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## SPIN-SHAPE MODEL FOR 33 POLYHYMNIA

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(Received: 2020 January 5 Revised: 2020 January 30)

We present a shape and spin axis model for main-belt asteroid 33 Polyhymnia. The model was achieved with the lightcurve inversion process, using combined dense photometric data acquired from five apparitions, between 2008-2019 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 18.60888 ± 0.00029 hours and two mirrored pole solutions at (λ = 19°, β = -65°) and (λ = 185°, β = -61°) with an uncertainty of ± 15 degrees.

The minor planet 33 Polyhymnia has been observed extensively by the authors in the past oppositions, covering a wide range of phase angle bisectors, essential condition for starting a lightcurve inversion work. Dense photometric data were downloaded from ALCDEF (ALCDEF, 2019) and, in order to improve the solution, we have also used sparse data from USNO Flagstaff Station (MPC Code 689), taken from the Asteroids Dynamic Site (AstDyS-2, 2019).

The observational details of the dense data used are reported in Table I with the mid-date of the apparition, longitude and latitude of phase angle bisector ($L_{PAB}$, $B_{PAB}$).

| Reference | Mid date | $L_{PAB}$° | $B_{PAB}$° |
|---|---|---|---|
| Pilcher (2009) | 2008-04-15 | 203 | -1 |
| Pilcher (2011) | 2011-01-15 | 112 | 2 |
| Audejean (2012) Web | 2012-03-13 | 163 | 1 |
| Ferrero (2012) | 2012-03-17 | 162 | 1 |
| Pilcher (2018) | 2018-04-28 | 221 | -1 |
| Pilcher (2020) | 2019-08-31 | 14 | 0 |

Table I. Observational details for the data used in the lightcurve inversion process for 33 Polyhymnia.

Lightcurve inversion was performed using MPO LCInvert v.11.7.5.1 (BDW Publishing, 2016). For a description of the modeling process see LCInvert Operating Instructions Manual, Durech et al. (2010) and references therein.

Figure 1 shows the PAB longitude/latitude distribution for dense/sparse data used in the lightcurve inversion process. Figure 2 (top panel) shows the sparse photometric data distribution (intensities vs JD) and (bottom panel) the corresponding phase curve (reduced magnitudes vs phase angle).

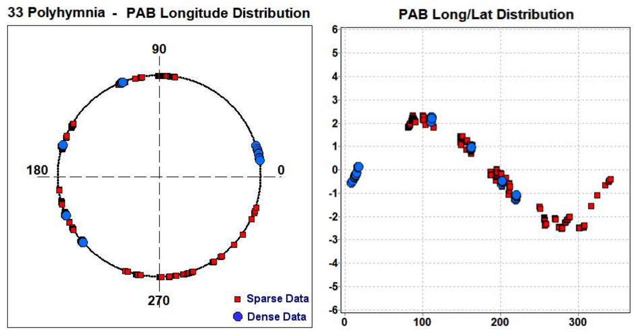


Figure 1: PAB longitude and latitude distribution of the data used for the lightcurve inversion model.

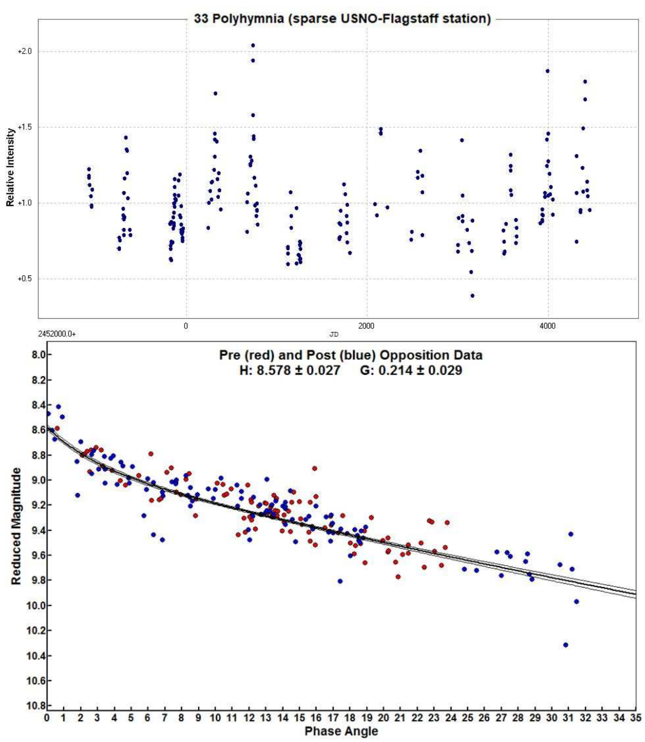


Figure. 2: Top: sparse photometric data point distribution from (689) USNO Flagstaff station (relative intensity of the asteroid's brightness vs Julian Day). Bottom: phase curve obtained from sparse data (reduced magnitude vs phase angle).

In the analysis, the processing weighting factor was set to 1.0 for dense data and to 0.3 for sparse data. The "dark facet" weighting factor was set to 0.5 to keep the dark facet area below 1% of total area and the number of iterations was set to 50.

The sidereal period search was started around the average of the synodic periods found in the asteroid lightcurve database (LCDB; Warner et al., 2009). We found one isolated sidereal periods with a Chi-Sq value within 10% of the lowest Chi-Sq (Figure 3).

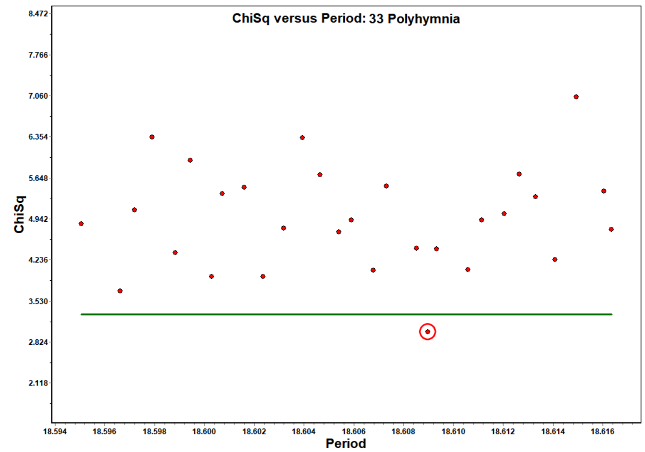


Figure 3: The period search for 33 Polyhymnia shows one isolated sidereal periods with Chi-Sq values within 10% of the lowest value.

The pole search was started using the "medium" option with the previously found sidereal period set to "float". From this step we found two roughly mirrored lower Chi-Sq solutions (Figure 4) separated by 180° in longitude at ecliptic longitude-latitude pairs (15°, -60°) and (195°, -60°).

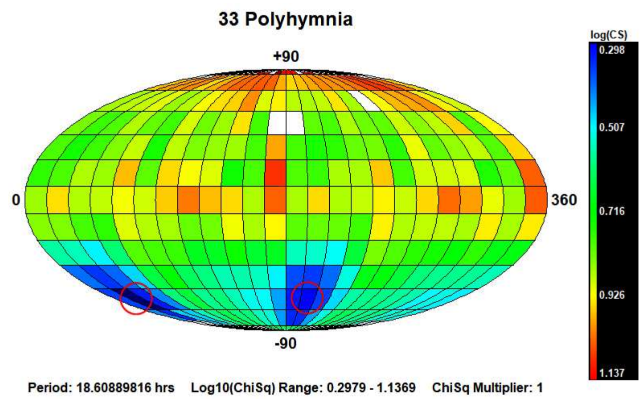


Figure 4: Pole search distribution. The dark blue indicates the better solutions (lower Chi-Sq), while maroon the worst ones.

The subsequent "fine" search, centered on these rough positions, allowed us to refine the position of the pole (Figure 5). The analysis shows two set of clustered solutions within 15° of radius that had Chi-Sq values within 10% of the lowest value, centered at ecliptic longitude-latitude (17°, -64°) and (191°, -65°).

The two best solutions (lower Chi-Sq) are reported in Table II. The sidereal period was obtained by averaging the two solutions found in the pole search process. Typical errors in the pole solution are ± 15° and the uncertainty in sidereal period has been evaluated as a rotational error of 30° over the total time span of the dense data set. Figure 6 shows the shape model (first solution) while Figure 7 shows the fit between the model (black line) and some observed lightcurves (red points).

| λ ° | β ° | Sidereal Period (hours) | RMS |
|---|---|---|---|
| 19 | -65 | 18.60888 ± 0.00029 | 0.0127 |
| 185 | -61 | | 0.0133 |

Table II. The two spin axis solutions for 33 Polyhymnia (ecliptic coordinates) with an uncertainty of ± 15 degrees. The sidereal period is the average of the two solutions found in the pole search process.

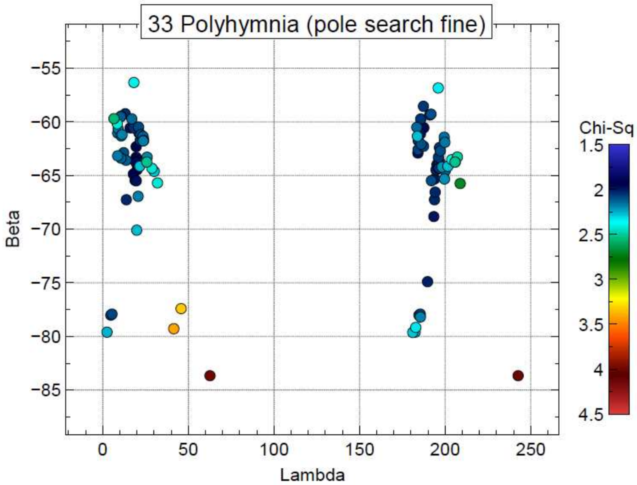


Figure 5: The "fine" pole search shows two clustered solutions centered at the ecliptic longitude / latitude (17°, -64°) and (191°, -65°) with radius approximately of 15° and Chi-Sq values within 10% of the lowest value.

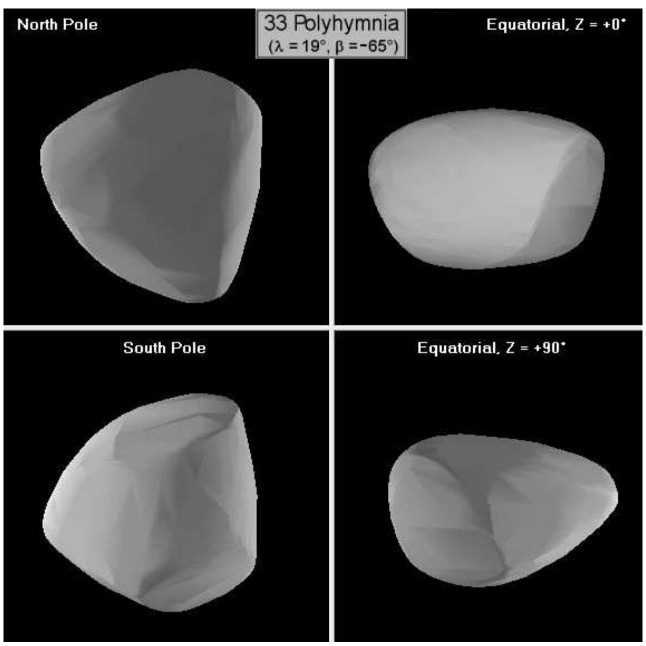


Figure 6: The shape model for 33 Polyhymnia (λ = 19°, β = -65°).

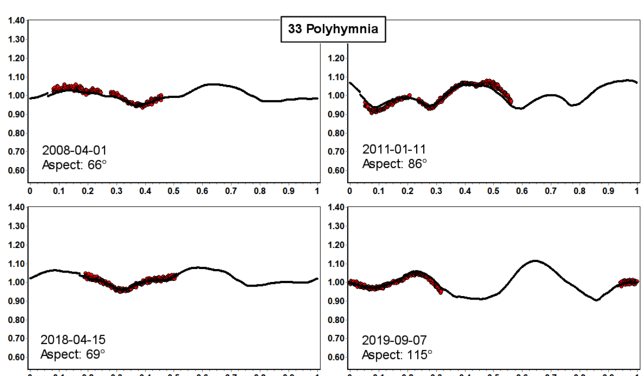


Figure 7: Model fit (black line) versus observed lightcurves (red points) for (λ = 19°, β = -65°) solution.

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## CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar year 2019 are encouraged to report them to this author on or before 2020 April 1. This will be the deadline for receipt of reports, for which results can be included in the "General Report of Position Observations for 2019," to be published in *MPB* Vol. 47, No. 3.