

**PHOTOMETRIC OBSERVATIONS AND
ROTATION PERIODS OF ASTEROIDS
2376 MARTYNOV, (7335) 1989 JA,
12923 ZEPHYR, AND (85184) 1991 JG1**

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Photometric observations of asteroids 2376 Martynov, (7335) 1989 JA, 12923 Zephyr, and (85184) 1991 JG1 were conducted in order to determine their synodic rotation period, the absolute brightness with its amplitude, and estimate their diameter. For 2376 Martynov we found $P = 11.133 \pm 0.005$ h, $H = 11.07 \pm 0.05$ mag, $A = 0.38 \pm 0.05$ mag, $D = 47.583 \pm 0.529$ km (for albedo $a = 0.0364$) and $D = 39.212 \pm 0.588$ km (for albedo $a = 0.0536$). For (7335) 1989 JA we found $P = 5.177 \pm 0.005$ h, $H = 17.48 \pm 0.05$ mag, $A = 0.27 \pm 0.05$ mag, $D = 0.849 \pm 0.009$ km (for albedo $a = 0.25$) and $D = 0.748 \pm 0.010$ km (for albedo $a = 0.322$). For 12923 Zephyr we found $P = 3.894 \pm 0.002$ h, $H = 15.73 \pm 0.05$ mag, $A = 0.21 \pm 0.05$ mag, $D = 2.260 \pm 0.025$ km (for albedo $a = 0.1764$) and $D = 2.072 \pm 0.027$ km (for albedo $a = 0.21$). For (85184) 1991 JG1 we found $P = 24.14 \pm 0.02$ h, $H = 18.37 \pm 0.07$ mag, $A = 0.65 \pm 0.07$ mag, $D = 0.631 \pm 0.008$ km (for albedo $a = 0.20$).

We observed asteroids 2376 Martynov, (7335) 1989 JA, 12923 Zephyr, and (85184) 1991 JG1 in order to determine their synodic rotation period, the absolute brightness with its amplitude, and estimate their diameter. Observations took place at six observatories: Simeiz Observatory (MPC code 094) in Crimea, ISON-Kitab Observatory (MPC code 186) in Uzbekistan, Kuban State University Astrophysical Observatory (MPC code C40) in Russia, ISON-Castelgrande Observatory (MPC code L28) in Italy, Tien-Shan Astronomical Observatory (MPC code N42) in Kazakhstan, and UAS-ISON Observatory (MPC code V26) in Mexico.

For data processing we used the following software: *Tycho v.9.0.6* (Parrott, 2022) at C40; *APEX v.2021.01.4* (Kouprianov, 2008; Devyatkin et al., 2010) at L28, N42 and V26; *Astrometrica v.4.11.1.442* (Raab, 2018) and *FoCAs v.3.66* (Roig et al., 2011) at 186. All images were calibrated with dark and flat-field frames. Photometry was done in the Gaia G band against reference stars from the Gaia DR3 catalog with near-solar color indices ($G_{BP} - G_{RP}$) = $0.818 \pm 10\%$ (Gaia Collaboration, 2022). For the calculation of the absolute brightness, we used a phase slope parameter $G = 0.15$. For the rotation period search we used a custom-written Python script with the PDM algorithm imported from the *PyAstronomy* package (Czesla et al., 2019); the underlying orbital data was retrieved from the NASA JPL Horizons System (JPL, 2022a) by the imported *Astroquery* package (Ginsburg et al., 2019).

For the conversion from Gaia G to Johnson-Cousins V band we used the transformation:

$$G - V = -0.02704 + 0.01424 * (G_{BP} - G_{RP}) - 0.2156 * (G_{BP} - G_{RP})^2 + 0.01426 * (G_{BP} - G_{RP})^3$$

where: G : Gaia G magnitude; V : Johnson-Cousins V magnitude; and $(G_{BP} - G_{RP})$: Gaia BP-RP color index (ESA, 2022).

For the estimation of the asteroid diameter, we used the formula:

$$D = 10^{(3.1236 - 0.5 * \log(a) - 0.2 * H)}$$

where: D : asteroid diameter in km, a : geometric albedo of asteroid, and H : absolute brightness of asteroid in Johnson-Cousins V magnitudes (JPL, 2022b).

Table I shows the observing circumstances and results.

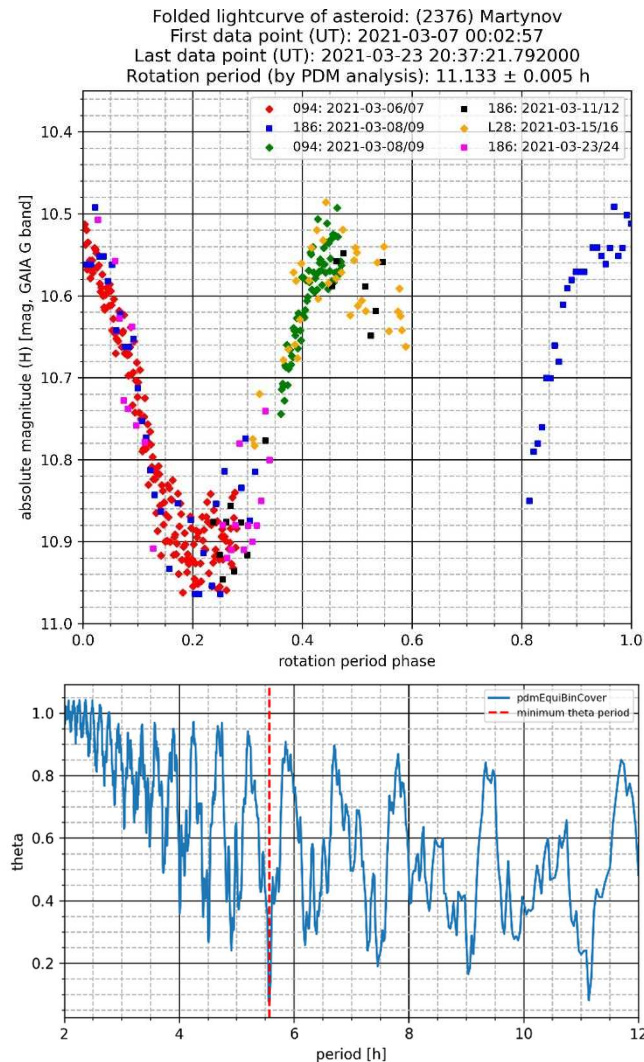
2376 Martynov was discovered on 1977 August 22 at the Crimean Astrophysical Observatory by N. S. Chernykh; it was named in honor of Dmitriy Yakovlevich Martynov, an outstanding astrophysicist, for many years the director of the Sternberg Astronomical Institute in Moscow, author of widely used texts on astrophysics (MPC, 1983). It is a main belt asteroid with a semi-major axis of $a = 3.20$ au, eccentricity $e = 0.119$, inclination $i = 3.84^\circ$, and an orbital period $P = 5.73$ years; its absolute magnitude has a value of $H = 11.03$ (MPC, 2022a), other reported values range from $H = 10.47$ (Colazo et al., 2021) to $H = 11.13$ (Masiero et al., 2020). A search of the Asteroid Lightcurve Database (Warner et al., 2009) did not find any reported rotation period for asteroid 2376 Martynov.

CCD photometric observations of the asteroid were carried out on five nights in 2021 March 6 to March 23 at three observatories: 094, 186, and L28. At 094 we used a 1-m $f/12.7$ Cassegrain telescope with a FLI ML-09000 CCD camera without filters at 3×3 binning and 0.58 arcsec/pix pixel scale with 60 s exposure times during the nights 2021 March 6 and 9; at 186 we used a 0.36-m $f/8$ Ritchey-Chrétien telescope with a FLI PL 09000 CCD camera without filters at 2×2 binning and 1.72 arcsec/pix pixel scale with 60 s exposure times during the nights 2021 March 8, 11 and 23; and at L28 we used a 0.22-m $f/2.38$ Newton-Hamilton telescope with a FLI PL-16803 CCD camera without filters at 1×1 binning and 3.54 arcsec/pix pixel scale with 120 s exposure times during the night 2021 March 15. In the course of the entire observation campaign, the phase angle of 2376 Martynov changed from 7.8° to 2.8° . For the analysis we collected 381 usable data points.

Number	Name	20yy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	D	Grp
2376	Martynov	21/03/07-21/03/23	7.8,2.8	191	3	11.133	0.005	0.38	0.05	47.583 39.212	MBA
7335	1989 JA	22/05/14-22/05/24	26.9,35.1	227	11	5.177	0.005	0.27	0.05	0.849 0.748	NEA
12923	Zephyr	21/05/10-21/06/20	17.2,51.0	215	9	3.894	0.002	0.21	0.05	2.260 2.072	NEA
85184	1991 JG1	20/05/12-20/05/23	20.5,40.0	229	19	24.14	0.02	0.65	0.07	0.631	NEA

Table I. Observing circumstances and results. The phase angle is given for the first and last exposure time. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

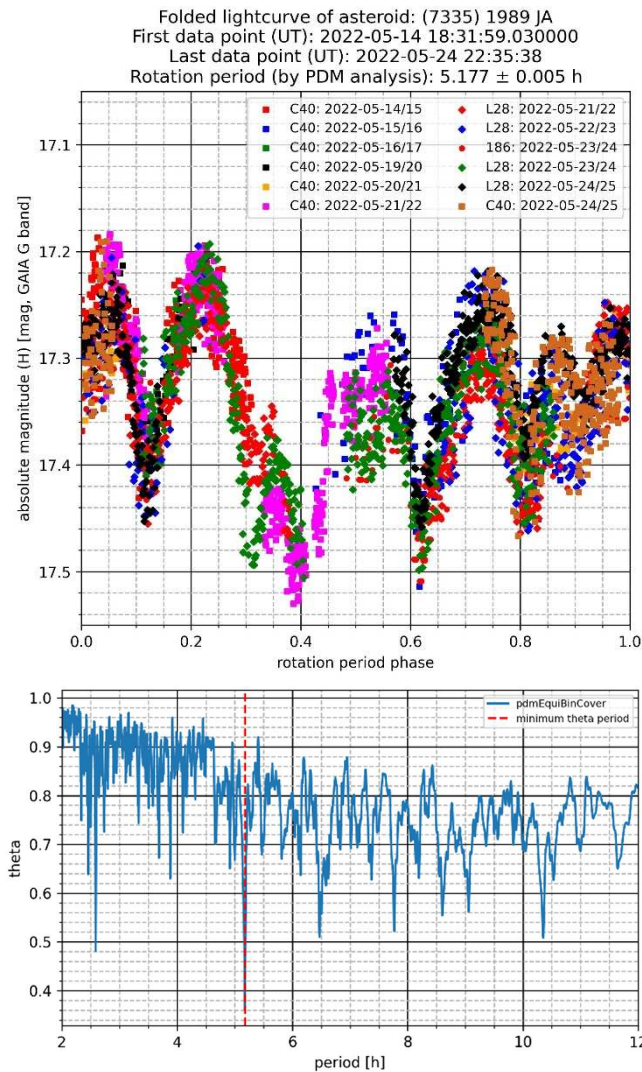
We found a synodic rotation period $P = 11.133 \pm 0.005$ h, median absolute brightness $H = 10.83 \pm 0.05$ mag in Johnson-Cousins V band, and brightness amplitude of the folded lightcurve $A = 0.38 \pm 0.05$ mag. For the smallest reported albedo, $a = 0.0364$ (Mainzer et al., 2011), we estimated the diameter to be $D = 47.583 \pm 0.529$ km; for the largest reported albedo, $a = 0.0536$ (Tedesco et al., 2004), we estimated the diameter as $D = 39.212 \pm 0.588$ km. The first figure shows the folded lightcurve. The second plot shows the PDM power spectrum in a rotation period range between 2 and 12 hours with a red dashed line indicating the best probable rotation period at 5.566 h, which produced a monomodal folded lightcurve, though; the second-best probable rotation period at 11.133 h is the one which we consider the real rotation period.



(7335) 1989 JA was discovered on 1989 May 1 at the Palomar Observatory by E.F. Helin (MPC, 1989). It is a potentially hazardous asteroid of the Apollo family with a semi-major axis of $a = 1.77$ au, eccentricity $e = 0.484$, inclination $i = 15.19^\circ$, and orbital period of $P = 2.36$ years; its absolute magnitude has a value of $H = 17.76$ (MPC, 2022b), other reported values are: $H = 17.8$ (Wisniewski et al., 1997), $H = 17.0$ (Mainzer et al., 2011; 2019), and $H = 17.82$ (Nugent et al., 2016). A search of the Asteroid Lightcurve Database (Warner et al., 2009) did not find any precise rotation period reported for asteroid (7335) 1989 JA; there is only one report of a rotation period “less than half a day” based on radar observations (Mahapatra et al., 2002).

CCD photometric observations were carried out on nine nights in 2022 May 14 to May 24 at three observatories: 186, C40, and L28. At 186 we used a 0.36-m $f/8$ Ritchey-Chrétien telescope with a FLI PL-09000 CCD camera without filters at 2×2 binning and 1.72 arcsec/pix pixel scale with 20 s exposure times during the night 2022 May 23; at C40 we used a 0.51-m $f/7.93$ Ritchey-Chrétien telescope with a FLI PL-16803 CCD camera without filters at 1×1 binning and 1.22 arcsec/pix pixel scale with 10 s exposure times during the nights 2022 May 14-16 and 19-21, and a 0.2-m $f/2.0$ Schmidt telescope with a FLI ML-8300 CCD camera without filters at 1×1 binning and 2.83 arcsec/pix pixel scale with 10 s exposure times during the night 2022 May 24; and at L28 we used a 0.22-m $f/2.38$ Newton-Hamilton telescope with a FLI PL-16803 CCD camera without filters at 1×1 binning and 3.54 arcsec/pix pixel scale with 10 and 20 s exposure times during the nights 2022 May 21-24. In the course of the entire observation campaign the phase angle of (7335) 1989 JA changed from 26.9° to 35.1° . For the analysis we collected 3493 usable data points.

We found a synodic rotation period $P = 5.177 \pm 0.005$ h, median absolute brightness $H = 17.48 \pm 0.05$ mag in Johnson-Cousins V band, and brightness amplitude of the folded lightcurve $A = 0.27 \pm 0.05$ mag. For the smallest reported albedo, $a = 0.25$ (Nugent et al., 2016), we estimated a diameter $D = 0.849 \pm 0.009$ km; for the largest reported albedo, $a = 0.322$ (Mainzer et al., 2011; 2019), we estimated a diameter $D = 0.748 \pm 0.010$ km. The PDM power spectrum covers a rotation period range between 2 and 12 hours with a red dashed line indicating the best probable rotation period corresponding to the one we found; the second-best probable rotation period at 2.589 h didn’t produce a well-fitted folded lightcurve, so we could exclude this solution.

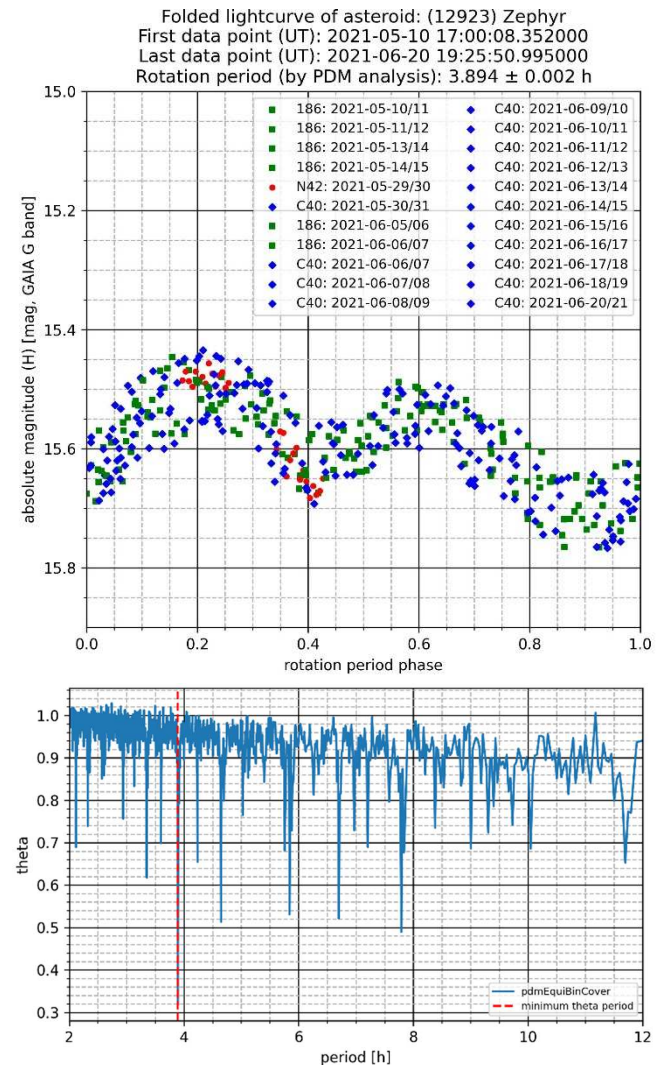


12923 Zephyr was discovered at the Anderson Mesa Station on 1994 November 11 by LONEOS; its name was suggested by M. Smitherman. The word “zephyr” derives from the name of the ancient Greek god of the west wind, Zephyros (MPC, 2004). It is a potentially hazardous asteroid of the Apollo family with a semi-major axis $a = 1.96$ au, eccentricity $e = 0.492$, inclination $i = 5.31^\circ$, and orbital period $P = 2.75$ years; its absolute brightness has a value of $H = 15.82$ (MPC, 2022c). Other reported values range from $H = 15.21$ (Mahlke et al., 2021) to $H = 15.93$ (Pravec et al., 2012). In the Asteroid Lightcurve Database (Warner et al., 2009) we found two reported rotation periods for asteroid 12923 Zephyr: 3.891 h (Pravec et al., 1999web) and 3.893 ± 0.002 h (Warner et al., 2021).

CCD photometric observations of asteroid 12923 Zephyr were carried out on 22 nights in 2021 May 10 to June 20 at three observatories: 186, C40 and N42. At 186 we used a 0.36-m $f/8$ Ritchey-Chrétien telescope with a FLI PL-09000 CCD camera without filters at 2×2 binning and 1.72 arcsec/pix pixel scale with 60 s exposure times during the nights 2021 May 10, 11, 13, 14 and June 5, 6; at C40 we used a 0.51-m $f/7.93$ Ritchey-Chrétien telescope with a FLI PL-16803 CCD camera without filters at 3×3 binning and 1.37 arcsec/pix pixel scale with 40 s exposure times during the nights 2021 May 30 and June 5-18, 20; and at N42 we used a 1-m $f/6.6$ Cassegrain telescope with an Apogee Alta U16M D9 CCD camera without filters at 2×2 binning and 0.56 arcsec/pix

pixel scale with 60 s exposure times during the night 2021 May 29. In the course of the entire observation campaign, the phase angle of 12923 Zephyr changed from 17.2° to 51.0° . For the analysis we collected 409 usable data points.

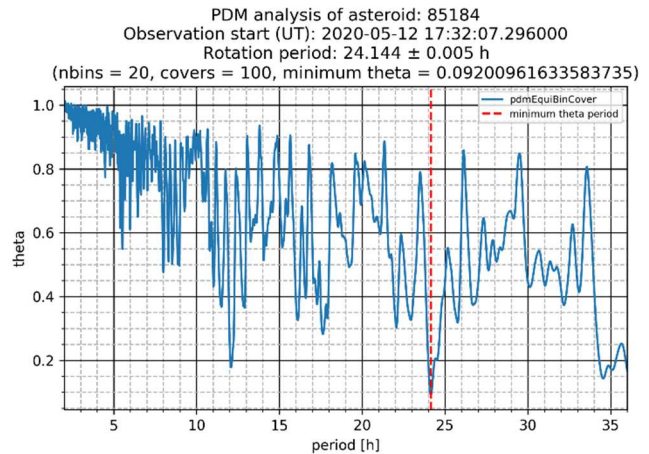
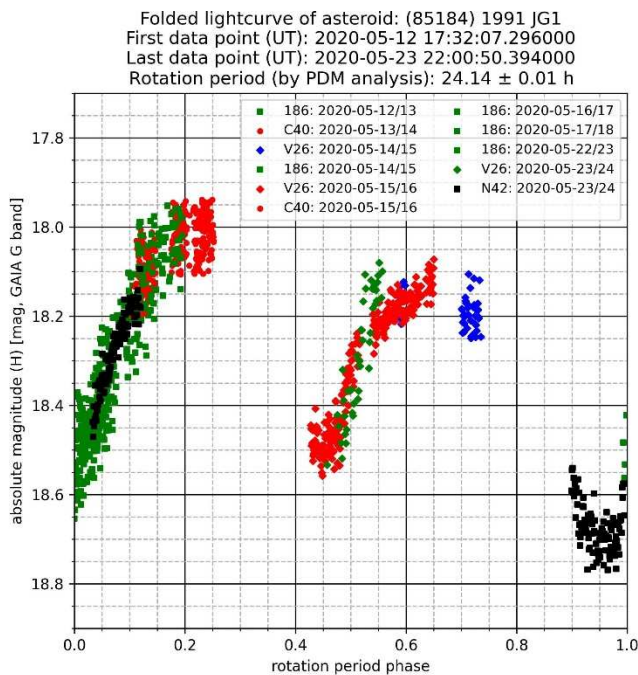
We found a synodic rotation period $P = 3.894 \pm 0.002$ h, median absolute brightness $H = 15.73 \pm 0.05$ mag in Johnson-Cousins V band, and brightness amplitude of the folded lightcurve $A = 0.21 \pm 0.05$ mag. For the smallest reported albedo, $a = 0.1764$ (Pravec et al., 2012), we estimated a diameter $D = 2.260 \pm 0.025$ km; for the largest reported albedo, $a = 0.21$ (Harris et al., 2011), we estimated a diameter $D = 2.072 \pm 0.027$ km. The PDM power spectrum covers a rotation period range between 2 and 12 hours with a red dashed line indicating the best probable rotation period corresponding to the one we found.



(85184) 1991 JG1 was discovered on 1991 May 9 at the Palomar Observatory by E.F. Helin (MPC, 1991). It is a near-Earth asteroid of the Amor family with a semi-major axis $a = 1.37$ au, eccentricity $e = 0.185$, inclination $i = 33.88^\circ$, and orbital period $P = 1.61$ years; its absolute magnitude is $H = 18.42$ (MPC, 2022d). (Pravec et al., 1999web) reported $H = 18.14$. In the Asteroid Lightcurve Database (Warner et al., 2009) we found a reported rotation period of 24.02 ± 0.05 h (Pravec et al., 1999web), and a series of four different solutions: 22.56 ± 0.05 h, 25.08 ± 0.04 h, 23.63 ± 0.03 h, and 24.19 ± 0.02 h (Warner and Stephens, 2020).

CCD photometric observations of asteroid (85184) 1991 JG1 were carried out on eight nights in 2020 May 12 to May 23 at four observatories: 186, C40, N42 and V26. At 186 we used a 0.36-m *f*/8 Ritchey-Chrétien telescope with a FLI ML-09000 CCD camera without filters at 2×2 binning and 1.72 arcsec/pix pixel scale with 60 s exposure times during the nights 2020 May 12, 14, 16, 17 and 22; at C40 we used a 0.51-m *f*/7.93 Ritchey-Chrétien telescope with a FLI PL-16803 CCD camera without filters at 3×3 binning and 1.37 arcsec/pix pixel scale with 20 s exposure times during the nights 2020 May 13 and 15; at N42 we used a 1-m *f*/6.6 Cassegrain telescope with an Apogee Alta U16M D9 CCD camera without filters at 2×2 binning and 0.56 arcsec/pix pixel scale with 60 s exposure times during the night 2020 May 23; and at V26 we used a 0.40-m *f*/4.2 Ritchey-Chrétien telescope with a FLI PL-09000 CCD camera without filters at 2×2 binning and 2.87 arcsec/pix pixel scale with 60 s exposure times during the nights 2020 May 14, 15 and 23. In the course of the entire observation campaign, the phase angle of (85184) 1991 JG1 changed from 20.5° to 40.0°. For the analysis we collected 1194 usable data points.

We found a synodic rotation period $P = 24.14 \pm 0.02$ h, median absolute brightness $H = 18.37 \pm 0.07$ mag in Johnson-Cousins V band, and brightness amplitude of the folded lightcurve $A = 0.65 \pm 0.07$ mag. For a theoretical albedo $a = 0.20$, we estimated a diameter $D = 0.631 \pm 0.008$ km. The PDM power spectrum covers a rotation period range between 2 and 36 hours with a red dashed line indicating the best probable rotation period corresponding to the one we found.



References

- Colazo, M.; Duffard, R.; Weidmann, W. (2021). “The determination of asteroid H and G phase function parameters using Gaia DR2.” *MNRAS* **504**, 761-768.
- Czesla, S.; Schröter, S.; Schneider, C.P.; Huber, K.F.; Pfeifer, F.; Andreasen, D.T.; Zechmeister, M. (2019). “PyA: Python astronomy-related packages.” Astrophysics Source Code Library, record ascl:1906.010. <https://github.com/sczesla/PyAstronomy>
- Devyatkin, A.V.; Gorshanov, D.L.; Kouprianov, V.V.; Verestchagina, I.A. (2010). “Apex I and Apex II software packages for the reduction of astronomical CCD observations.” *Solar System Research* **44**, 68-80.
- ESA (2022). “5.5.1 Relationships with other photometric systems.” Gaia Data Release 3. Documentation Release 1.1. https://gea.esac.esa.int/archive/documentation/GDR3/Data_processing/chap_cu5pho/cu5pho_sec_photSystem/cu5pho_ssec_photRelations.html
- Gaia Collaboration: Creevey, O.L.; Sarro, L.M.; Lobel, A.; and 444 colleagues (2022). “Gaia Data Release 3: A Golden Sample of Astrophysical Parameters.” *Astronomy & Astrophysics* (accepted). <https://arxiv.org/abs/2206.05870>
- Ginsburg, A.; Sipőcz, B.M.; Brasseur, C.E.; and 22 colleagues. “astroquery: An Astronomical Web-querying Package in Python.” *The Astronomical Journal* **157**, id. 98.
- Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). “Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Geytis.” *Icarus* **57**, 251-258.
- Harris, A.W.; Mommert, M.; Hora, J.L.; and 14 colleagues (2011). “ExploreNEOs. II. The Accuracy of the Warm Spitzer Near-Earth Object Survey.” *The Astronomical Journal* **141**, id. 75.

- JPL (2022a). Horizons. <https://ssd.jpl.nasa.gov/horizons/>
- JPL (2022b). Asteroid Size Estimator. https://cneos.jpl.nasa.gov/tools/ast_size_est.html
- Kouprianov, V. (2008). “Distinguishing features of CCD astrometry of faint GEO objects.” *Advances in Space Research* **41**, 1029-1038.
- Mahapatra, P.R.; Benner, L.A.M.; Ostro, S.J.; Jurgens, R.F.; Giorgini, J.D.; Yeomans, D.K.; Chandler, J.F.; Shapiro, I.I. (2002). “Radar observations of asteroid 7335 (1989 JA).” *Planetary and Space Science* **50**, 257-260.
- Mahlke, M.; Carry, B.; Denneau, L. (2021). “Asteroid phase curves from ATLAS dual-band photometry.” *Icarus* **354**, id. 114094.
- Mainzer, A.; Grav, T.; Masiero, J.; Hand, E.; Bauer, J.; Tholen, D.; McMillan, R.S.; Spahr, T.; Cutri, R.M.; Wright, E.; Watkins, J.; Mo, W.; Maleszewski, C. (2011). “NEOWISE Studies of Spectrophotometrically Classified Asteroids: Preliminary Results.” *The Astrophysical Journal* **741**, id 90.
- Mainzer, A.K.; Bauer, J.M.; Cutri, R.M.; Grav, T.; Kramer, E.A.; Masiero, J.R.; Sonnett, S.; Wright, E.L. (2019). “NEOWISE Diameters and Albedos V2.0.” *NASA Planetary Data System*.
- Masiero, J.R.; Mainzer, A.K.; Bauer, J.M.; Cutri, R.M.; Grav, T.; Kramer, E.; Pittichová, J.; Sonnett, S.; Wright, E.L. (2020). “Asteroid Diameters and Albedos from NEOWISE Reactivation Mission Years 4 and 5.” *The Planetary Science Journal* **1**, id 5.
- MPC (1983). *Minor Planet Circular* **7783**.
- MPC (1989). *Minor Planet Circular* **14556**.
- MPC (1991). *Minor Planet Circular* **18342**.
- MPC (2004). *Minor Planet Circular* **52768**.
- MPC (2022a). Orbits Database. https://minorplanetcenter.net/db_search/show_object?object_id=2376
- MPC (2022b). Orbits Database. https://minorplanetcenter.net/db_search/show_object?object_id=7335
- MPC (2022c). Orbits Database. https://minorplanetcenter.net/db_search/show_object?object_id=12923
- MPC (2022d). Orbits Database. https://minorplanetcenter.net/db_search/show_object?object_id=85184
- Nugent, C.R.; Mainzer, A.; Bauer, J.; Cutri, R.M.; Kramer, E.A.; Grav, T.; Masiero, J.; Sonnett, S.; Wright, E.L. (2016). “NEOWISE Reactivation Mission Year Two: Asteroid Diameters and Albedos.” *The Astronomical Journal* **152**, id 63.
- Parrott, D. (2022). *Tycho software*. <https://www.tycho-tracker.com>
- Pravec, P.; Wolf, M.; Sarounova, L. (1999web). Ondrejov Asteroid Photometry Project. <http://www.asu.cas.cz/~ppravec/neo.htm>
- Pravec, P.; Harris, A.W.; Kušnirák, P.; Galád, A.; Hornoch, K. (2012). “Absolute magnitudes of asteroids and a revision of asteroid albedo estimates from WISE thermal observations.” *Icarus* **221**, 365-387.
- Raab, H. (2018). *Astrometrica* software. <http://www.astrometrica.at>
- Roig, J.C.; Nogues, R.N.; Lorenz, E.S.; Gonzalez, J.L.S. (2011). *Fotometrica Con Astrometrica*, a Software Tool. <http://www.astrosurf.com/cometas-obs>
- Tedesco, E.F.; Noah, P.V.; Noah, M.; Price, S.D. (2004). “IRAS Minor Planet Survey V6.0.” *NASA Planetary Data System*, id. IRAS-A-FPA-3-RDR-IMPS-V6.0.
- Warner, B.D.; Harris, A.W.; Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146. Updated 2022 Jul. <http://www.minorplanet.info/lightcurvedatabase.html>
- Warner, B.D.; Stephens, R.D. (2020). “Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2020 April - June.” *The Minor Planet Bulletin* **47**, 290-304.
- Warner, B.D.; Stephens, R.D.; Coley, D.R. (2021). “Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2021 March - April.” *The Minor Planet Bulletin* **48**, 337-340.
- Wisniewski, W.Z.; Michalowski, T.M.; Harris, A.W.; McMillan, R.S. (1997). “Photometric Observations of 125 Asteroids.” *Icarus* **126**, 395-449.