

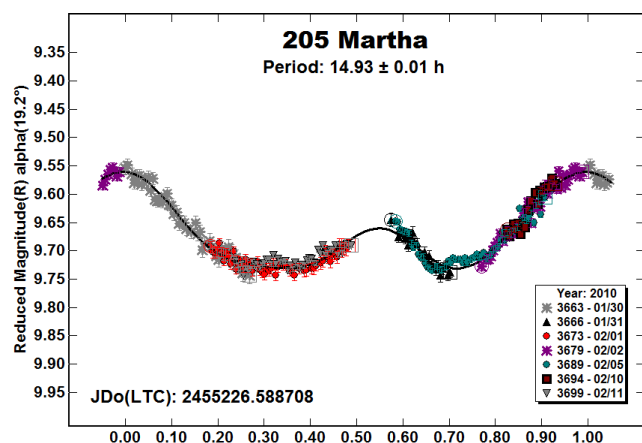


Figure 3: Warner's 2010 data forced to 14.91 h.

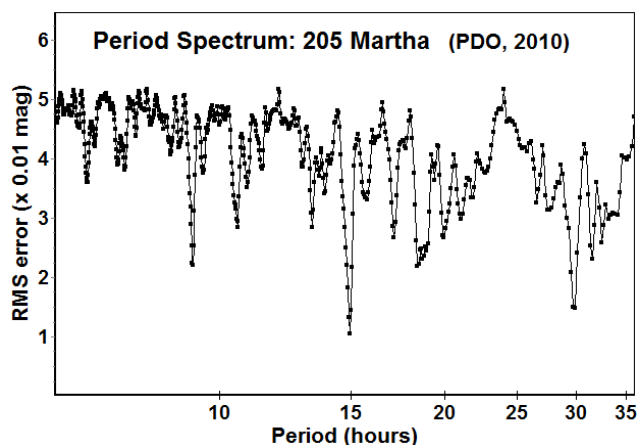


Figure 4: Period spectrum from Warner's 2010 data.

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SHAPE AND SPIN AXIS MODEL FOR 161 ATHOR

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We present shape and spin axis model for main-belt asteroid 161 Athor. The model was obtained with lightcurve inversion process, using combined dense photometric data from apparition in 1979, 1980, 1982, 2008, 2009, 2010-11 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period $P = 7.280087 \pm 0.000005$ h and two mirrored pole solution at $(\lambda = 350^\circ, \beta = -6^\circ)$ and $(\lambda = 170^\circ, \beta = 4^\circ)$, with an error of ± 10 degrees.

The main-belt asteroid 161 Athor has been observed in recent years by Pilcher and Higgins in three consecutive apparitions, with wide phase angles and phase angle bisectors, optimal conditions for starting with a lightcurve inversion project. 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: <http://asteroid.astro.helsinki.fi/apc>. The observational circumstances for the six apparitions are reported in Table I.

To obtain a more robust 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 171 data points. Figures 1, 2 and 3 show respectively the PAB Longitude/Latitude distribution for the dense/sparse data and the phase curve for the sparse data. The lightcurve inversion process was performed using MPO LCInvert v.2.4. Software (Bdw Publishing), which implements algorithms and code provided by Mikko Kaasalainen and Josef Ďurech. For guidelines and a description of the modeling process see the 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, respectively 1.0 and to 0.3. The first critical step is to find an accurate sidereal rotational period. For this, we started the period search centered on the average of the synodic periods found in the previously published work. The second crucial step is

to find the pole spin axis. The pole search was done using the “Fine” search option (612 fixed pole position with 10° 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.

Data analysis shows a result clustered around two lower chi-square mirrored solution, centered at ($\lambda = 350^\circ$, $\beta = 0^\circ$) and ($\lambda = 170^\circ$, $\beta = 10^\circ$), see Figure 4 for log(chi-square) values distribution. These values were then refined by running again the pole search with the previous period/longitude/latitude set to “float”. The two best solutions are reported in Table II with an averaged sidereal period. 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. Figure 5 shows the shape model with first solution and Figure 6 shows the good agreement between the model (black line) and observed lightcurves (red points). This pole solution agrees also with those reported by Pilcher and Higgins (2008) and independently by Ďurech (private communication) using more or less the same observational dataset.

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

Acknowledgement

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Year	#LCs	Data Points	PA°	PABL°	PABB°	Ref.
1979	4	148	11/9	238	-7	(1)
1980	3	16	7/13	57	7/8	(2)
1982	1	120	9/11	159	7	(3)
2008	12	1457	11/10	191	3/1	(4)
2009	3	714	20/10	359/2	-6/-5	(5)
2010-11	7	1691	21/6	121/124	10/11	(6)

Table I. Observational circumstances for 161 Athor over six apparitions, a total of 30 lightcurves were used for lightcurve inversion analysis. References: (1) Debehogne and Zappala (1980), (2) Harris and Young (1989), (3) Carlsson and Lagerkvist (1983), (4) Pilcher and Higgins (2008), (5) Higgins/Pilcher on MPC Lightcurve Database and website: <http://aslc-nm.org/161Athor2009.jpg>, (6) Pilcher (2011).

λ°	β°	Sidereal Period(h)	ChiSq	RMS
350	-6	7.280087 $\pm$ 0.000005	1.2226	0.0163
170	4		1.2632	0.0165

Table II. The two best spin axis solutions for 161 Athor.

Pilcher, F. (2011). “Rotation Period Determinations for 28 Bellona, 81 Terpsichore, 126 Velleda, 150 Nuwa, 161 Athor, 419 Aurelia, and 632 Pyrrha.” *Minor Planet Bull.* **38**, 156-158.

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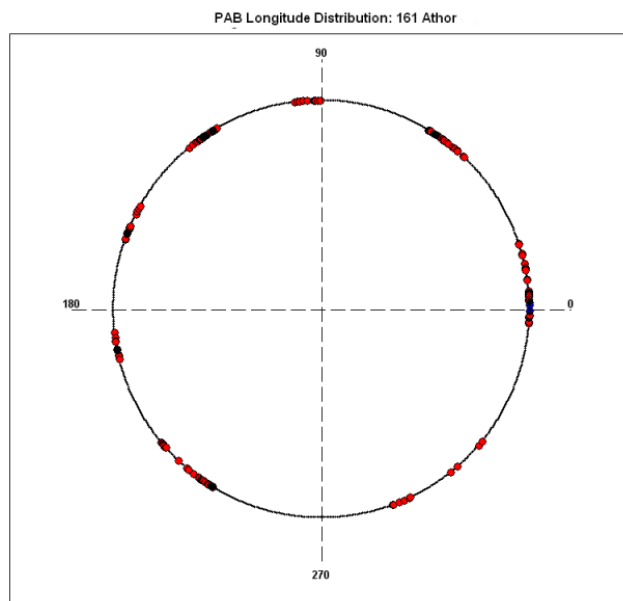


Figure 1. PAB Longitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

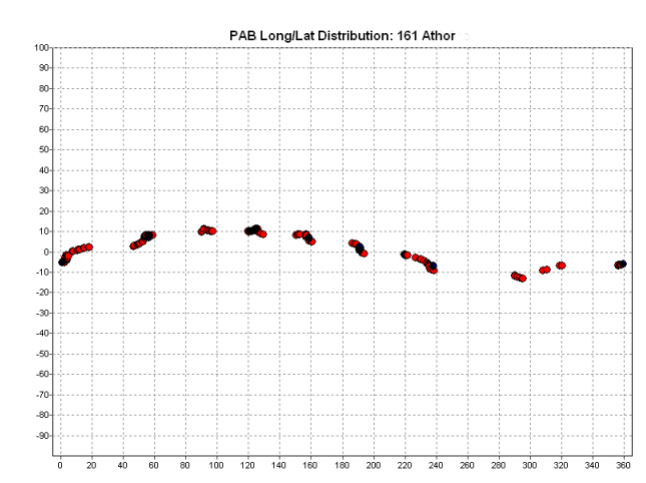


Figure 2. PAB Latitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

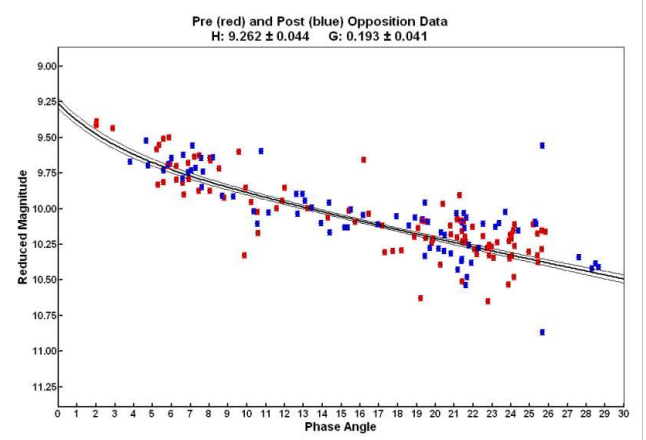


Figure 3. Visual reduced magnitude vs phase angle for sparse data from USNO Flagstaff Station.



Figure 4. Pole Search Plot of $\log(\text{ChiSq})$ values, where dark blue identify lower ChiSq values and Dark red underlying the worst solutions.

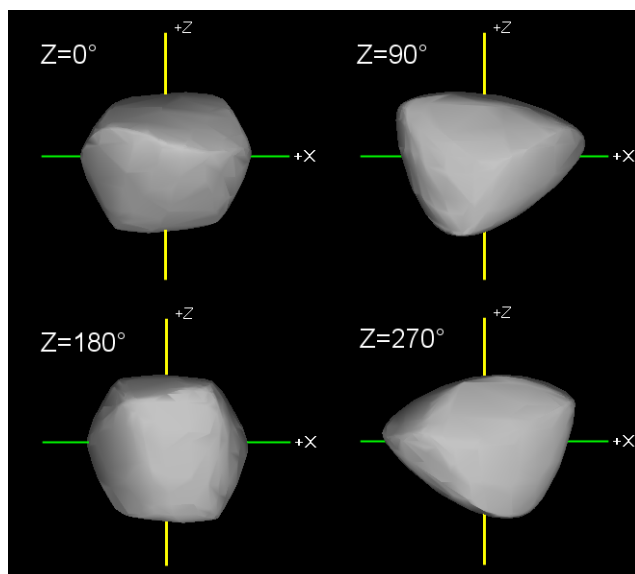


Figure 5. The shape model for 161 Athor ($\lambda = 350^\circ$, $\beta = -6^\circ$).

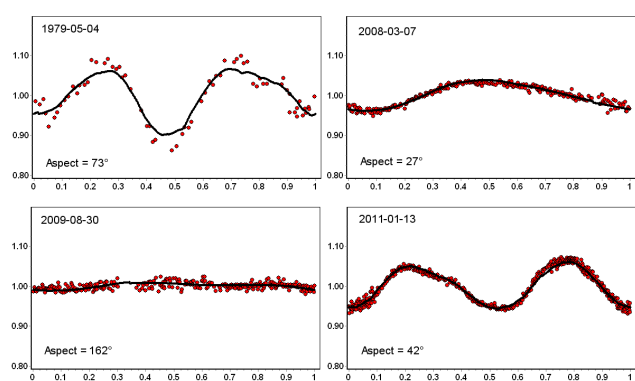


Figure 6. Comparison of model lightcurve (black line) versus a sample of four observed lightcurves (red points).

LIGHTCURVE ANALYSIS FOR FOUR ASTEROIDS

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Lightcurves for four asteroids were obtained at Phillips Academy Observatory (PAO) and HUT observatory from 2012 March to May: 2927 Alamosa, 4419 Allancook, 5374 Hokutosei, and (28704) 2000 GU91.

Lightcurves for four asteroids were obtained at Phillips Academy Observatory and HUT Observatory between 2012 March and May. HUT and Phillips Academy Observatory have twin telescopes: a