

ROTATION PERIOD, COLOR INDICES, AND H-G PARAMETERS FOR 49 PALES

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, NM 88011-8403 USA
fpilcher35@gmail.com

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA

Daniel A. Klinglesmith III
Etsorn Campus Observatory (719)
New Mexico Tech
101 East Road
Socorro, NM USA 87801

(Received: 2016 January 15)

For 49 Pales a synodic rotation period 20.704 ± 0.001 hours and an amplitude 0.17 ± 0.01 magnitudes are found. This is double the period found in the LCDB and shows that correct rotation periods still have not been found for all low-numbered asteroids. Color indices are found $\langle B-V \rangle = 0.71 \pm 0.02$, $\langle V-R \rangle = 0.35 \pm 0.03$ and $\langle B-R \rangle = 1.07 \pm 0.05$. In the V band $H = 7.61 \pm 0.06$, $G = 0.019 \pm 0.030$.

Authors Pilcher, Benishek, and Klinglesmith agreed to collaborate to make photometric observations of this low-numbered asteroid when it became apparent that the previously believed rotation period was not correct. Pilcher at Organ Mesa Observatory used a 0.35 m f/10 Meade LX200 GPS S-C, SBIG STL-1001E CCD, unguided, R filter. Benishek at Sopot Observatory used a 0.35 m SCT operating at f/6.3, SBIG ST-8 XME CCD. Klinglesmith at Etsorn Campus Observatory used a Celestron 35 cm SCT and SBIG STL-1001E CCD. Photometric measurement, lightcurve analysis, and data sharing were enabled by *MPO Canopus* software. The large number of data points obtained have been binned in sets of three with time difference not exceeding five minutes to draw the lightcurves.

No lightcurves have been published for 49 Pales since 1979. In that year two rotation periods were published by Schober et al. (1979), 10.42 hours; and by Tedesco (1979), 10.3 hours. Seventeen all night sessions were made by the three authors 2015 Oct. 27 – Dec. 16 and provide a fit to a somewhat irregular lightcurve with period 20.704 ± 0.001 hours and amplitude 0.17 ± 0.01 magnitudes. A few apparent deviations from the lightcurve are quite likely observational artifacts (often beginning- or end-of-session features) and not a real behavior of the asteroid. The 20.704 hour period is twice the value found in the much less dense earlier investigations, and a period near 10.4 hours may now be ruled out.

Color indices and H-G parameters determination

In order to determine the B-V, V-R and B-R color indices, Benishek at Sopot Observatory conducted multi-color photometric observations using the Johnson B and V and Cousins R photometric filters on 9 nights between 2015 November 17 and 2015 December 30. The V-band photometry was omitted over the first three of these nine nights. The Comparison Star Selector procedure of MPO Canopus was used to perform the photometric

reduction process implying differential photometry using field comparison stars of near solar color ($0.5 \leq B-V \leq 0.9$). The instrumental magnitudes were calibrated using the Johnson B and V magnitudes taken directly from the AAVSO Photometric All-Sky Survey (APASS) catalog, Data Release 9 (Henden et al., 2009) and the Cousins R magnitudes derived from the APASS Johnson B and V magnitudes using the following catalog independent conversion formula based on the LONEOS (Lowell Observatory Near-Earth-Object Search) Johnson-Cousins photometry for faint field stars (Seiichi Yoshida's Home Page, 2016): $R = V - 0.508 * (B - V) - 0.040$, which is applicable under the following condition: $0.3 < B-V < 0.9$. This condition is certainly fulfilled for the comparison stars of near solar color as defined in MPO Canopus (see the aforementioned criterion).

The color indices were determined for each night separately from the data sets obtained in the corresponding photometric filters. The relevant differences in magnitude between the data taken with different filters were found by shifting the zero point of one of the data sets from the respective pair to bring them up to the best match in terms of the minimum RMS error. The amount of this shift determines a color index value for a particular night. The summary of the color index values found for particular nights is shown in the Table 1. There is a considerable consistency of the corresponding color index values within the limits which do not exceed a few hundredths of magnitude. The average values with the related standard deviations for all three color indices calculated from the corresponding values for the individual nights are as follows: $\langle B-V \rangle = 0.71 \pm 0.02$ mag., $\langle V-R \rangle = 0.35 \pm 0.03$ mag. and $\langle B-R \rangle = 1.07 \pm 0.05$ mag. Having in mind that 49 Pales has been already classified as an CG Tholen spectral type asteroid (JPL, 2016), it can also be stated that our values found for the B-V and V-R color indices are well matched with the corresponding average color indices typical for the C-type asteroids as shown in Shevchenko and Lupishko (1998).

Date and mid-time (UT)	B-V	V-R	B-R
2015 Nov. 17.1	/	/	1.129
2015 Nov. 17.9	/	/	1.079
2015 Nov. 19.9	/	/	1.085
2015 Dec. 13.7	0.736	0.409	1.145
2015 Dec. 14.8	0.674	0.344	1.017
2015 Dec. 17.8	0.703	0.353	1.057
2015 Dec. 27.8	0.706	0.335	1.041
2015 Dec. 28.9	0.710	0.324	1.034
2015 Dec. 30.9	0.712	0.342	1.055

Table 1. Color indices for particular nights

Using the spreadsheet method described by Buchheim (2010) the R-band mean light values of the lightcurves for individual nights for the overall data obtained by all authors using an R photometric filter were calculated. These were converted into reduced magnitudes by applying $-5 \cdot \log(r\Delta)$ with r and Δ being, respectively, the asteroid-Sun and asteroid-Earth distances. The R-band reduced magnitudes obtained in such a way were used in the H-G Calculator tool of MPO Canopus based on the FAZ algorithm developed by Alan Harris (1989) to establish the phase curve and determine the R-band absolute magnitude HR and slope parameter G. Our analysis found the following pair of values: $HR = 7.256 \pm 0.028$ and $G = 0.019 \pm 0.030$. The V-band absolute magnitude $H_v = 7.61 \pm 0.06$ was calculated by adding the value found for V-R color index to the R-band absolute magnitude HR. This enables the estimation of the asteroid size using the formula by Pravec and Harris (2007) for an asteroid diameter (D) in kilometers:

$$D(\text{km}) = \frac{1329}{\sqrt{P_v}} 10^{-0.2H_v}$$

Assuming the value for the geometric albedo of 0.0597 (JPL, 2016) we obtain an estimated diameter of nearly 168 km for 49 Pales. This is a somewhat larger value than that found by IRAS: 149.8 km (JPL, 2016). In either case, the values obtained for the color indices and slope parameter G as well as the estimated size indicate that 49 Pales is a fairly large and dark asteroid.

Acknowledgments

The Etsorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Technology (NMIMT). The authors thank Dr. Petr Pravec for help in the data analysis and interpretation.

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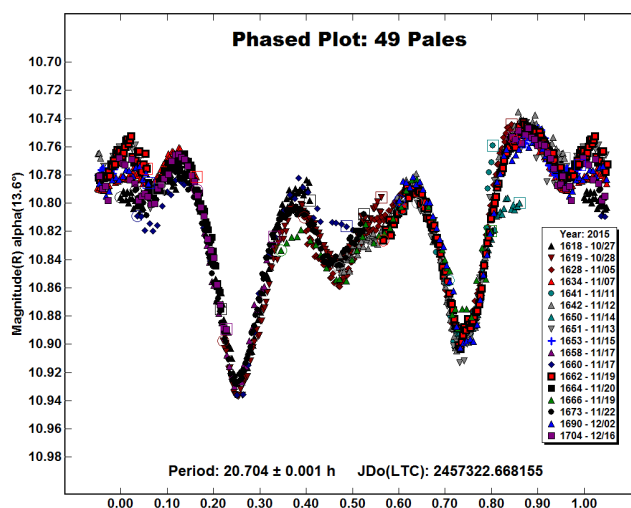


Fig. 1. Rotational lightcurve of 49 Pales phased to 20.704 hours.

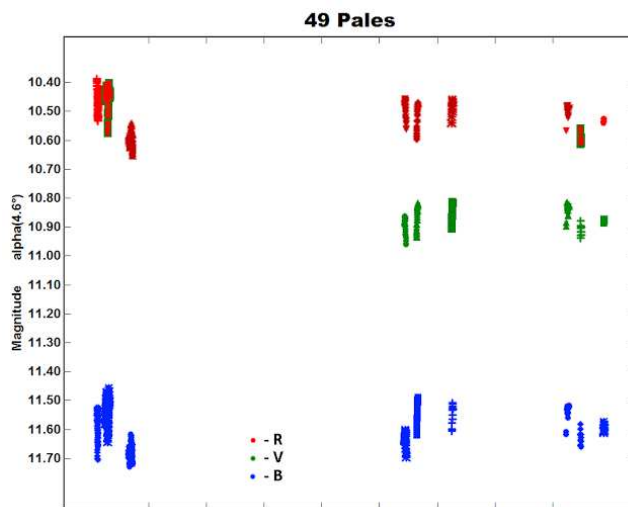


Figure 2. B, V, and R lightcurves obtained on particular nights for color indices determination

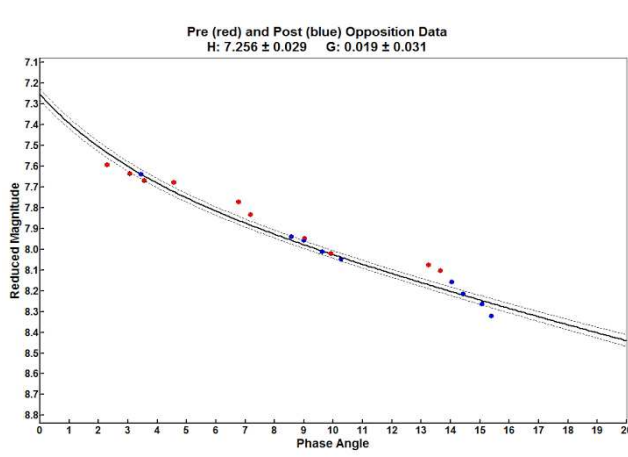


Figure 3. The phase curve of 49 Pales