) reported B-V = 0.91, and their observations found no variation in color index with rotational phase angle. Altimira Observatory made observations on two nights using 2 minute exposures in V- and R-band, and 4 minute exposures in B-band (giving signal-to-noise ratio ≈ 50:1 in B-band), to determine the asteroid's color

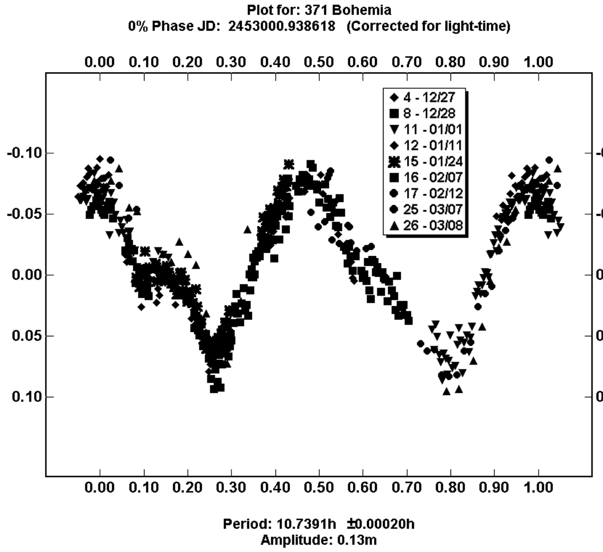

Figure 1: Lightcurve of 371 Bohemia, using 2003-4 data wrapped to P= 10.3791 hrs

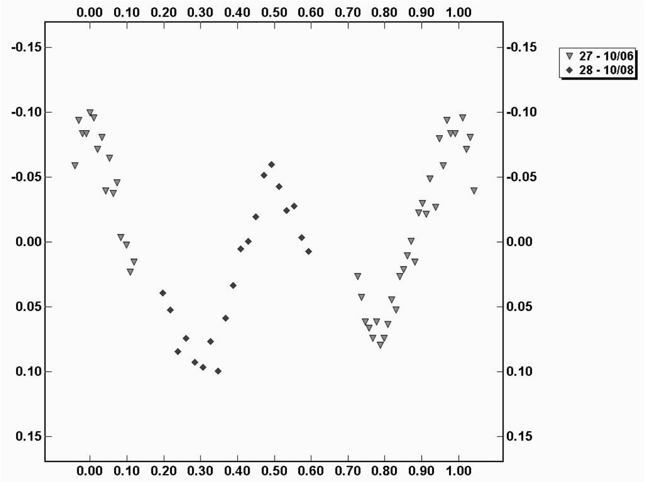

Figure 2: 371 Bohemia observed at Harfleur Observatory in 2002, compiled using P=10.7391 h.

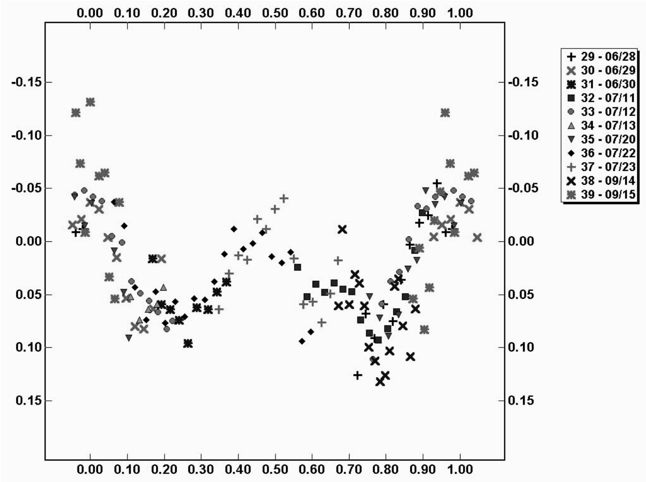

Figure 3: 371 Bohemia observed at Cabris Obsevatory in 2001, compiled using P=10.7391 h.

index. Landolt standard fields were used to determine transformation coefficients. Atmospheric extinction was determined using the Hardie method (Hardie, 1962). In the case of B-V results reported here, we applied first order extinction corrections, but not second-order corrections.

In each band, three exposures were made, and the resulting instrumental magnitudes averaged before further reductions. The resulting color indices were: B-V = 0.84 ± 0.06 and V-R = 0.49 ± 0.03. Detailed studies of the V-R color made at Altimira Observatory on the night of 1/11/2004 UT showed a constant V-R color to within ± 0.03 magnitude over rotational phases from 0.05 to 0.55 (referring to Figure 1).

Finally, we made an attempt to discriminate between two reported values for the absolute magnitude (H) and slope parameter (G) for this asteroid. Figure 4 shows the reduced magnitude (in V-band) vs. phase angle, using 2003-4 data from Altimira Observatory. The raw data have been adjusted to account for the asteroid's rotational phase angle at the time of measurement, so that this data set reflects the "average" or "ΔM = 0" line on Figure 1. The Small Bodies Node reports H= 8.72, and uses the "default" value of G=0.15 for this asteroid. Tedesco (1989) reports H= 8.79 and G= 0.25. Unfortunately, the smallest observed phase angle (1.6 degrees) did not clearly show the opposition effect, and the present data cannot differentiate between these two reported values.

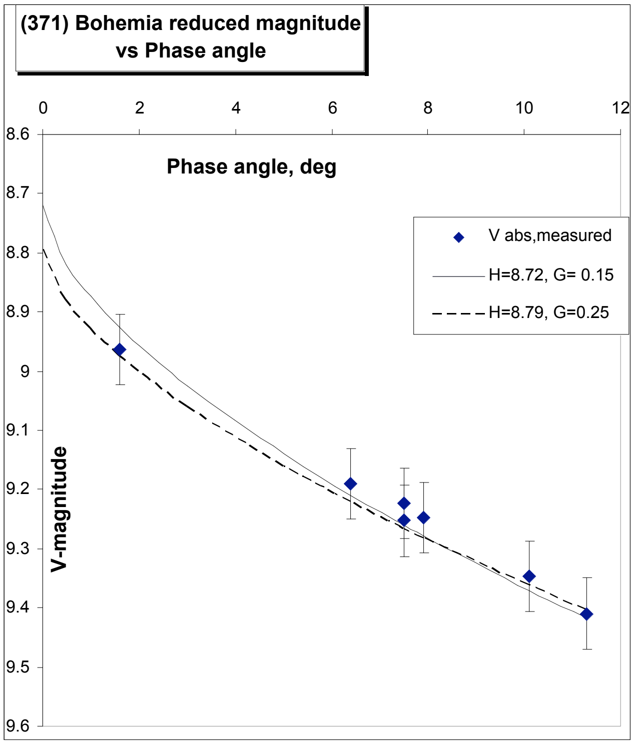

Figure 4. Reduced magnitude vs. Phase angle.

Acknowledgements

Altimira Observatory's transformation coefficients, lightcurves, and color indices were calculated using Brian Warner's MPO Canopus and PhotoRed programs. European observers used IRAF and Prism. AstOrb and MPCOrb online databases were used as sources of orbital elements. Very special thanks to Eileen Buchheim, who sacrificed a portion of her garden for the construction of Altimira Observatory.

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HISTORICAL ESSAY:
LIGHTCURVES AND THE DIVINE DIPSOMANIA

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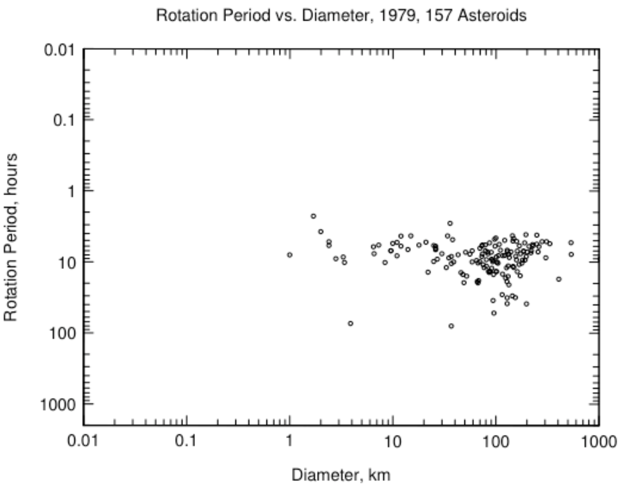
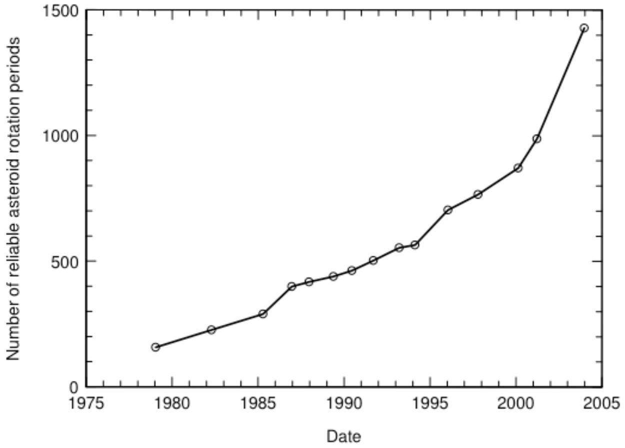
In her 1977 Henry Norris Russell Prize Lecture, Cecelia Payne-Gaposchkin remarked:

> *The reward of the young scientist is the emotional thrill of being the first person in the history of the world to see something or to understand something. Nothing can compare with that experience, it engenders what Thomas Huxley called the Divine Dipsomania. The reward of the old scientist is the sense of having seen a vague sketch grow into a masterly landscape. Not a finished picture, of course; a picture that is still growing in scope and detail, with the application of new techniques and new skills. The old scientist cannot claim that the masterpiece is his own work. He may have roughed out part of the design, laid on a few strokes, but he has learned to accept the discoveries of others with the same delight that he experienced his own when he was young.*

This lovely quotation captures the very essence of why we do science, and how we are rewarded. And while I pause to accept the role of "the old scientist" (I would prefer maybe "the more mature scientist"), the metaphor of the unfinished landscape captures well the advance I have seen in lightcurve studies over the years. When I published my first study of asteroid rotations in 1979, the "landscape" looked like this:

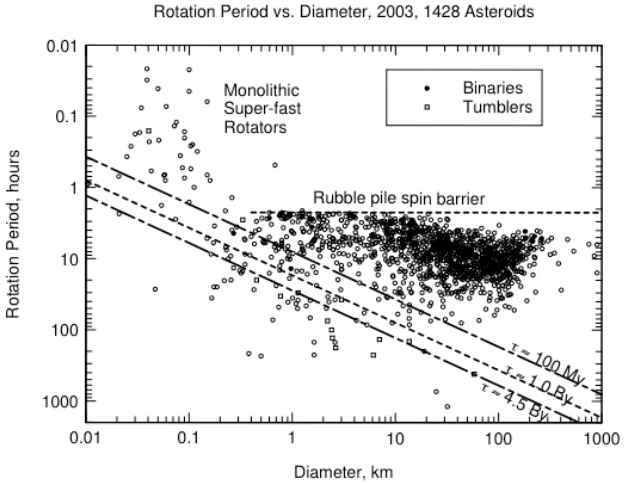


I did in fact "rough out part of the design". The basic format of the picture, in log-log scale with rotation frequency increasing upward, was my invention. Early on the figure required only two decades of period (frequency) and three decades of diameter to contain all the data. And in the years that followed I "laid on a few strokes", adding lightcurve results from my own observing program at Table Mountain Observatory. In the years since 1979, the number of lightcurve results has grown remarkably.



The jump around 1986 was due to the publication of the thesis of your editor, Richard Binzel; the jump following 1995 was due to the publication of results of the late Wieslaw Wisneiwski. I may have played some modest part in the slow upward slope in between, but really, my contributions to the total data set were modest, just "laying on a few strokes." The astounding, almost exponential, increase in the last half decade has been in large part due to amateur contributions.

So here's the "landscape" now. In the figure below, I have added a few dashed lines to aid in interpretation, but they are hardly necessary, so clear are the features in this now-detailed "landscape".



Looking back, I wonder how we could have drawn any conclusions at all from the first meager data set available to us. And over the years, as more and more data became available, we boldly suggested new features in the "landscape" hoping to be correct and not fooled by small number statistics. Now most of the features are clear and require no sophisticated analysis. We can see the dip in mean rotations around 50-200 km diameter; we can see clearly the "rubble pile spin barrier" at about 2.25 hours rotation period, we can see the transition from "rubble piles" that must obey the speed limit to the "monolithic" small bodies that know no speed limit; and we can see the excess of slow rotators, among them the "tumbling asteroids", which spin like a badly thrown (American style) football instead of spinning about a single axis. We can see the exceptions that ought to have damped to simple rotation, according to the damping timescales indicated by the sloping lines, but haven't, maybe due to recent collisions, or anomalously high interior strength or high rigidity. And we can begin to see a pattern in newly discovered binaries, which mostly cluster near the rubble pile spin barrier, part of the landscape yet to be explained definitively. What more is there to see? No doubt much, but it will require more "laying on of strokes" to complete the picture, using "new techniques and new skills."

In the last year or two a new paradigm has emerged, where it appears that the evolution of spins of asteroids smaller than a few tens of kilometers in diameter are dominated by radiation pressure, the so-called YORP effect. This may explain both the fast and slow rotators, and maybe tumbling and binary formation as well. It's a rich new field for theorists, but requires observational data to vindicate (or refute) the theories. Observationally, we have "new techniques and new skills", with automated robotic telescopes, radar, adaptive optics, and new lightcurve inversion techniques to obtain reliable shapes and spin axis orientations from lightcurves. In summary, it's an exciting time for asteroid studies generally, and lightcurve studies in particular, so I look forward to future contributions from the many small observatories now engaged in this work. Like "the old scientist" of Payne-Gaposchkin's remarks, I have learned to accept the discoveries of others with the same delight as my own, and here extend my sincere thanks to all of you who have contributed to this magnificent "landscape."

BUCKNELL UNIVERSITY OBSERVATORY LIGHTCURVE RESULTS FOR 2003-2004

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We report photometric lightcurve results for asteroids measured and analyzed throughout the 2003-2004 college year at Bucknell University. The following lightcurve period and amplitudes are found: 970 Primula 2.721 ± 0.001 hours and 0.13 ± 0.03 mag; 1027 Aesculapia 6.83 ± 0.10 hours and 0.15 ± 0.03 mag; 1127 Mimi 8.541 ± 0.1 hours and 0.95 ± 0.02 mag; 1501 Baade 10.501 ± 0.001 hours and 0.19 ± 0.05 mag; 2112 Ulyanov 3.000 ± 0.001 hours and 0.33 ± 0.05 mag. Observations were also made of asteroids 978, 1007, 1645, 2525, 4497, and 10374. However, the results were inconclusive as the scatter in the measurements apparently exceeds the amplitude of the lightcurve.

Equipment and Procedures

Observations were made at the Bucknell Observatory, on the campus of Bucknell University in Lewisburg, Pennsylvania. The elevation is 171 m. Two Schmidt-Cassegrain telescopes were used. One type was a 20 cm f/6.3 LX200. The other telescope was a 35.4 cm, f/11 Celestron used with a focal reducer at f/7. The LX200 was fitted with an SBIG ST-7E CCD camera, while an SBIG ST-9E was used with the Celestron. All images were unfiltered and were reduced with dark frames and sky flats.

The asteroids were chosen from the Collaborative Asteroid Lightcurve Link (CALL) home page that is maintained by Brian Warner. Image analysis was accomplished using differential photometry and the images were measured using the program "Canopus," developed by Brian Warner. All of the lightcurves except for 1127 were created with this program. "Canopus" uses a routine based on the work of Dr. Alan Harris (Harris et al. 1989). Differential magnitudes were calculated using reference stars from the USNO-A 2.0 catalog. Different comparison stars were used on different nights because of the asteroid's movement. "Canopus" compensates for night-to-night observation by offsetting each night's magnitude scales and then obtaining a best fit. The sizes of the minor planets were estimated using the "Conversion of Absolute Magnitude to Diameter" table on MPC's website (http://cfa-www.harvard.edu/iau/lists/Sizes.html). Details of the discovery of each minor planet were taken from MPC's "Discovery Circumstances" page (http://cfa-www.harvard.edu/iau/lists/NumberedMPs.html).

Results

970 Primula

Primula was discovered on November 29, 1921 by K. Reinmuth in Heidelburg and has an estimated diameter around 10 km. The synodic period of rotation was 2.721 ± 0.001 hours, with an amplitude of 0.13 ± 0.03 magnitude, consistent with the results of Sada et al. (2004). A total of 300 images were taking during five observation sessions over a period of nine weeks. All of the images were three minute exposures.

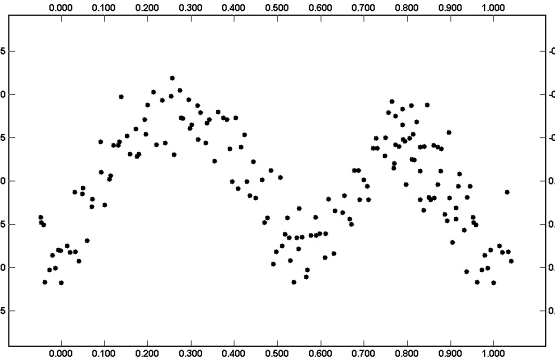

Figure 1: Lightcurve for 970 Primula with a period of 2.721 hours. The Zero point is J.D. 2452952.736923. Relative magnitude is used as the ordinate.

1027 Aesculapia

Aesculapia is an estimated 20 km asteroid that was discovered on November 11, 1923 by G. Van Biesbroeck at Williams Bay. Attempts to produce a double peaked lightcurve have so far been inconclusive. More observations of this asteroid are needed. The period shown below for Aesculapia is 6.83 ± 0.10 hours with an amplitude of 0.15 ± 0.03 magnitude. A total of 445 images were

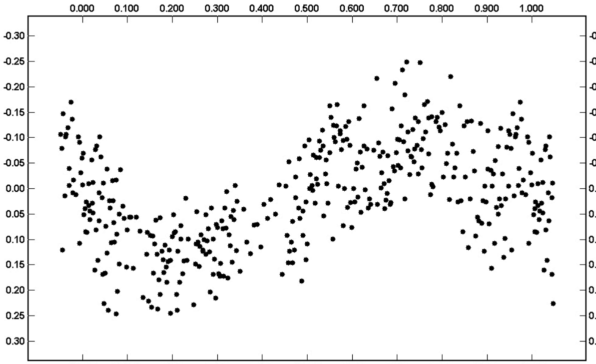

Figure 2: Lightcurve for 1027 Aesculapia with a period of 6.830 hours. The Zero point is J.D. 2453061.616612. Relative magnitude is used as the ordinate.

taken over during two observations sessions over a period of four days using one minute exposures.

1127 Mimi

Discovered on January 13, 1929 by S. J. Arend at Uccle, Mimi has a diameter of about 25 km. We find the period for Mimi to be 8.541 ± 0.001 hours with an amplitude of 0.95 ± 0.02 magnitude. A total of 129 images that were taken over two consecutive nights using three minute exposures. When these observations showed identical parts of the lightcurve, a request was made on the CALL website for international co-operation. Additional images were taken by René Roy from Blauvac, France [627], and the data was compiled by Raoul Behrend from Geneva, Switzerland [517] to form the lightcurve presented here.

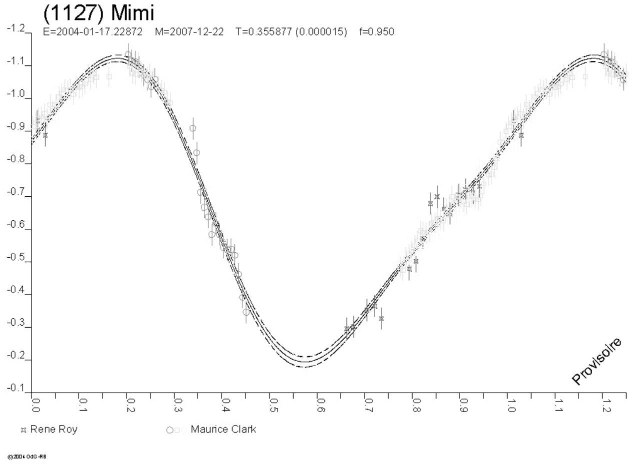

Figure 3: Lightcurve for 1127 Mimi with a period of 8.541 hours. Relative magnitude is used as the ordinate. Graph courtesy of Raoul Behrend.

1501 Baade

Asteroid Baade was discovered on October 20, 1938 by A. Wachmann at Bergedorf and has an estimated diameter of about 20 km. Observations were made on seven nights over a period of ten weeks which resulted in a total of 414 images of three minutes duration. We find a period solution of 10.501 ± 0.001 hours, with an amplitude of 0.19 ± 0.05 magnitude. Despite the range of dates over which the observations were made, it was not possible to observe the entire lightcurve.

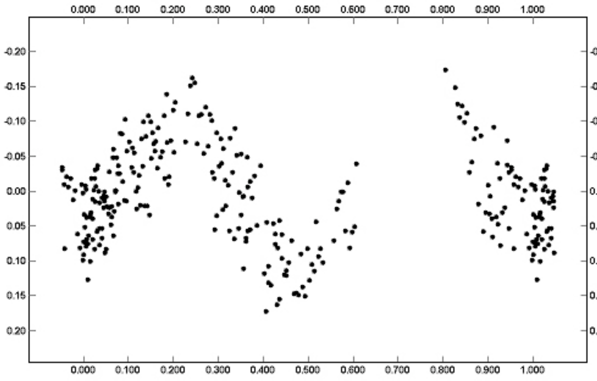

Figure 4: Lightcurve for 1501 Baade with a period of 10.501 hours. The Zero point is J.D. 2452926.707450. Relative magnitude is used as the ordinate.

2112 Ulyanov

This approximately 10 km diameter asteroid was discovered on July 13, 1972 by T.M. Smirnova at Nauchnyj. The period of rotation for this asteroid found was 3.000 ± 0.001 hours with an amplitude of 0.33 ± 0.05 magnitude. Observations were made on two nights that were two weeks apart. A total of 208 images were taken using both one and three minute exposures.

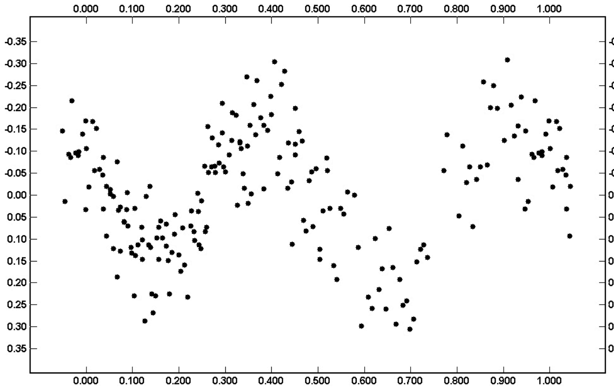

Figure 5: Lightcurve for 2112 Ulyanov with a period of 3.000 hours. The Zero point is J.D. 2452952.739708. Relative magnitude is used as the ordinate.

Acknowledgments

We would like to thank both René Roy and Raoul Behrend for their work on 1127 Mimi, as well as Brian Warner for all of his work with the program “Canopus.”

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PHOTOMETRY OF 1196 SHEBA, 1341 EDMEE, 1656 SUOMI, 2577 LITVA, AND 2612 KATHRYN

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Results for the following asteroids (lightcurve period and amplitude) observed from Santana Observatory during the period April to June 2004 are reported: 1196 Sheba (6.32 ± 0.01 hours and 0.28 mag.), 1341 Edmee (11.89 ± 0.01 hours and 0.30 mag.), 1656 Suomi (2.59 ± 0.01 hours and 0.50 mag.), 2577 Litva (2.82 ± 0.01 hours and 0.50 mag.), 2612 Kathryn (7.71 ± 0.01 hours and 0.50 mag.).

Santana Observatory (MPC Code 646) is located in Rancho Cucamonga, California at an elevation of 400 meters and is operated by Robert D. Stephens. Temporarily, a 0.35 meter SCT operating at F/11 with an SBIG ST1001E CCD camera were used for these observations. This telescope is on a Paramount ME jointly owned with Glenn Malcolm and is being tested before delivery to a new observatory at a remote location. Further details can be obtained at the author's web site. Aperture photometry was done using the software program "Canopus" developed by Brian Warner and including the Fourier analysis routine developed by Alan Harris (Harris et al, 1989). This program allows combining data from different observers and adjusting the zero points to compensate for different equipment and comparison stars. It also adjusts for light-time differences between observations. Dark frames and flat fields were used to calibrate the images. Further details on "Canopus" can be found in Warner (2003).

All of the asteroids were selected from the "CALL" web site (Warner 2004). 1341 Edmee and 2612 Kathryn did not have a previously reported period. The others were selected because of their high altitude and '2' uncertainty rating.

1196 Sheba

Discovered May 21, 1931 by C. Jackson at Johannesburg, Sheba is a Main Belt II asteroid with an estimated radius of 15 km. Sheba is named for the biblical Queen of Sheba. 452 unfiltered observations on three nights between April 23 and 26, 2004 were used to determine the synodic period of 6.32 ± 0.01 hours with an amplitude of 0.28 ± 0.03 magnitude. The period originally was reported as 7.08 hours (Binzel 1987). It was observed on three nights over November 21-27, 1984 and reported with a quality code of the period as a 2, where the result is a reasonable composite showing roughly half or more of a complete cycle and there may be some ambiguity with alias periods, but is probably not in error by more than 20%. The period ended up being within 10% the originally reported value. A high density of observations was obtained on each of the three nights covering the entire period and clearly defining the maxima and minima.

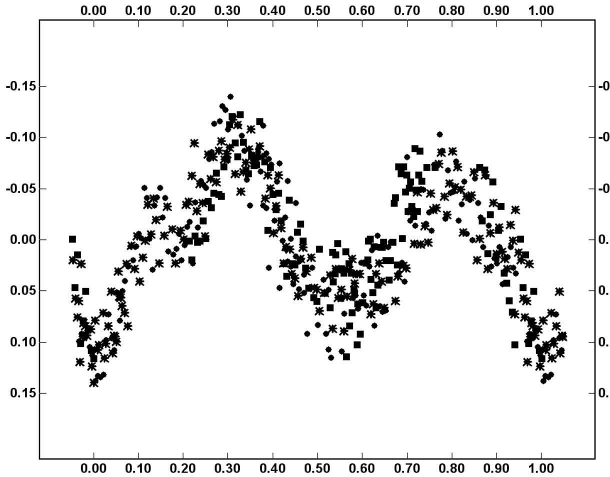

Figure 1. Lightcurve of 1196 Sheba based upon a derived period of 6.32 ± 0.01 hours. The 0% Phase is equal to 2453081.850860 JD (corrected for light-time).

1341 Edmee

Discovered January 27, 1935 by E. Delporte at Uccle, Edmee is a Main Belt IIb asteroid with an estimated radius of 14 km. Edmee is named in honor of Mrs. Edmée Chandon who was an astronomer at the Paris Observatory. 795 unfiltered exposures on five nights between April 8 and 21, 2004 were used to determine the synodic rotational period of 11.89 ± 0.01 hours with an amplitude of 0.30 ± 0.03 magnitude. It was apparent early into the project that I could not obtain an easy solution. Seemingly, the same segment of the curve was repeating on every run. Most of the observing sessions had a short drop in brightness, a reversal to a maximum, and then a strong decline in brightness. This pattern repeated over two weeks implying that the period had a strong correlation to the Earth's rotation, either 12 or 24 hours. A noise spectrum of the RMS values implied that either a 11.89 or 23.78 hour solution was possible. Reviewing the resulting lightcurves, I deemed the 11.89 hour solution more likely because it showed a slightly bimodal curve whereas the 23.78 hour lightcurve had a steep slope and other unlikely features. Still, even with 80% of the lightcurve obtained, I have to apply an uncertainty rating of '2'.

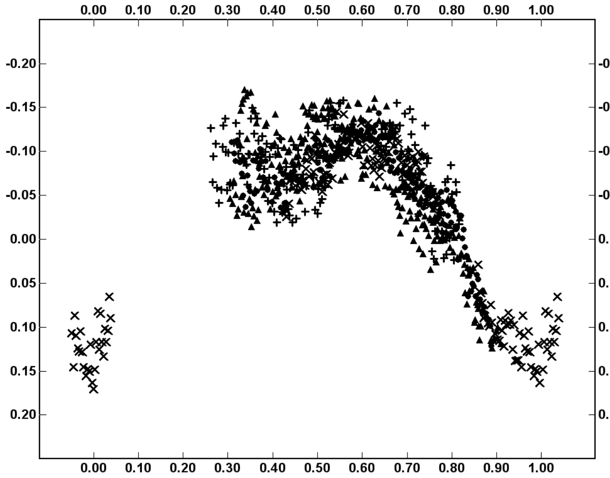

Figure 2. Lightcurve of 1341 Edmee based upon a derived period of 11.89 ± 0.01 hours. The 0% Phase is equal to 2453080.680183 JD (corrected for light-time).

1656 Suomi

Discovered March 11, 1942 by Y. Väïsälä at Turku, Suomi is a Hungaria Family asteroid with an estimated radius of 4 km. Suomi is named in honor of Finland, the country in which it was discovered. 573 unfiltered observations on five nights between April 27 and May 2, 2004 were used to determine the synodic rotational period of 2.59 ± 0.01 hours. Suomi was originally reported to have a period of 2.42 hours (Wisniewski 1997). The original period was reported with a quality code of the period as a 2, where the result is a reasonable composite showing roughly half or more of a complete cycle and there may be some ambiguity with alias periods. The period ended up being within 7% of the originally reported period. A high density of observations was obtained on each of five nights clearly defining the extrema. Each separate night of observations covered over two rotations of the asteroids. The low amplitude and noisiness of the data made it difficult to clearly define the period, however, after five nights of data, the extrema could be clearly seen in the phased lightcurve. Within the Fourier noise spectrum plot, the 2.59 hour solution is the strongest candidate and the lightcurve shows the best correlation. Various binning strategies for the data were tried, all arriving at the same period of 2.59 hours.

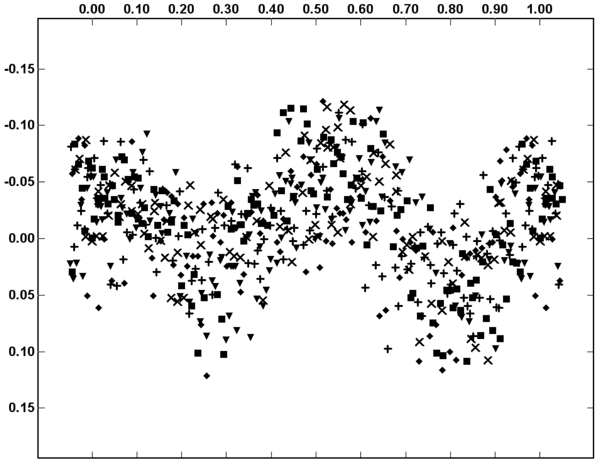

Figure 3. Lightcurve of 1656 Suomi based upon a derived period of 2.59 ± 0.01 hours. The 0% Phase is equal to 2453034.986312 JD (corrected for light-time).

2577 Litva

Discovered March 12, 1975 by N. S. Chernykh at Nauchnyj, Litva is a Hungerias Family asteroid with an estimated radius of 4 to 9 km. Litva is named for the Lithuanian Soviet Socialist Republic, since 1991 the independent state of Lithuania. Two hundred ninety six observations between April 15 and April 17, 2004 were used to determine the synodic rotational period of 2.82 ± 0.01 hours with an amplitude of 0.30 ± 0.03 magnitude. Litva was originally reported to have a period of 5.618 hours (Wisniewski 1997). It was observed it on two nights in 1988. It was noted that the data could be fit only by a rather unusual triply periodic curve and that the period could be doubly periodic with some erroneous points in the data. Applying the 5.618 period to my data yielded a single hump lightcurve. Using the half period of 2.82 hours produced a classic bimodal lightcurve. In addition, data from each of the three nights indicates the second maximum to be .04 magnitudes dimmer than the primary maximum.

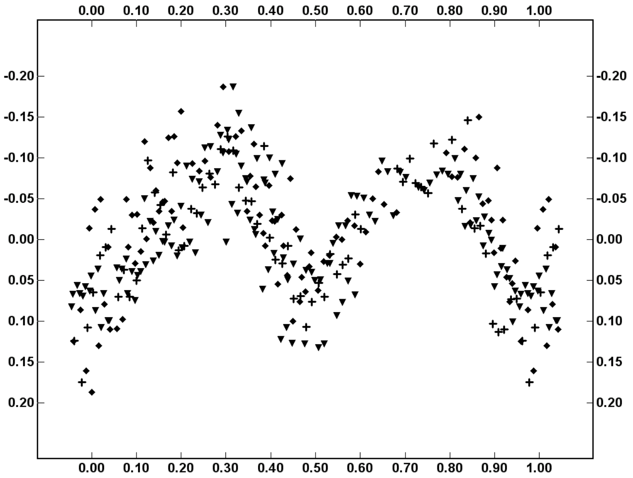

Figure 4. Lightcurve of 2577 Litva based upon a derived period of 2.82 ± 0.01 hours. The 0% Phase is equal to 2453111.713182 JD (corrected for light-time).

2612 Kathryn

Discovered February 28, 1979 by N. G. Thomas at Anderson Mesa, Kathryn is named in honor of Kathryn Gail Thomas-Hazelton, daughter of the discoverer. It is a Main Belt III asteroid with an estimated diameter between 20 and 50 km. 347 observations on six nights between May 4 and 13, 2004 were used to determine the synodic rotational period of 7.71 ± 0.01 hours with an amplitude of 0.48 ± 0.04 magnitude. Because the asteroid was close to the nearly Full Moon on several nights, red and infrared filters were used to increase the signal to noise ratio.

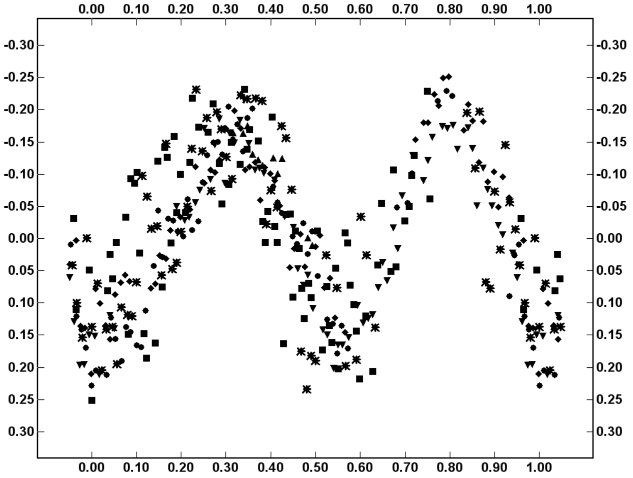

Figure 5. Lightcurve of 2612 Kathryn based upon a derived period of 7.71 ± 0.01 hours. The 0% phase is equal to 2453130.698788 JD (corrected of light-time).

Acknowledgements

Many thanks to Brian Warner for his continuing work and enhancements to the software program "Canopus" which makes it possible for amateur astronomers to analyze and collaborate on asteroid rotational period projects and for maintaining the CALL Web site which helps coordinate collaborative projects between amateur astronomers.

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CORRIGENDUM: ROTATIONAL PERIODS OF ASTEROIDS 1165 IMPRINETTA, 1299 MERTONA, 1645 WATERFIELD, 1833 SHMAKOVA, 2313 ARUNA, AND (13856) 1999 XZ105

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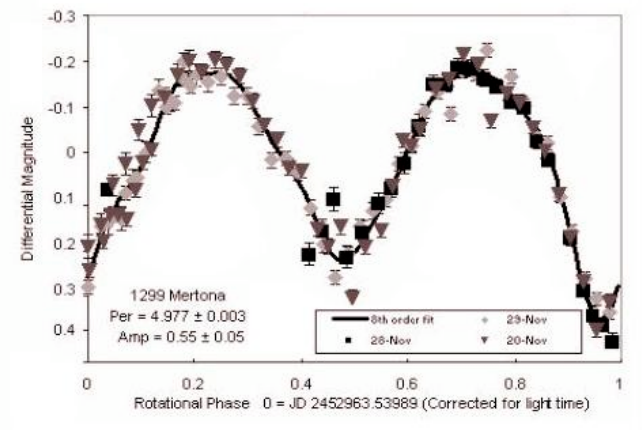
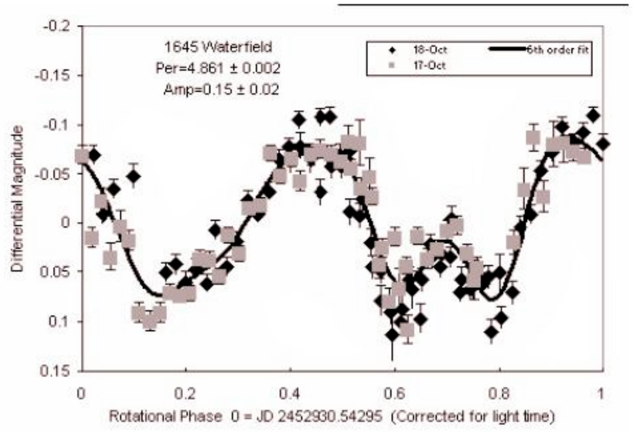
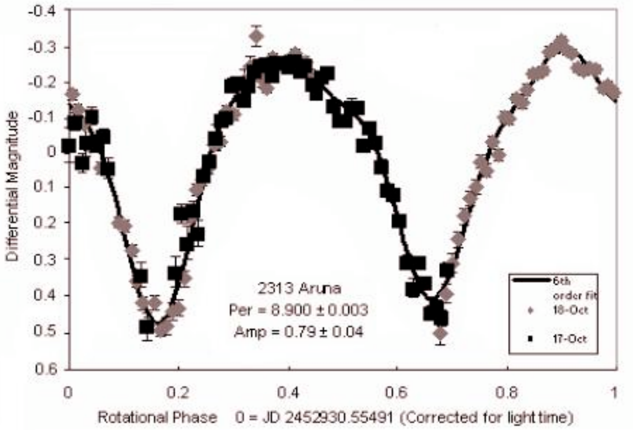
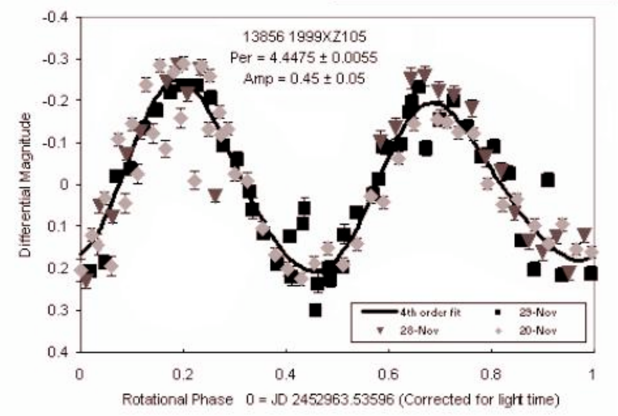
Vertical scales were inadvertently inverted for four lightcurve figures published by us in *Minor Planet Bulletin* **31**, 71-73 (2004). Corrected figures for 2313 Aruna, 1299 Mertona, 1645 Waterfield and (13856) 1999 XZ105 are given here. The reported period and amplitude results are unchanged.









THE MINOR PLANET OBSERVER: WORKING AND LEARNING TOGETHER

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Those of you who attend meetings that involve amateurs know that one topic of discussion that always seems to come up is "what is an amateur?" The definition over time has become increasingly blurred, especially with the off-the-shelf equipment now available. The definition becomes even more difficult when one sees the level of work being done by the non-professional community. I saw many examples of such at two meetings in May and June.

The first was the Society for Astronomical Sciences Symposium on Telescope Science in Big Bear Lake, CA. This annual affair brought together a strong and dynamic mix of professionals and amateurs who presented papers on a wide range of topics including asteroid occultations and lightcurves, extrasolar transits, and spectroscopy from the basic to a level of sophistication far beyond "amateur" status yet done by so-called "amateurs."

The American Astronomical Society is putting a strong commitment behind its Working Group on Professional-Amateur Collaboration. This was demonstrated by the second event, a special topic session at the AAS meeting in Denver, CO, arranged by Dr. James C. White of Rhodes College, TN, where, among other things, a pro-am team presented results of a multi-year study of Ha regions in the Southern Hemisphere sky. Plans are to expand that to cover other bands as well. The survey was conducted using a small observatory amongst the giants at CTIO in Chile that was run remotely from the U.S. – with occasional "kick the dome or reboot the computer" help from the observing staff at CTIO.

One point that is very clear from the two meetings is that pro-am collaborations are growing, not only in number but quality and sophistication. What's not quite as clear is how meetings should proceed. Some people prefer the topics to cover possible collaborations and how-to technique. Others prefer seeing the results of those collaborations. I think there's room for both and the trick is finding the right balance. I encourage you to get involved by becoming a member of SAS (www.socastrosci.org), the AAVSO (www.aavso.org), or any other group of like-minded observers. I also encourage you to "spread the gospel" of doing research when attending star parties, club meetings, or whenever an opportunity presents itself.

Another point made more often is how the Internet has changed the way things are done. It's also opened doors of research opportunities for the entire astronomical community as the data from the Sloan Digital Sky Survey and others are put on-line. From a desktop computer, any researcher can explore the distribution of stars and galaxies, determine color dependencies among specific types of targets – even asteroids, and much more. Cloudy skies and a full moon are no longer valid reasons for research grinding to a halt.

However, I'm a "photon collector", meaning I like to gather them myself. I don't let a full moon stop me but I've yet to figure a way around rain and snow clouds. As I've said before, I like looking at the images as they come down and measuring them to get an asteroid's lightcurve. Sometimes there's a nice surprise as in one case in early June. I used several stars in the fields for comparisons in differential photometry. I plotted the data for each comparison to be sure none of them was variable. As has happened about a half-dozen times before, one of the stars did prove to be variable and with no listing in the General Catalog of Variable Stars or other catalogs I searched. Another target to put on the list for follow up.

Yet another target! It seems there are too many at times. I know that diversity is the spice of life but a bland diet is not always bad. Put another way: moderation in all things. While I've tended to stick to a narrow field of research, other amateurs I know are engaged in several fields, all at the same time. I admire their energy and skills. On the other hand, there's something to be said for a leisurely pace and I find it suits me well. Whatever path you take, don't worry about the one not taken. Leave that to the poets and philosophers and try your best to enjoy the one you're on.

I'd like to call your attention to a worthwhile program, Project ASTRO, which was started by the Astronomical Society of the Pacific in the early 90's. This program has as one of its principal goals to form partnerships between educators (usually grades 4-9) and astronomers (professional or amateur). At least four times a year, often more, the astronomer visits the educator's class to give talks and hands on demonstrations. These promote not only astronomy but also the fundamentals of science and the wonders of even the simplest discovery. The beginnings of a coalition for Colorado formed in June with the Space Science Institute of Boulder, CO, acting as the broker. There are about fifteen such coalitions in the country. More would be better, much better. For more information about Project ASTRO, visit the ASP web site at www.astrosociety.org/education/astro/about/astrosites.html.

The state of amateur astronomy is changing fast. More and more the non-professional is becoming an integral part of research and educational outreach. Both are vital roles. If you are among the group of dedicated "uncompensated" astronomers, I encourage you to try to connect with the professional and/or educational community. If a professional scientist or educator, you would do well to seek out the amateurs. They form a vast pool of dedicated, often well-trained and talented observers that can augment and compliment your work in any number of ways.

Finally, it was gratifying to get the previous issue of the Minor Planet Bulletin and see so many lightcurves and some new names amongst the submitting authors. I can remember the time when the entire MPB was only four pages, maybe eight. The last issue was 32! Of the nearly two thousand known lightcurves, amateurs can easily lay stake to a quarter of those, if not more. I don't know if there's a specific limit on the number of pages that the Editor imposes. On the chance there is, then it behooves us all to get our lightcurve papers in early in hopes of being towards the front of the line and so avoid delaying publication more than necessary. Of course, as I write this I have yet to do mine. Sigh! Yet another item for the list.

Clear Skies!

LIGHTCURVE PHOTOMETRY OPPORTUNITIES
OCTOBER – DECEMBER 2004

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A quick glance at the short list of asteroids in the “Lightcurve Opportunites” section shows things are wide open in that none of them has a known lightcurve of any degree of certainty. Of course, there’s always the chance that between the time the list was prepared and it appears in print that matters have changed but that should not deter you. The objects are all reasonably bright and so should be within easy reach of most backyard scopes. The most significant complication may come for those asteroids reaching brightest late in the year. They will likely be wandering within the crowded fields of the Milky Way in Gemini, Orion, and surrounding constellations.

This calls for much more care when measuring images, especially if, like most people, you’re using aperture photometry. Even PSF fitting has trouble in very crowded fields but it can help in those intermediate situations. However, PSF is a much more difficult process and so is not used as often. If using aperture photometry, be sure to use as small an aperture as possible, without taking the extreme case. The general recommendation is 3-4x the average FWHM of the stars in the field. In a crowded field, you might be able to take this down to 2x FWHM. Make sure to have a good “dead zone”, a region between the measuring aperture area and the sky annulus where all data is rejected. This helps avoid contamination of either the target or sky data.

When working crowded fields, it’s not a bad idea to at least review the placement of the apertures for the target and comparisons for each image. Invert the image so that you have dark stars on a lighter field and, if your software allows, use a zoom window that lets you see the target area magnified. All of these help you to spot a faint field star more easily and so avoid it encroaching into the target-measuring aperture. When working asteroids that may be binary and so even a 0.02-0.03mm change can be important, you must do all you can to get “pure” data. The same applies if you are working an asteroid for shape modeling.

When it comes time to plot your data, be sure to follow the several conventions adopted for asteroid work. One that seems still to be a frequent problem is presenting plots with brightness increasing downward. The correct method is to have points at the top represent when the asteroid is brightest. It sometimes appears that magnitudes are computed in the sense of "comparison minus asteroid", rather than the other way around. In other cases, magnitudes are computed correctly but plotted upside down simply because of the default used by commercial plotting routines of having Y-axis scale values increase upwards. If you use such a package be sure to reverse the Y-axis scale.

While reverse plotting does not necessarily affect the period analysis it does has a significant impact on pole and shape determinations. If you’re not certain that you’re plotting things correctly, remember that – assuming a basic triaxial ellipsoid – the light variation is approximately sinusoidal in units of intensity squared. When intensity is converted to a magnitude scale, the plot should result in broad maxima and sharp minima. If the reverse is true for your plots, then you should check at least two possibilities before assuming the curve is correct. First, that the curve is not plotted upside-down and, second, that the derived period is not a shorter harmonic of the true period. For the latter, check a range of periods and, if your software allows, view the period “spectrum.” If you find multiple solutions that are of nearly equal potential, you should include that information in your article.

An additional help for those analyzing your work from the plots alone is to use different symbols for each run. This allows the researcher to determine how the data fits into the phased curve and whether or not one or more runs covers a significant portion of the curve. All this can be important when trying to determine if the suggested period might have been influenced by an alias, e.g., the meshing of data using a given period on a nearly symmetrical curve places the data for one maximum at the location of the opposite maximum. This would be a “half-period” alias issue and is often difficult to avoid when the curve is symmetrical and a single run cannot catch enough of the entire curve.

Ultimately, the perfect solution is to make public the data used to produce the lightcurves. Many observers are now including that data on their web sites where they post their plots as well. There are also plans to create – maybe soon – a central clearinghouse for lightcurve observations that will be regularly maintained. Of course, there is the concern that posting data and curves on a web site places them in the public domain. It’s up to the individual to decide when and how he’s comfortable making his data public but we encourage that he eventually do so.

Finally, we strongly encourage that if working a target with a previously unknown or uncertain period that you stick with it, even if it appears to be one with a long period or small amplitude. There is a strong temptation to move on to easier, more quickly determined targets. While understandable, putting the difficult targets aside only increases statistical biases, the reduction of which is the purpose of most observing programs in the first place. The overall picture of rotational statistics is rapidly being filled in. It is the details, the fine brushstrokes made by working the more difficult targets, that will bring the scene to full brilliance.

Lightcurve Opportunities

		Brightest				
#	Name	Date	V	Dec	Per.	Amp
1326	Losaka	10 02.3	13.6	-24		
723	Hammonia	10 10.4	13.5	+ 3		
3220	Murayama	10 19.1	14.0	+10		
1459	Magnya	10 19.5	12.9	+ 3		
463	Lola	10 21.8	13.2	+ 7		
1473	Ounas	10 22.2	13.8	+15		
1023	Thomana	10 28.7	13.6	+ 8		
1423	Jose	11 02.2	13.8	+13		
299	Thora	11 03.9	13.8	+16		
1185	Nikko	11 17.1	13.9	+16		
319	Leona	11 27.4	13.5	+ 7		
2892	Filipenko	11 27.5	13.8	+48		
906	Caltech	12 15.1	13.9	+22		
553	Kundry	12 18.6	13.9	+26		
1181	Lilith	12 19.6	13.7	+22		

Low Phase Angle Opportunities

#	Name	Date	PHA	V	Dec
787	Moskva	10 01.4	0.84	12.5	+01
490	Veritas	10 01.8	0.91	12.1	+01
1572	Posnania	10 05.2	1.00	12.9	+07
454	Mathesis	10 26.3	0.04	13.0	+13
205	Martha	10 27.0	0.20	12.6	+12
636	Erika	11 03.3	0.53	12.8	+17
257	Silesia	11 04.5	0.27	13.0	+16
599	Luisa	11 06.7	0.04	11.0	+16
147	Protogeneia	11 06.9	0.38	12.4	+17
150	Nuwa	11 09.1	0.45	11.6	+16
64	Angelina	11 10.0	0.80	10.8	+19
32	Pomona	11 19.9	0.92	11.1	+17
378	Holmia	11 22.9	0.66	12.7	+19
1122	Neith	11 25.4	0.00	12.6	+21
268	Adorea	11 29.8	0.84	12.8	+19
106	Dione	12 05.7	0.52	10.9	+24
62	Erato	12 10.2	0.97	12.1	+20
517	Edith	12 13.1	0.45	12.6	+24
832	Karin	12 13.9	0.07	14.7	+23
261	Prymno	12 29.5	0.07	11.7	+23

Shape/Spin Modeling Opportunities

		Brightest				
#	Name	Date	V	Dec	Per.	Amp
165	Loreley	10 07.5	12.1	+21	7.226	0.12-0.15
125	Liberatrix	10 13.8	12.6	+05	3.968	0.29-0.71
40	Harmonia	10 13.6	9.4	+01	8.910	0.15-0.36
944	Hidalgo	10 28.2	13.4	+36	10.063	0.35-0.60
376	Geometria	10 27.1	12.8	+22	7.734	0.14-0.18
505	Cava	10 26.2	11.2	-03	8.1789	0.23
47	Aglaja	10 30.8	11.5	+18	13.20	0.03-0.17
683	Lanzia	11 16.3	12.7	+30	8.630	0.12
80	Sappho	11 23.9	10.0	+14	14.030	0.10-0.40
283	Emma	12 03.6	12.7	+32	6.888	0.31
423	Diotima	12 20.9	11.7	+29	12.79	0.11
238	Hypatia	12 21.6	12.2	+04	8.86	0.12-0.15

Note that the amplitude in the table just above could be more, or less, that what's given. Use the listing as a guide and double-check your work. Asteroids 376 Geometrica and 423 Diotima are probably the least deserving of attention while 683 Lanzia is very close to having sufficient coverage and so only a small number of additional lightcurves will allow devising a pole and shape determination. Any of the others need more coverage and so any lightcurve would be greatly welcomed.

For a more complete listing of lightcurve targets visit the CALL site: www.MinorPlanetObserver.com/astlc/default.htm

NEW CLUSTERS FOR HIGHLY INCLINED MAIN-BELT ASTEROIDS

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We search for new, high-inclination clusters in the main-belt asteroid population using the D-criterion. We find three possible new clusters: 31 Euphrosyne; 702 Alauda and 945 Barcelona. We provide simple ephemerides for the next oppositions in the time interval 2004-2008, in order to motivate physical observations of the candidates, to check their reliability as families.

Thanks to the availability of Synthetic proper elements (Knezevic and Milani, 2000) it was possible to apply the D-criterion (Lindblad and Southworth, 1994) to find new clusters in the highly inclined main belt asteroid population. Synthetic proper elements (Knezevic and Milani, 2000) have better accuracy with respect to the previously available ones by more than a factor 3; in terms of the relative velocities at breakup this means that the typical accuracy is the order of ~ 5 m/s. Analytical proper elements were usually involved in asteroid families identification but they are computed with the limitation of (sin i) < 0.3 so we do not have any family for orbital inclination greater than 17.5 degrees.

Identification Method

The D-criterion method for identifying dynamical families was introduced by Lindblad and Southworth (1971) and modified by Lindblad (1994) and may be written in the following form:

$$D(m,n)^2 = (e_n - e_m)^2 + (q_n - q_m)^2 + \left(2 \cdot \sin\frac{i_n - i_m}{2}\right)^2 \qquad (1)$$

where m and n represent the two orbits to be compared, e and i are eccentricity and inclination, q = a · (1 – e) is the perihelion distance and a the semi-major axis; D is a generalized distance in proper elements space: D=0 indicates two orbits which are identical in proper (q, e, i) space.

The D-criterion search method may be described as a cluster analysis program based on a neighbor linking technique. The program computes a distance D(m,n) for all possible pairs in proper elements space; if for a given pair the discriminant D(m,n) is less than a priori stipulated distance D_s the program accepts these two orbits as neighbors, i.e. as belonging to a cluster. A problem in any cluster analysis based on the neighbor searching technique is how to specify the rejection level, i.e. the appropriate cut-off distance D_s. The rejection level D_s = 0.011 was adopted and to study the statistical significance of the obtained clusters several rejection levels were adopted and the robustness factor R was defined as follows:

$$R = \frac{N_{0.009}}{N_{0.011}} \qquad (2)$$

where $N_{0.011}$ is the number of members in a given family at the adopted rejection level $D_s = 0.011$ and $N_{0.009}$ is the number of members in the same family at the next stricter rejection level $D_s = 0.009$. R is a degree of persistance or stability of a family to changes in the rejection level.

Results

Found clusters are shown in Fig. 1 with the (a, sin i) distribution; numbers are the catalogue number of the first member of clusters.

Pallas family (a ~ 2.771 AU, e ~ 0.281, sin i ~ 0.548, i ~ 33.2) is well known and it was found by Hirayama and using proper elements computed by Lemaitre and Morbidelli (1994); finally it was confirmed by Bus with spectroscopic observation.

Hansa family (a ~ 2.644 AU, e ~ 0.009, sin i ~ 0.375, i ~ 22.1) is proposed by Hergenrother, Larson and Spahr (1996) and also by Knezevic and Milani (2000) but no results are currently available.

Phocaea region is clearly visible in the inner part of the Main Belt, with proper elements 2.2 < a < 2.5 AU and sin i > 0.3. Condensation of objects should not necessarily be interpreted as a family, with a common origin from a single parent body; it might be instead a stability island, which means that the group might be separated from the other asteroids by gaps resulting from the destabilizing effect of some resonances.

For the first time we suggest the following clusters:

31 Euphrosyne cluster

(a ~ 3.155 AU, e ~ 0.208, sin i ~ 0.447, i ~ 26.5)

702 Alauda cluster

(a ~ 3.194 AU, e ~ 0.021, sin i ~ 0.369, i ~ 21.7)

945 Barcelona cluster

(a ~ 2.637 AU, e ~ 0.251, sin i ~ 0.513, i ~ 30.8)

Table I: Identified clusters

MPC	$N_{0.050}$	$N_{0.020}$	$N_{0.011}$	$N_{0.009}$	R	a	e	sin i	i
2	23	14	4	1	0.250	2.771	0.281	0.548	33.2
31	34	18	8	5	0.625	3.155	0.208	0.447	26.5
480	70	25	13	11	0.846	2.644	0.009	0.375	22.1
702	71	28	9	7	0.321	3.194	0.021	0.369	21.7
945	19	5	3	1	0.333	2.637	0.251	0.513	30.8

Table II: Physical parameters of involved minor planets

MPC	Fam	Taxonomy Thol	SMII	Abs. Magn.	Diam. Km	Albedo	Period hours	Amplitude Magn.	N
2	2	B	B	4.13	498.07	0.1587	7.8132	0.03-0.16	4
2382	2		B	11.60	26.00	0.06	>0.05		
4969	2		C						
5222	2		B						
31	31	C	Cb	6.74	255.90	0.0543	5.531	0.09-0.13	4
480	480	S		8.38	56.22	0.2485	16.19	0.58	3
702	702	C	B	7.25	194.73	0.0587	8.36	0.07-0.10	2
1101	702			10.10	37.86	0.1124	12.68	0.05-0.23	2
1838	702			10.60	34.90	0.0836	16.141	0.8	3
3139	702			9.90	41.69	0.1115	8.33	0.34	2
945	945	S	Sq	10.13	25.47	0.2416	7.36	0.09	3

Table I shows the obtained results, where MPC is the catalogue number of the minor planet representing the cluster; $N_{0.050}$, $N_{0.020}$, $N_{0.011}$ and $N_{0.009}$ give the number of members in a given family at the adopted rejection levels Ds = 0.050, 0.020, 0.011, 0.009 respectively; R is the robustness factor, a is the proper semi-major axis, e is the proper eccentricity, sin i is the sine of the proper inclination, i is the proper inclination.

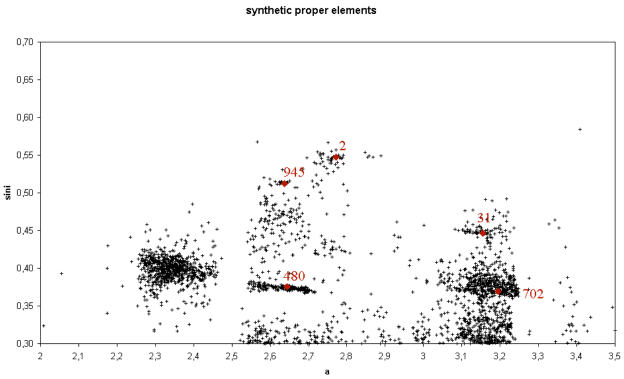

Figure 1: Main Belt asteroids: (a, sin i) distribution with (sin i)>0.3

Spectroscopic campaign: from clusters to families?

The first step in the process leading to the discovery of a family consists in identifying it as a statistically significant clustering of objects in the space of proper elements. The following step is to compare the physical properties of the supposed members with what is known about the outcomes of catastrophic impacts, and with the mineralogical properties of asteroidal bodies. As a first step we call these groups of asteroids "clusters"; the term "families" should be used only when both the statistical and physical definitions are coincident.

In order to investigate the physical properties of these objects, we have calculated basic ephemeredes for the incoming oppositions, lying in the time interval 2004-2008. Those interested can retrieve these data at the following URL:

http://www.uai.it/sez_ast/family/index.htm

More pictures are available there too.

Table II reports the current knowledge about physical parameters of involved minor planets, MPC is the catalogue number, Fam is the suggested cluster, taxonomy class from Tholen and SMASSII, absolute magnitude, diameter, albedo and photometric parameters are reported.

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