In *Asteroids, Comets, Meteors (ACM) 2012*, May 16-20, 2012, Nigata, Japan, Abstract 6398.

Stellingwerf, R.F. (1978). "Period determination using phase dispersion minimization." *Astrophysical Journal* **224**, 953-960.

Stephens, R.D. (2011). "Asteroids observed from Gmars and Santana observatories: 2011 January-March." *Minor Planet Bulletin* **38**, 165-166.

Strabla, L., Quadri, U., and Girelli, R. (2011). "Minor planet lightcurve analysis at Bassano Bresciano observatory 2010 October-2011 March." *Minor Planet Bulletin* **38**, 169-172.

Vanmunster, T. (2006). *Peranso 2.0. User manual*, CBA Belgium Observatory, *CBABelgium.com*.

Warner, B.D. (2009). "Notes from the acting editor." *Minor Planet Bulletin* **36**, 1.

Warner, B.D., Harris, A.W., and Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146, and the up-to-date version available at *http://www.minotplanet.info/lightcurvedatabase.html* (The March 2013 version was consulted.)

Wisniewski, W.Z., Michałowski, T., Harris, A.W., and McMillan, R.S. (1997). "Photometric observations of 125 asteroids." *Icarus* **126**, 395-449.

LIGHTCURVE INVERSION FOR 38 LEDA

Lorenzo Franco
A81 Balzaretto Observatory, Rome, ITALY
lor_franco@libero.it

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA

Josef Ďurech
Astronomical Institute
Faculty of Mathematics and Physics
Charles University in Prague
V Holesovickach 2
18000 Prague, CZECH REPUBLIC

(Received: 15 July)

We present shape and spin axis model for main-belt asteroid 38 Leda. The model was obtained with lightcurve inversion process, using combined dense photometric data from apparitions in 1979, 1995, 2000, 2008, 2009-10, 2011, 2012 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 12.836164 ± 0.000016 h and two possible pole solution at (λ = 160°, β = -17°) and (λ = 343°, β = -6°), with an error of ± 10 degrees. From sparse data from the USNO Flagstaff station we find H = 8.61 ± 0.04, G = 0.09 ± 0.04.

The main-belt asteroid 38 Leda has been observed in last four consecutive apparitions by Frederick Pilcher, with a variety of phase angles and phase angle bisectors. To improve the coverage at various aspect angles, we found in the literature further observations, whose lightcurves were downloaded from the Asteroid Photometric Catalogue (APC) by Lagerkvist et al. (2001) at website: *http://asteroid.astro.helsinki.fi/apc*. The observational circumstances for the seven apparitions are reported in Table I.

The data from two of the three sessions of Wang and Shi (2002) were reconstructed by Frederick Pilcher, starting from the published lightcurves, following the failed attempt to contact via email the authors.

To improve the solution we have also used sparse data from USNO Flagstaff Station, as has been shown by Kaasalainen (2004), Ďurech et al. (2009). Sparse data were taken from the AstDys website (*http://hamilton.dm.unipi.it/astdys/index.php/*) for a total of 211 data points. Figures 1, 2 and 3 shows respectively PAB Longitude/Latitude distribution for dense/sparse data and phase curve for the sparse data.

Lightcurve inversion process ware performed using MPO LCInvert v.11.0.0.2. Software (Bdw Publishing), which implement algorithms and code provided by Mikko Kaasalainen and Josef Ďurech. For guidelines and a description of the modeling process see LCInvert Operating Instructions manual and Warner et al. (2008).

Data Analysis

All data from thirty dense lightcurves and one sparse dataset were imported in *LCInvert* for analysis, assigning them a different weighting factor, from 1.0 for best data to 0.3 for sparse data.

In the inversion process the first step is to find an accurate sidereal rotational period. We have started the period search centered on the average of the synodic periods found in the previously published works. The search process found a isolated sidereal period of 12.83611412 h with lower chi-square value (Figure 4).

For pole search we have started using the "Medium" search option (312 fixed pole position with 15° longitude-latitude steps) and the previously found sidereal period set to "float". The "dark facet" weighting factor was increased from 0.1 (default) to 0.5 to keep the dark facet area below 1% of total area. The number of iterations of processing was increased from 50 (default) to 75 for best convergence.

Data analysis shows two lower chi-square solutions differing by 180°, centered at (λ = 165°, β = -15°) and (λ = 345°, β = -15°), see Figure 5 for log(chi-square) values distribution. These values were then refined by running again the pole search using the "Fine" option with the previous period/longitude/latitude set to "float" (49 fixed pole steps with 10° longitude-latitude pairs). The two best solutions are reported in Table II with an averaged sidereal period obtained from the two values found in the pole search process. Typical errors in the pole solution are ± 10 degrees and the uncertainty in period has been evaluated as a rotational error of 10° over the total time-span of the observations.

We prefer the first solution as it has a stronger convergence, small chi-square and RMS values. We have a better lightcurve fit removing the sparse data from the generation of the shape model. The sparse data instead have been much useful to constrain the period and spin axis search. Figure 6 shows the shape model with first solution and Figure 7 shows the good agreement between the model (black line) and observed lightcurves (red points). The second shape solution is very similar to the first and has not been reported.

The model and the data will be stored in Database of Asteroid Models from Inversion Techniques (DAMIT, Ďurech 2012).

Acknowledgement

The work of J. Ďurech was supported by grant GACR P209/10/0537 of the Czech Science Foundation.

References

Bdw Publishing (2012). *http://www.minorplanetobserver.com/MPOSoftware/MPOLCInvert.htm*

Denchev, P., Magnusson, P., and Donchev, Z. (1998) "Lightcurves of nine asteroids, with pole and sense of rotation of 42 Isis." *Planetary and Space Science* **46**, 673-682.

Ďurech, 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." *Astronomy and Astrophysics* **493**, 291-297.

Ďurech,, J. (2012), Database of Asteroid Models from Inversion Techniques (DAMIT). *http://astro.troja.mff.cuni.cz/projects/asteroids3D/web.php*

Harris, A.W., and Young, J.W. (1989). "Asteroid lightcurve observations from 1979-1981." *Icarus* **81**, 314-364.

Kaasalainen, M. (2004). "Physical models of large number of asteroids from calibrated photometry sparse in time." *Astronomy and Astrophysics* **422**, L39-L42.

Lagerkvist C.-I., Piironen J., and Erikson A., eds. (2001). Asteroid Photometric Catalogue, 5th edition. Astronomical Observatory, Uppsala University, Sweden. 201 pp.

Pilcher, F. (2009). "Period Determinations for 33 Polyhymnia, 38 Leda, 50 Virginia, 189 Phthia, and 290 Bruna." *Minor Planet Bull.* **36**, 25-27.

Pilcher, F. (2010). "Period Determinations for 11 Parthenope, 35 Leukothea, 38 Leda, 111 Ate, 194 Prokne, 262 Valda, 728 Leonisis, and 747 Winchester." *Minor Planet Bull.* **37**, 119-122.

Pilcher, F. (2010). "Rotation Period Determinations for 11 Parthenope, 38 Leda, 99 Dike, 111 Ate, 194 Prokne, 217 Eudora, and 224 Oceana." *Minor Planet Bull.* **38**, 183-185.

Pilcher, F. (2010). "Lightcurves and derived rotation periods for 18 Melpomene, 38 Leda, and 465 Alekto." *Minor Planet Bull.* **44**, 33.

Wang, X.-B., and Shi, Y. (2002) "CCD Photometry of Asteroids 38, 174, 276 and 346." *Earth, Moon, and Planets* **91**, 181-186

Warner, B.D., Ďurech, J., Faurerbach, M., and Marks, S., (2008). "Shape and Spin Axis Models for Four Asteroids." *Minor Planet Bull.* **35**, 167-171.

Year	#LCs	Data Points	PA°	PABL°	PABB°	Ref.
1979	2	13	5/4	188	-9	(1)
1995	3	109	10	27/28	9	(2)
2000	2	47	17/14	89/90	5	(3)
2008	8	1551	9/14	329	4/5	(4)
2009-10	3	971	11/14	78/80	6/4	(5)
2011	5	1205	14/4	211	-9	(6)
2012	7	1206	12/5	290	-2/-1	(7)

Table I. Observational circumstances for 38 Leda over seven apparitions, a total of 30 lightcurves were used for lightcurve inversion analysis. Where: PA, PABL and PABB are respectively the phase angle, phase angle bisector longitude and latitude. References: (1) Harris and Young (1989), (2) Denchev, Magnusson and Donchev (1998), (3) Wang and Shi (2002), (4) Pilcher (2009), (5) Pilcher (2010), (6) Pilcher (2011), (7) Pilcher (2013).

λ°	β°	Sidereal Period(h)	ChiSq	RMS
160	-17	12.836164 ± 0.000016	1.5420	0.0170
343	-6		1.5668	0.0172

Table II. The two best spin axis solutions for 38 Leda. The sidereal period was the average of the two solutions found in the pole search process.

PAB Longitude Distribution: 38 Leda

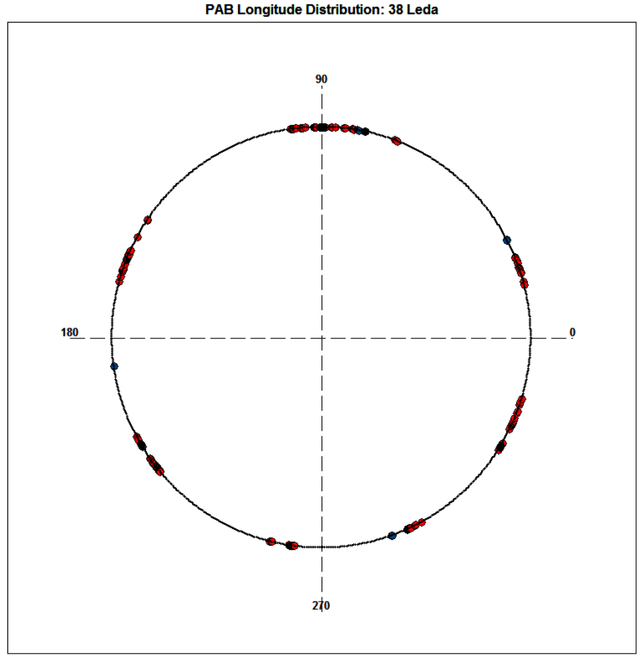

Figure 1. PAB Longitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

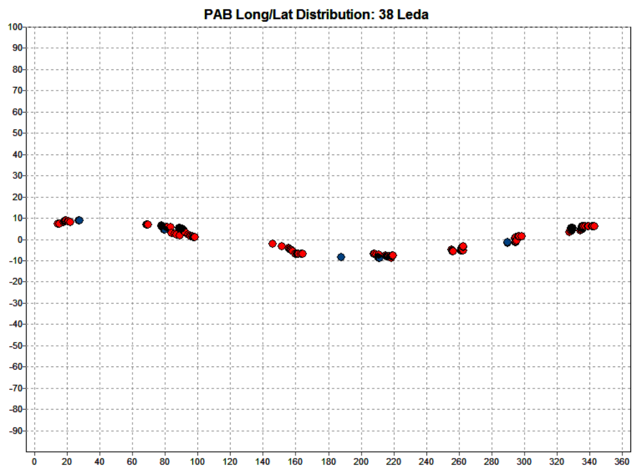

Figure 2. PAB Latitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

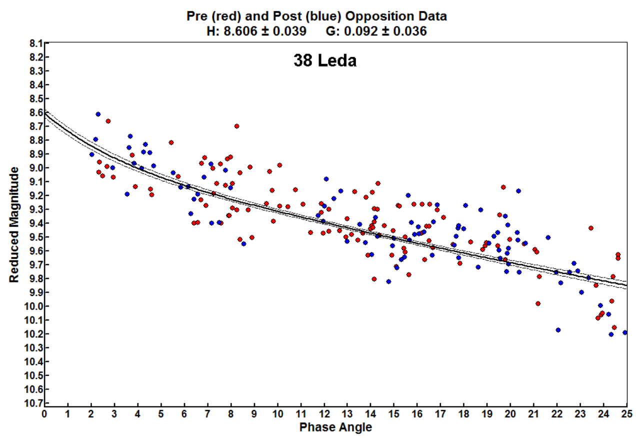

Figure 3. Visual reduced magnitude vs phase angle for sparse data from USNO Flagstaff Station.

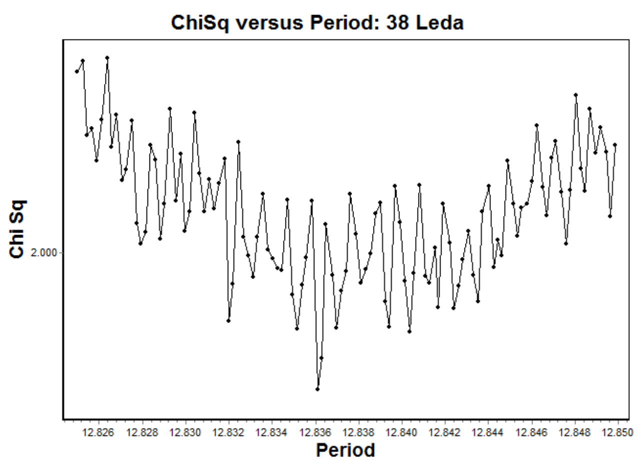

Figure 4. The period search plot from LCInvert shows an isolated minimum at 12.83611412 h.

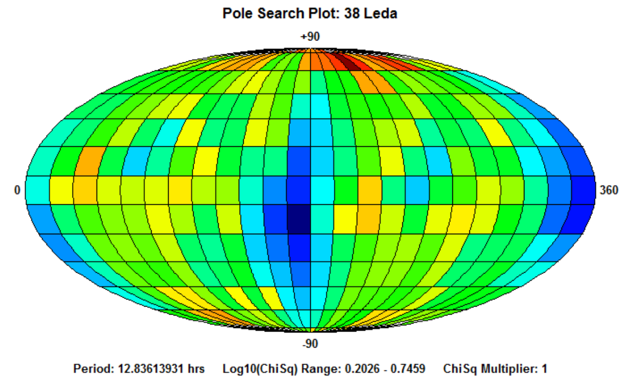

Figure 5. Pole Search Plot of log(ChiSq) values, where dark blue identify lower ChiSq values and Dark red underlying the worst solutions.

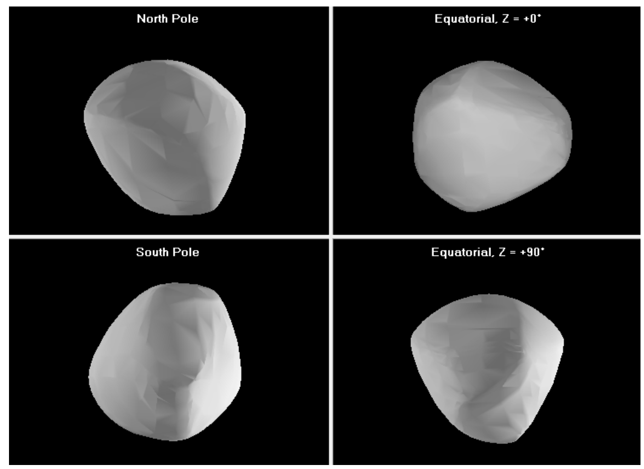

Figure 6. The shape model for 38 Leda (λ = 160°, β = - 17°).

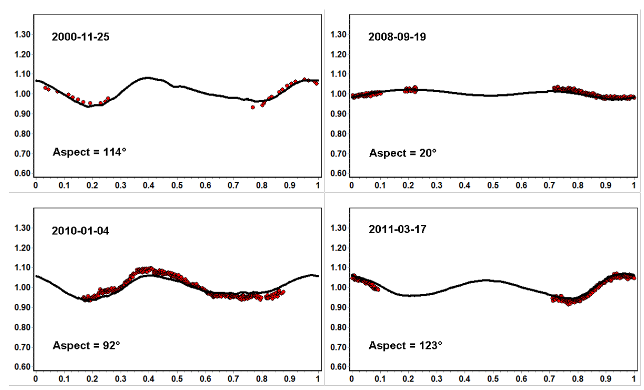

Figure 7. Comparison of model lightcurve (black line) versus a sample of four observed lightcurves (red points).