LIGHTCURVE, ROTATION PERIOD AND SPIN-SHAPE MODEL FOR 2764 MOELLER

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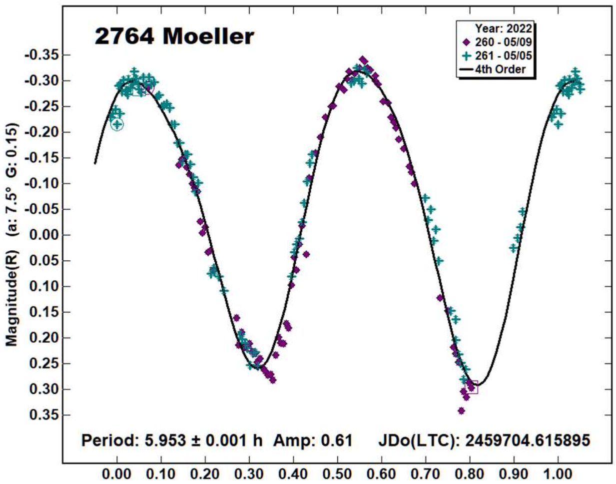
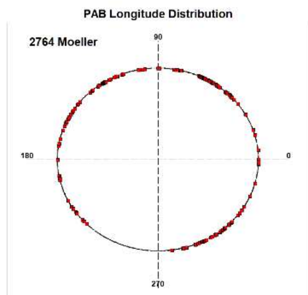
We present a new lightcurve measurement and a shape and spin axis model for main-belt asteroid 2764 Moeller. The model was achieved with the lightcurve inversion process, using combined dense photometric data acquired from two apparitions, between 2018 and 2022 and sparse data from Catalina Sky Survey (693, 703, G97) and Asteroid Terrestrial-impact Last Alert System (ATLAS, T05-T08). Analysis of the resulting data found a sidereal period P = 5.953424 ± 0.000001 h and two mirrored pole solutions at (λ = 310°, β = 41°) and (λ = 133°, β = 39°) with an uncertainty of ± 20 degrees.

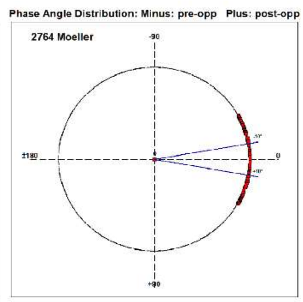
We report on photometric observations obtained with the 0.6m telescope of the Southeastern Association for Research in Astronomy (SARA) consortium at Cerro Tololo Inter-American Observatory. The telescope is coupled with an Andor iKon-L series CCD. A detailed description of the instrumentation and setup can be found in the paper by Keel et al. (2017). The data was calibrated using *MaximDL* and photometric analysis was performed using *MPO Canopus* (Warner, 2021a). Fauerbach observed 2764 Moeller on the nights of 2022 May 05 and 2022 May 09. The derived rotational period of 5.953 ± 0.001 h with an amplitude of 0.61 mag is in excellent agreement with the prior results by Waszczak et al. (2015, 5.954 h), Pravec et al. (2018, 5.953 h), Benishek (2018, 5.954 h), Ditteon (2019, 5.95 h) and Fauerbach and Nelson (2019, 5.952 h).

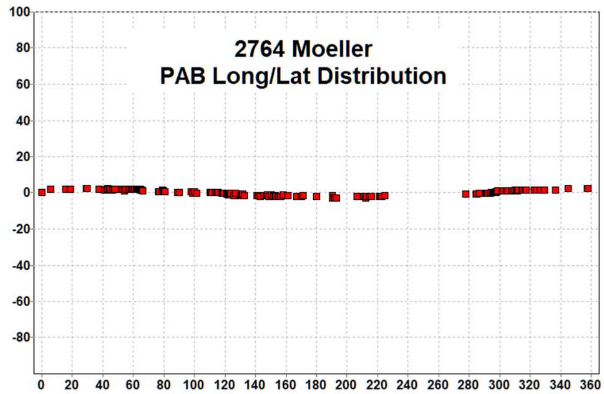
Dense lightcurves for 2764 Moeller were obtained during two apparitions (2018, 2022). The observational details of the dense data used are reported in Table I. Unfortunately, the dense lightcurves do not cover enough variation in viewing geometry to derive a reliable pole solution. Furthermore, as the dense lightcurves were all taken close to opposition, the phase angle coverage of the observations is very small. In order to cover several apparition geometries and a wider range of phase angles, we used sparse data from the Catalina Sky Survey (693, 703, G97, V-band only) and Asteroid Terrestrial-impact Last Alert System (ATLAS, T05-T08), downloaded from the Asteroids Dynamic Site (AstDyS-2, 2022). Figure 2 shows the PAB longitude/latitude, as well as the phase angle distribution for sparse data used in the lightcurve inversion process. For clarity purposes, we also plot the dates during which the sparse data was observed. The ATLAS data covers fewer apparitions but is overall denser than the data from the Catalina Sky Survey.

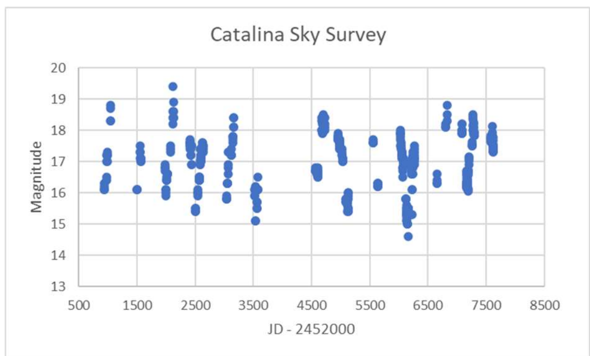
Lightcurve inversion was performed using *MPO LCInvert* v.11.8.4.1 (Warner, 2021b). For a description of the modeling process see the *LCInvert Operating Instructions Manual* (Warner, 2009) and references therein.

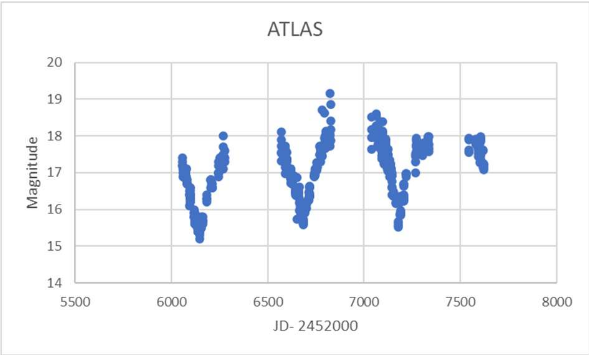






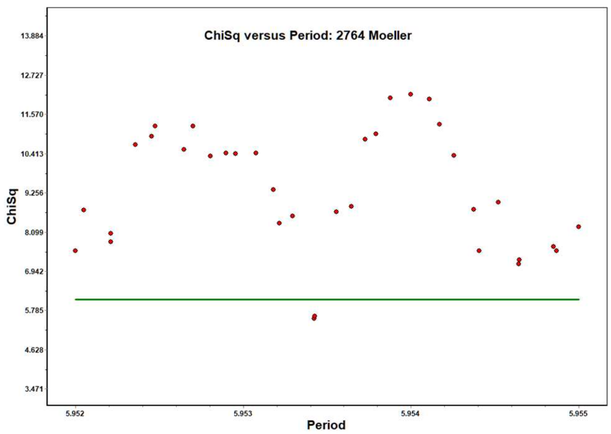


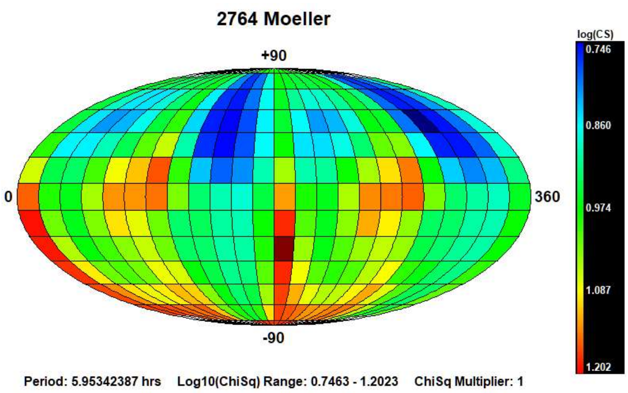


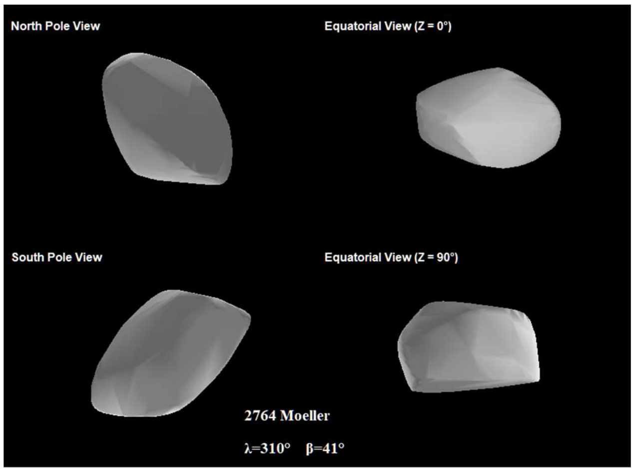


For the data analysis the weighting factor was set to 1.0 for dense and 0.3 for sparse data from Catalina and 0.5 for the sparse data from the ATLAS survey.

The sidereal period search was started with a wide margin on either side of the average of the synodic periods found in the asteroid lightcurve database (LCDB; Warner et al., 2009). In subsequent calculations the search area was narrowed down, and the step width decreased to get a finer measure. We found two almost identical sidereal periods with χ^2 values within 10% of the lowest values (Figure 3). The two best solutions were 5.95342351 h and 5.95342540 h respectively. The 5.95342351 h provided not only a slightly smaller χ^2 value, but also a significantly smaller dark area and therefore was used as starting value for the subsequent calculations.







The pole search was started using the "medium" search option (312 fixed pole position with 15° longitude-latitude steps) and the sidereal period with the lowest χ^2 value set to "float". From this step we found two roughly mirrored lowest χ^2 solutions (Figure 4) separated by about 180° in longitude at ecliptic longitude-latitude pairs (300°, 45°) and (135°, 45°).

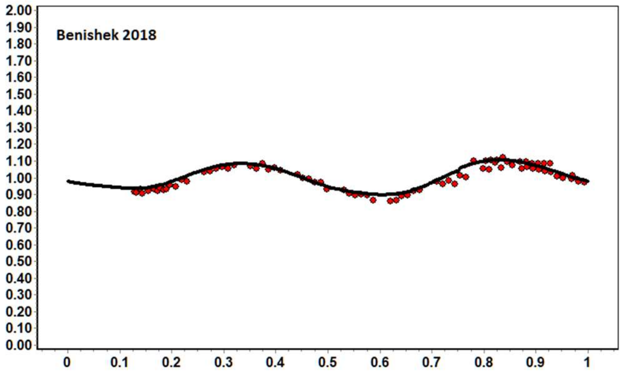
These two solutions were then used as inputs for fine pole searches. The final results -the two best solutions (lowest χ^2)- are reported in Table II. The sidereal period of 5.953424 ± 0.000001 h was obtained by averaging the two solutions found in the pole search process. Typical errors in the pole solution are ± 20°. Figure 5 shows the shape model (first solution with a lower χ^2) while Figure 6 shows the fit between the model (black line) and some observed lightcurves (red points). The overall agreement between the observed and calculated lightcurves is excellent.

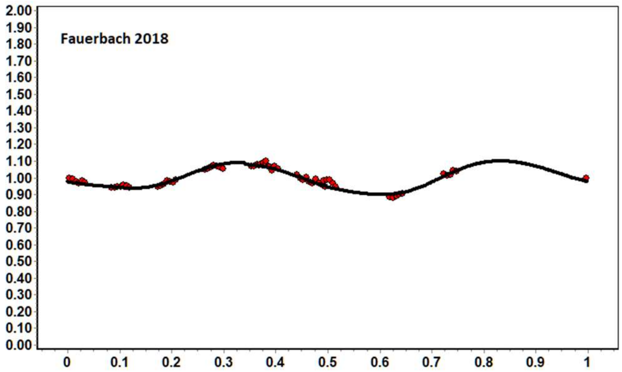
The analysis did not identify a unique solution but two mirrored solutions with almost identical χ^2values. The good reproduction of the observed lightcurves by the modeled data is encouraging, but as is so often the case the call for "more data" is needed in order to increase the confidence in the results.

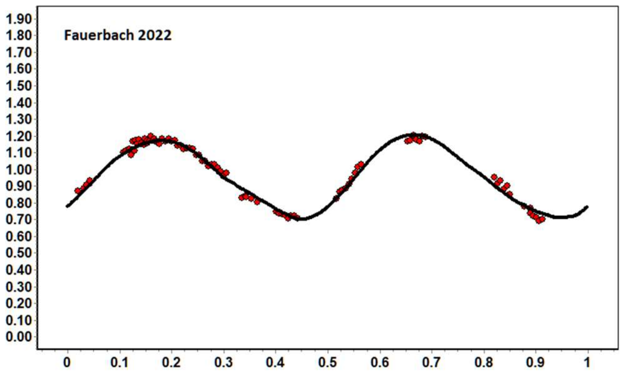
λ°	β°	Sidereal Period (hours)	RMS	Dark Area
310	41	5.953424 ± 0.000001	0.0686	0.1254903
133	39		0.0687	0.0827130

Observer	yyyy	mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
Fauerbach	2018	01/19,01/21	2.2,1.1	122	-1	5.952	0.003	0.25	0.04
Benishek	2018	01/24,01/26	1.4,2.1	122	-1	5.954	0.005	0.26	0.02
Fauerbach	2022	05/05,05/09	9.7,7.6	240	-2	5.953	0.001	0.61	0.04

Table I. Observing circumstances and results for the dense data used in the lightcurve inversion process for 2764 Moeller. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).







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