Lightcurve analysis of asteroid 15691 Maslov using NAO Rozhen observations and sparse data

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Abstract. Photometric observations of the asteroid 15691 Maslov, were performed with 2 m and 50/70 cm Schmidt telescopes at NAO Rozhen during the asteroid's opposition in 2015 and 2022. Calculated colour indices suggest that 15691 Maslov belongs to the S spectral type. The composite lightcurve shows synodic rotation period of 7.8 ± 0.2h hours and amplitude of about 0.2 magnitudes. For calculation of the sidereal period with the lightcurve inversion technique we used our dense photometric data in combination with the sparse data from the AstDys2[1] database.

Key words: Minor planets, asteroids, photometric-Asteroids: individual: 15691 Maslov

1 Introduction

Asteroid photometry shows how the brightness of the asteroid's surface depends on its illumination and geometry. Using data collected from the photometric observations we can determine both, the synodical and the sidereal period of the asteroid. The lightcurve or the composite lightcurve from several observational nights gives us enough information to reveal the synodic period of the asteroid. On the other hand, determining the sidereal period requires collecting data from different oppositions of the asteroid i.e., different viewing geometries, which can directly imply more observational time. To decrease the observational time and still be able to obtain the sidereal period of the asteroid, we can use the so-called sparse photometric data. This type of data provides us with data from some oppositions we have never observed and directly increases the distribution of the aspect data.

2 Observations and data reduction

Asteroid 15691 Maslov was discovered by Soviet astronomer L. G. Karachkina on 14^{th} October 1982 at the Crimean Astrophysical Observatory and named after her friend V. A. Maslov, who was an inventor in the field of storage and transport of oil (Schmadel 2012). 15691 Maslov is a representative from the inner part of the main belt with orbital period around Sun of 3.64 years. According to the NEOWISE Diameters and Albedos Database[2] (Mainzer et al. 2019) this asteroid has a diameter of 3.78 km and an albedo of 0.135.

For the photometric observations of 15691 Maslov we used 2 channel focal reducer Rozhen (FoReRo 2) of the 2 m Ritchey Chretien Coude (RCC) telescope with VersArray 1300B CCD and Photometrics CE200A and 50/70 cm

[1] https://newton.spacedys.com/astdys/index.php?pc=3.0

[2] https://sbn.psi.edu/pds/resource/neowisediam.html

Schmidt telescope with FLI PL16803 CCD camera. Aperture photometry of the asteroid and the comparison stars were performed using the *CCDPHOT* program (Buie 1996) and regarding the lightcurve analysis, software packages MPO Canopus and *LCInvert* v.11 (Warner 2016) were used.

In Table 1 the aspect data for 15691 Maslov for the nights of observations are presented. The first column is the date of the observation referring to the mid time of the lightcurve observed. The next columns are: asteroid distance from the Sun (r), from the Earth (Δ), the solar phase angle, and the J2000.0 ecliptic longitude (λ) and latitude (β) of the asteroid referred to the time in the first column.

Table 1. Aspect data

Date (UT)	r (AU)	Δ (AU)	Phase angle (°)	λ (°)	β (°)
2015 Dec 09.01	2.167	1.208	8.00	93.67	5.18
2022 Nov 26.83	1.885	1.016	19.45	25.34	5.52

We used sparse photometric data from 27 nights since 3rd January 2019 to 30th October 2022 taken in cyan (c, 420-650 nm) filter with the Asteroid Terrestrial-impact Last Alert System (ATLAS - observatory codes T05 and T08, Tonry et al. 2018, Ďurech et al. 2022).

In Fig. 1 the Phase Angle Bisector (PAB) longitude, PAB latitude, and phase angle distributions are presented for data used in the sidereal period determination. In order to show how the sparse photometric data enlarge the distribution in this figure both cases are presented one using only dense data and the other using the combination of dense and sparse data.

3 Results

15691 Maslov was observed on 8/9 December 2015 accidentally in the field of view in which we were following flickering activity of the nova like-variable KR Aur. At the time of observation, the asteroid was 17.3 mag and the solar phase was 8° before the opposition. The R, B and V band lightcurves were derived from the differential magnitudes between the asteroid and comparison stars. B and R frames are obtained simultaneously at a 2m telescope, and V and I are obtained consequently, with an alternation of filters at a 50/70 cm Schmidt telescope. Typical photometric errors are 0.06 mag for B, 0.01-0.02 mag for R, 0.10 for V, and 0.12 for the I band. On December 8th, 2015, simultaneous observations of the asteroid *BR's* brightness were performed, shown in Fig. 2.

Although all frames are not suitable for deriving the magnitude because of overlapping with stars, there are two clear minima in the light curve, giving us the possibility to obtain the average colour indices of the asteroid with acceptable accuracy. From observations performed in *BVRI* photometric system at a 2m telescope, we calculated asteroid colour indices B-V = 0.90 ± 0.06,

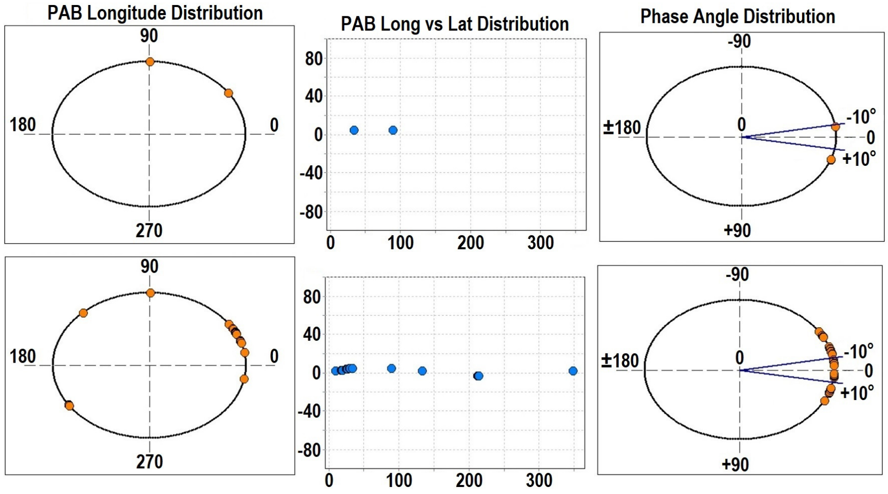

Fig. 1. Left: Distribution of PAB longitude; Center: Distribution of PAB longitude vs PAB latitude; Right: Distribution of phase angle (minus – pre opposition, plus – post opposition). First row is for dense observations and the second row is for combination of dense and sparse observations.

V-R = 0.52 ± 0.02, R-I = 0.35 ± 0.02. From all observed patrol frames we calculated the average values of B-R = 1.43 ± 0.06 (2m telescope) and V-I = 0.84 ± 0.16 (50/70 cm telescope).

Using the Asteroid Lightcurve Database (LCDB) Bundle V4.0[3] (Warner et al. 2021) we compared the obtained colour indices of our object to the average colour indexes of all taxonomical classes. The comparison suggests that the asteroid is laying between S and C classes, but its reported albedo of 0.1353 ± 0.0671 by NEOWISE Diameters and Albedos Database (Mainzer et al. 2019) suggests that it cannot be a C class object, which should be a pristine dark object, but a brighter S class asteroid.

The observations on both telescopes were in a time interval of 8 hours which, if we take a typical lightcurve with two maxima and minima, covered the whole rotational period of the asteroid. The obtained R band lightcurve in Fig. 3 from 2 m telescope observations has two maxima and minima with slight asymmetry. In Fig. 4 the R band lightcurve is composed with the V band lightcurve from Schmidt telescope and the obtained amplitude of the composite lightcurve, Fourier fitted of order 7, is 0.19 mag. The estimated synodic period is 7.8 ± 0.2h and it was determined by a standard Fourier analysis (Harris et al. 1989).

Using the amplitude value we calculate the ratio of the largest to smallest reflecting surface areas during the observed asteroid rotation a/c=1,2. This ratio number suggests an asteroid shape that is nearly spherical. Lightcurves from future observations at different geometrical conditions could reveal bigger amplitudes and more elongated forms.

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[3] https://sbn.psi.edu/pds/resource/doi/lcdb$_4$.0.*html*

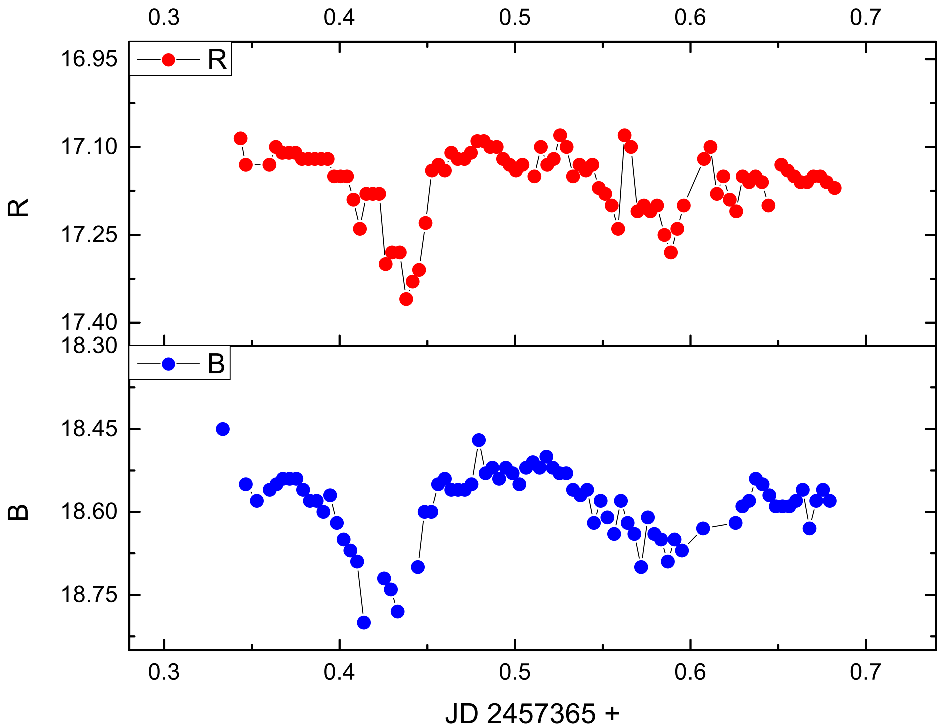

Fig. 2. The simultaneous R band and B band lightcurve of 15691 Maslov obtained from 2 m telescope.

15619 Maslov with the Schmidt telescope was observed on 26^{th} November of 2022 at the solar phase angle of 19.6° after its opposition. The observation of about 5 hours covered just a little more than half of the rotational period (Fig. 5).

Taking the value of the synodic period (7.8h) obtained from previous observations and using the split-halves utility in MPO Canopus, the second half of the lightcurve was superimposed on top of the first half. In this case, due to the significant difference between the phase angles of the sparse data (30^{th} of October and the 3^{rd} of November 2022, have solar phase angles of 5.5 and 7.5 degrees respectively) and our data (19.6° as mentioned above), we can not fill the phase interval 0.65-1.0 with sparse data, using the method of composite lightcurve construction. Nevertheless, using only our data, we can construct split-halves phased plot for period of 7.8h, which shows moderate symmetry between these two halves (Fig. 6).

Sidereal period of the asteroid was calculated with the light curve inversion technique (Kaasalainen et al., 2001, 2002) in which the creation of the asteroid model is done by taking the sidereal period to be one of the fitted parameters. The period with the lowest χ^2 is P = 7.7684h (Fig. 7). The other deep minima

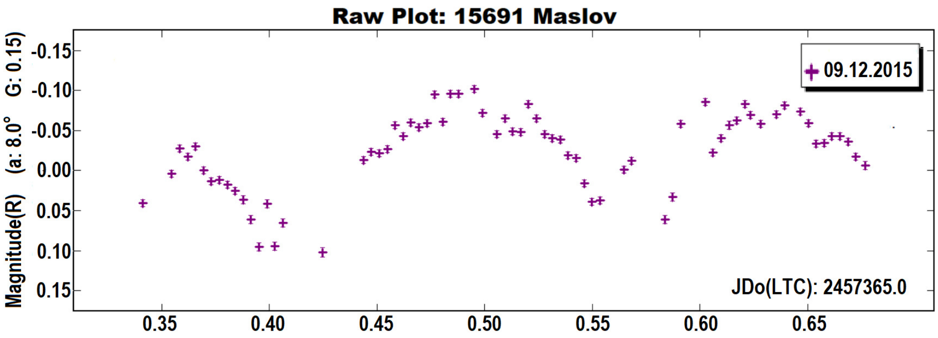

Fig. 3. The relative partial lightcurve of 15691 Maslov on 9^{th} December 2015 (differential R magnitudes versus Julian Date).

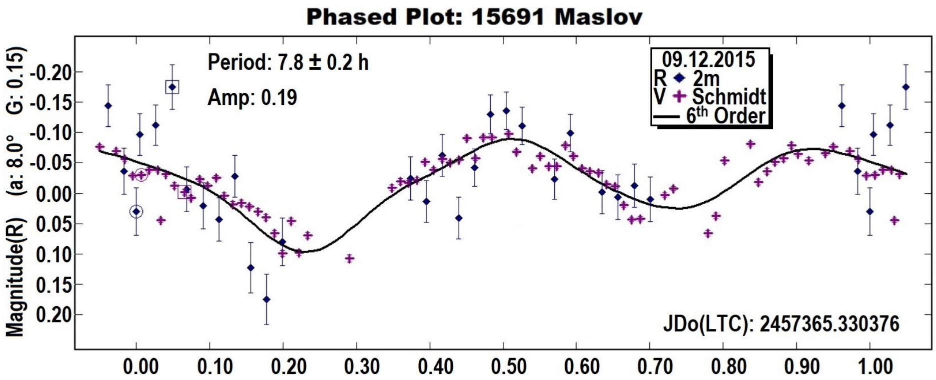

Fig. 4. The composite lightcurve of 15691 Maslov constructed from data (R filter) obtained from 2m telescope observations and from data (V filter) from Schmidt telescope.

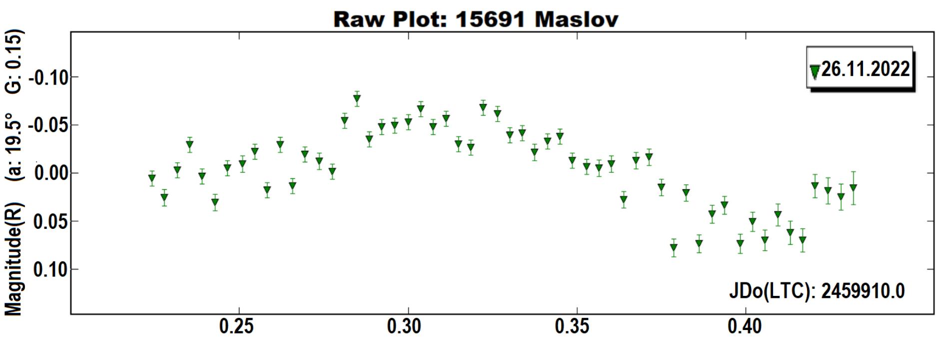

Fig. 5. The relative partial lightcurve of 15691 Maslov on 26 November 2022 (differential magnitudes versus Julian Date).

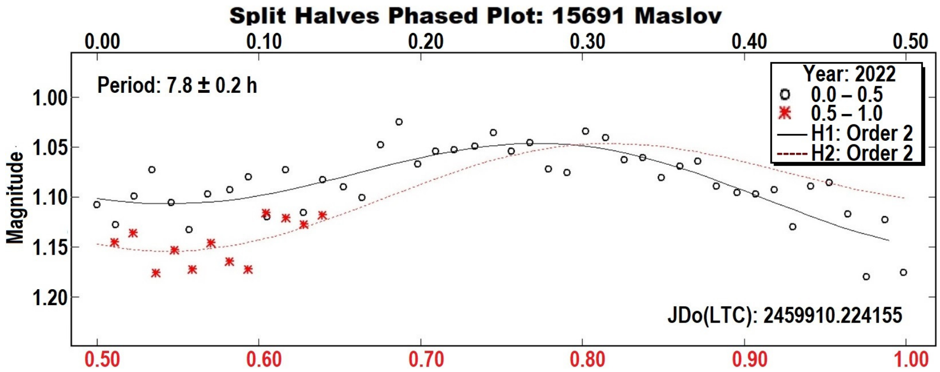

Fig. 6. The partial lightcurve from Fig. 5, using the split-halves phased plot, shows moderate symmetry between the two halves.

with a value of 9.3314 h might be connected with more complex lightcurve than typical one constructed with 2015 observations.

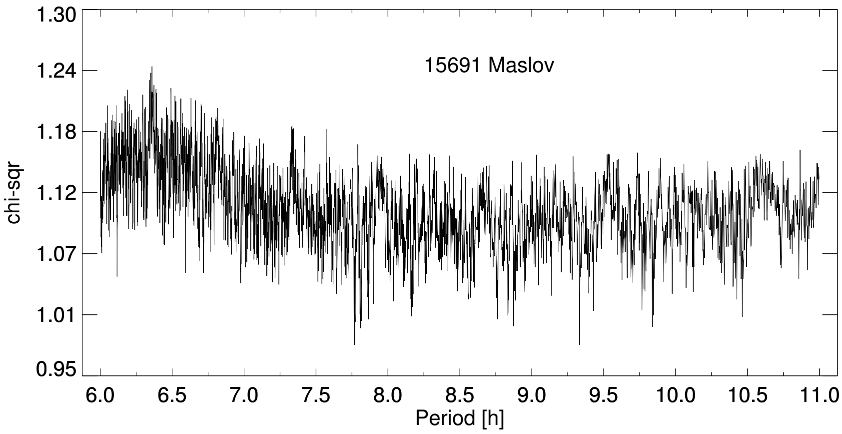

Fig. 7. Chi-square (χ^2) vs probe period plot used for a sidereal period search.

Conclusions

From observations of 15691 Maslov performed in the *BVRI* photometric system, we have calculated asteroid colour indices whose values classified it as an S - type asteroid. Using observations from NAO Rozhen and accepting the typical asteroid light curve with two extrema, we have calculated the synodic rotational period of 15691 Maslov. The obtained amplitude of one complete period light curve gave us insight into the axis ratio, based on which we can make our first assumptions about its shape. For the determination of the sidereal period, we have used the lightcurve inversion method, in which we combined our dense data with the sparse data collected from the AstDys database.

We found no other published lightcurve or rotational period of 15691 Maslov in the Asteroid Lightcurve Photometry Database ALCDEF[4]. The obtained results for this asteroid give contribution to the enlargement of the database for physical characteristics of the asteroids.

To obtain more precise results for the period and to determine the direction of the rotation axis and asteroid's shape, we need, as much as possible, new data collected either by our dense observations or from the sparse data databases.

Acknowledgements

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[4] https://alcdef.org/