

LIGHTCURVES FOR SHAPE MODELING: 852 WLADILENA, 1089 TAMA, AND 1180 RITA

David Polishook

Department of Earth, Atmospheric, and Planetary Science
Massachusetts Institute of Technology, Cambridge MA 02139
davidpol@mit.edu

(Received: 15 July)

The folded lightcurves and synodic periods of 852 Wladilena, 1089 Tama, and 1180 Rita are reported. The data are used by Hanus *et al.* (2012) to derive the rotation axis and to construct a shape model by applying the inversion lightcurve technique.

The shapes of asteroids can be constructed by using inversion techniques when the asteroids are observed from different aspect angles and at different apparitions (Kaasalainen *et al.*, 2001). Josef Durech and Josef Hanus from the Astronomical Institute of the Charles University in Prague use archival data and new observations to model the shapes of asteroids and constrain their spin axis orientations (<http://astro.troja.mff.cuni.cz/projects/asteroids3D/web.php>). Three asteroids that were measured in the past by other observers were observed at the Wise Observatory and their lightcurves were used by Hanus *et al.* (2012) for shape modeling. This paper presents the lightcurves and the derived synodic rotation periods.

The observations were performed using the two telescopes of the Wise Observatory (code: 097, E 34:45:47, N 30:35:46): A 1-m Ritchey-Chrétien telescope and a 0.46-m Centurion telescope (Brosch *et al.*, 2008). At the $f/7$ focus, the 1-m telescope is equipped with a wide-field SITe CCD (field of view [FOV] of $34^\circ \times 17'$, 4096×2048 pixels, $0.872''$ per pixel, binned 2×2). The 0.46-m telescope was equipped with an SBIG STL-6303E (FOV of $75^\circ \times 55'$, 3072×2048 pixels, $1.47''$ per pixel, unbinned) at the $f/2.8$ prime focus. While a V filter was mounted on the 1-m telescope, the 0.46-m was used in white light with no filters (Clear). Exposure times were 30–180s, determined by the brightness and angular velocity of the asteroids. All images were taken with an auto-guider. The observational circumstances are summarized in Table I.

The images were reduced in a standard way. IRAF *phot* function was used for the photometric measurements with an aperture of four pixels. After measuring, the photometric values were calibrated to a differential magnitude level using local comparison stars. The brightness of these stars remained constant to ± 0.02 mag. The measurements of 1089 Tama from the 2006 apparition were also calibrated to a standard magnitude system by observing Landolt equatorial standards (Landolt, 1992). This usually adds an error of ~ 0.03 mag. and allows fitting the data to $H-G$ system (Bowell *et al.*, 1989). Astrometric solutions were obtained using *PinPoint* (www.dc3.com) and the asteroids were identified in the MPC web database. Analysis for the lightcurve period and amplitude was done by the Fourier series analysis (Harris and Lupishko, 1989). See Polishook and Brosch (2009) for a complete description about reduction, measurements, calibration and analysis.

Results

The lightcurves and synodic rotation periods of 852 Wladilena (Fig. 1), 1089 Tama (Fig. 2, 3), and 1180 Rita (Fig. 4) are reported.

Reliability code is determined by the definitions that appeared in Warner *et al.* (2009). 1089 Tama was observed at four different apparitions (2006, 2008, 2009, and 2011), but here data are presented from only 2006 (Fig. 2) and 2009 (Fig. 3) when enough points were obtained to cover the entire lightcurve. The derived rotation periods of 852 Wladilena and 1089 Tama are similar to those appear in the literature (e.g., Kiss, 1999; Harris 1999; Behrend, 2006; Durech, 2009). The derived rotation period of 1180 Rita (9.605 ± 0.006 h) is different from the literature values, which range between 14.72 h (Gonano, 1991), 14.902 h (Dahlgren, 1998), and 20.496 h (Slyusarev, 2012), and is partially similar to the 9 h deduced by Binzel and Sauter (1992) from a partial measurement of the entire period. In order to test the reliability of these different periods, the obtained data points were folded to try to match the periods in the literature (Fig. 5). It is clear from the figure that none of the literature values match to the measurements. Therefore, it seems certain that the true rotation period of 1180 Rita is 9.605 ± 0.006 h.

A list of candidate asteroids for the inversion modeling appears at the end of this issue.

Acknowledgement

The author is thankful to the AXA research grant. The collaboration with Dr. Durech and Mr. Hanus was very fruitful. I thank the Wise Observatory staff for their continuous support.

References

- Behrend, R., Bernasconi, L., Roy, R., Klotz, A., Colas, F., Antonini, P., Aoun, R., Augustesen, K., Barbotin, E., Berger, N., Berrouachdi, H., Brochard, E., Cazenave, A., Cavadore, C., Coloma, J., Cotrez, V., Deconihout, S., Demeautis, C., Dorseuil, J., Dubos, G., Durkee, R., Frappa, E., Hormuth, F., Itkonen, T., Jacques, C., Kurtze, L., Laffont, A., Lavayssière, M., Lecacheux, J., Leroy, A., Manzini, F., Masi, G., Matter, D., Michelsen, R., Nomen, J., Oksanen, A., Pääkkönen, P., Peyrot, A., Pimentel, E., Pray, D., Rinner, C., Sanchez, S., Sonnenberg, K., Sposetti, S., Starkey, D., Stoss, R., Teng, J.-P., Vignand, M., and Waelchli, N. (2006). “Four new binary minor planets: (854) Frostia, (1089) Tama, (1313) Berna, (4492) Debussy.” *Astron. Astrophys.* **446**, 1177-1184.
- Binzel, R.P. and Sauter, L.M. (1992). “Trojan, Hilda, and Cybele asteroids - New lightcurve observations and analysis.” *Icarus* **95**, 222-238.
- Brosch, N., Polishook, D., Shporer, A., Kaspi, S., Berwald, A. and Manulis, I. (2008). “The Centurion 18 telescope of the Wise Observatory.” *Astrophys. Space Sci.* **314**, 163-176.
- Dahlgren, M., Lahulla, J.F., Lagerkvist, C.-I., Lagerros, J., Mottola, S., Erikson, A., Gonano-Beurer, M., and di Martino, M. (1998). “A Study of Hilda Asteroids.” *Icarus* **133**, 247-285.
- Durech, J., Kaasalainen, M., Warner, B.D., Fauerbach, M., Marks, S.A., Fauvaud, S., Fauvaud, M., Vugnon, J.-M., Pilcher, F., Bernasconi, L., and Behrend, R. (2009). “Asteroid models from combined sparse and dense photometric data.” *Astron. Astrophys.* **493**, 291-297.
- Gonano, M., Mottola, S., Neukum, G., and di Martino, M. (1991). “Physical study of outer belt asteroids.” *Advances in Space Research* **11**, 197-200.

Asteroid	Scope	Filter	Date	Time span [hours]	N	r [AU]	Δ [AU]	α [Deg]	L _{PAB} [Deg]	B _{PAB} [Deg]
(852) Wladilena	C18	C	Mar 10, 2010	2.7	94	2.84	1.9	8.56	164.2	19.2
	C18	C	Mar 11, 2010	2.12	74	2.83	1.9	8.66	164.2	19.1
	C18	C	Mar 13, 2010	1.83	56	2.83	1.9	8.92	164.2	19
(1089) Tama	1m	V	Oct 19, 2006	8.16	120	1.97	0.99	7.13	35.2	-3.1
	1m	V	Oct 23, 2006	5.07	49	1.96	0.98	4.87	35.9	-3
	1m	V	Nov 23, 2006	7.37	149	1.94	1.02	14.6	41.3	-2.1
	1m	V	Nov 24, 2006	6.94	67	1.94	1.03	15.13	41.4	-2.1
	1m	V	Nov 25, 2006	7.87	73	1.94	1.03	15.63	41.6	-2
	1m	R	May 1, 2008	3.04	61	2.45	1.45	4.34	214.3	2.7
	1m	R	May 9, 2008	6.23	74	2.45	1.48	8.04	214.8	2.6
	C18	C	Oct 11, 2009	5.1	104	2.1	1.29	20.27	344.5	-4.6
	C18	C	Oct 12, 2009	2.63	37	2.1	1.3	20.61	344.6	-4.6
	C18	C	Oct 13, 2009	4.56	88	2.1	1.3	20.98	344.8	-4.6
	C18	C	Oct 15, 2009	3.05	44	2.1	1.32	21.63	345.1	-4.6
	C18	C	Oct 17, 2009	4.77	99	2.09	1.33	22.27	345.5	-4.5
	C18	C	Oct 22, 2009	4.58	72	2.09	1.38	23.72	346.4	-4.5
	C18	C	Oct 24, 2009	4.3	76	2.08	1.39	24.24	346.8	-4.4
	C18	C	Nov 7, 2009	2.64	39	2.06	1.52	27.05	349.7	-4.2
	C18	C	Nov 8, 2009	3.42	41	2.06	1.53	27.2	350	-4.1
	C18	C	Nov 11, 2009	3.5	52	2.06	1.56	27.6	350.7	-4.1
	C18	C	Nov 20, 2009	4.02	60	2.05	1.65	28.5	352.9	-3.9
	C18	C	Nov 22, 2009	3.99	70	2.04	1.67	28.63	353.5	-3.8
	C18	C	Dec 18, 2009	1.02	18	2.01	1.94	28.77	1.4	-3.3
	C18	C	Dec 19, 2009	2.81	48	2.01	1.95	28.72	1.7	-3.2
	C18	C	Dec 20, 2009	1.84	28	2.01	1.96	28.68	2.1	-3.2
	C18	C	Apr 02, 2011	2.39	55	2.30	1.34	9.31	177.4	4.5
(1180) Rita	C18	C	Mar 19, 2010	1.25	33	4.23	3.25	2.27	176.9	8.2
	C18	C	Mar 20, 2010	2.21	57	4.23	3.25	2.34	176.9	8.2
	C18	C	Mar 21, 2010	3.06	82	4.23	3.25	2.45	176.9	8.2
	C18	C	Apr. 9, 2010	1.6	40	4.21	3.3	6.41	176.8	8.1

Table I: Observational circumstances. Legend: asteroid name, telescope, filter, observation date, nightly time span of the specific observation, the number of images obtained (N), the object's heliocentric (r) and geocentric distances (Δ), the phase angle (α), and the Phase Angle Bisector (PAB) ecliptic coordinates (LPAB, BPAB). The table includes data from 2008 and 2011 that are not plotted.

Name	Period [hours]	Reliability code	Amplitude [mag]	H [mag]
(852) Wladilena	4.608 ± 0.002	3	0.28 ± 0.01	9.9
(1089) Tama	16.464 ± 0.004	3	0.14 ± 0.03	11.7
(1180) Rita	9.605 ± 0.006	2	0.15 ± 0.03	9.14

Table II: Analysis results. Legend: asteroid name, rotation period, reliability code, amplitude, absolute magnitude H from the MPC website.

Harris, A.W. and Lupishko, D.F. (1989). "Photometric lightcurve observations and reduction techniques." In *Asteroids II* (R. P. Binzel, T. Gehrels, M. S. Matthews, eds.), pp. 39-53. Univ. of Arizona Press, Tucson.

Harris, A.W., Young, J.W., Bowell, E., and Tholen, D.J. (1999). "Asteroid Lightcurve Observations from 1981 to 1983." *Icarus* **142**, 173-201.

Hanuš, J., Durech, J., Brož, M., Marciniak, A., Warner, B.D., Pilcher, F., Stephens, R.D., Behrend, R., Antonini, P., Audejean, M., Augustesen, K., Barbotin, E., Baudouin, P., Bayol, A., Bernasconi, L., Borczyk, W., Boschl, J.-G., Brochard, E., Brunetto, L., Casullil, S., Cazenave, A., Charbonnel, S., Christophe, B., Colas, F., Colias, J.-F., Coloma, J., Conjat, M., Cooney, W., Correia, H., Cotrez, V., Coupier, A., Crippa, R., Cristofanelli, M., Dalmás, Ch., Danavaro, C., Demeautis, Ch., Droege, T., Durkee, R., Esseiva, N., Esteban, M., Fagas, M., Farroni, G., Fauvaud, M., Fauvaud, S., Del Frio, F., Garcia, L., Geier, S., Godon, C., Grangeon, K., Hamanowa, H., Hamanowa, H., Heck, N., Higgins, D., Hirsch, R., Husarik, M., Ikonen, T., Jade, O., Kaminski, A., Kankiewicz, P., Klotz, A., Koff, R.A., Kryszczyńska, A., Kwiatkowski, T., Laffont, A., Leroy, A.,

Lecacheux, J., Leonie, Y., Leyrat, C., Manzini, F., Martin, A., Masi, G., Matter, D., Michalowski, J., Michałowski, M.J., Michałowski, T., Michelet, J., Michelsen, R., Morelle, E., Naves, R., Nomen, J., Oey, J., Ogloza, W., Oksanen, A., Oszkiewicz, D., Pääkkönen, P., Paiella, M., Pallares, H., Paulo, J., Pavic, M., Payet, B., Polinska, M., Polishook, D., Poncy, R., Revaz, Y., Rinner, C., Rocca, M., Roche, A., Romeuf, D., Roy, R., Saguin, H., Salom, P.A., Sanchez, S., Santacana, G., Santana-Ros, T., Sareyan, J.-P., Sobkowiak, K., Sposetti, S., Starkey, D., Stoss, R., Strajnic, J., Teng, J.-P., Trégon, B., Vagnozzi, A., Velichko, F.P., Waelchli, N., Wagrez, K., and Wucher, H. (2012). "Physical models of asteroids derived by lightcurve inversion." *Astron. Astrophys.*, submitted.

Kaasalainen, M., Torppa, J., and Muinonen, K. (2001). "Optimization methods for asteroid lightcurve inversion. II. The complete inverse problem." *Icarus* **153**, 37-51.

Kiss, L.L., Szabo, G., and Sarneczky, K. (1999). "CCD photometry and new models of 5 minor planets." *Astronomy and Astrophysics Supplement Series* **140**, 21-28.

Landolt, A. (1992). “*UBVRI* Photometric Standard Stars in the Magnitude Range of $11.5 < V < 16.0$ Around the Celestial Equator.” *The Astronomical Journal* **104**, 340-371.

Polishook, D. and Brosch, N. (2009). “Photometry and Spin Rate Distribution of Small Main Belt Asteroids.” *Icarus* **199**, 319-332.

Slyusarev, I.G., Shevchenko, V.G., Belskaya, I.N., Krugly, Y.N., and Chiorny, V.G. (2012). “CCD Photometry of Hilda Asteroids.” *LPI Contributions* **1667**, 6398.

Warner, B.D., Harris, A.W., and Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146.

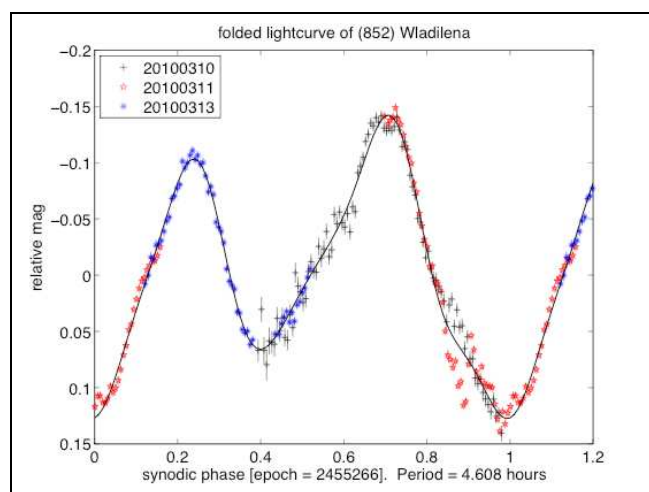


Figure 1. Lightcurve of 852 Wladilena based on $P = 4.608$ h.

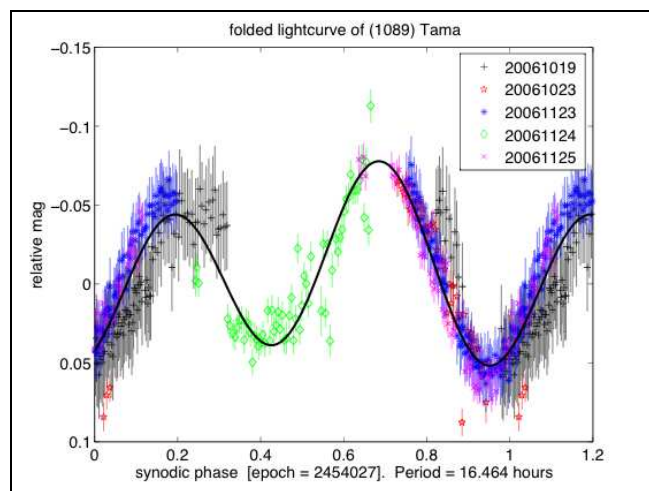


Figure 2. Lightcurve of 1089 Tama in 2006 based on $P = 16.464$ h.

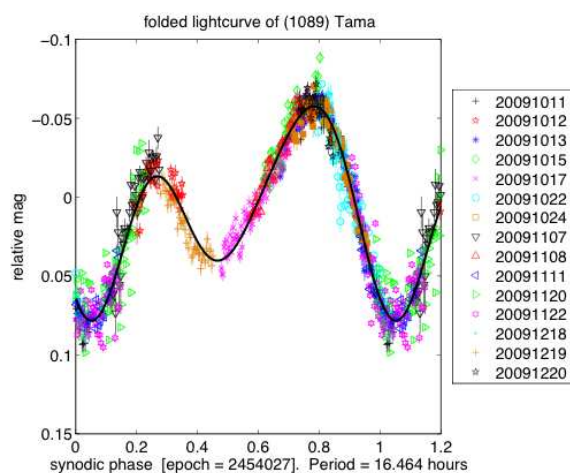


Figure 3. Lightcurve of 1089 Tama in 2009 based on $P = 16.464$ h.

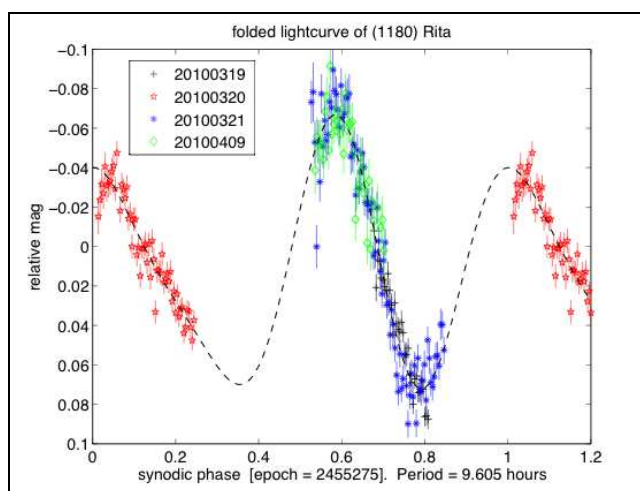


Figure 4. Lightcurve of 1180 Rita based on $P = 9.605$ h.

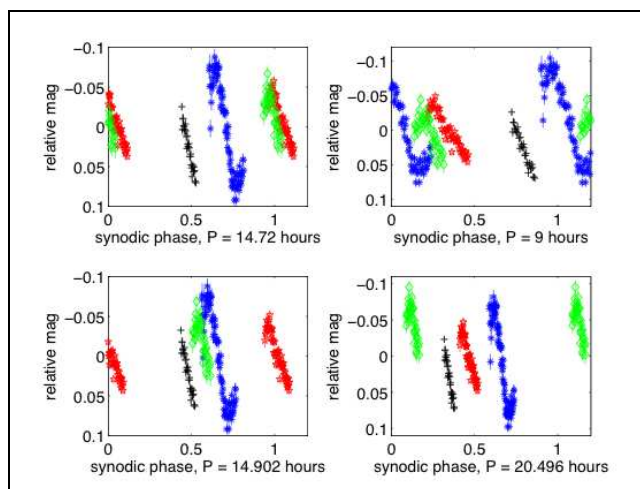


Figure 5. Lightcurve of 1180 Rita using data from 2010 but forced to previously-reported periods. Based on the poor fits, the new result of $P = 9.605$ h is considered highly reliable.