# MAIN-BELT ASTEROIDS OBSERVED FROM CS3: 2021 SEPTEMBER – 2022 JANUARY

Robert D. Stephens
Center for Solar System Studies (CS3)
11355 Mount Johnson Ct., Rancho Cucamonga, CA 91737 USA
rstephens@foxandstephens.com

Brian D. Warner
Center for Solar System Studies (CS3)
Eaton, CO

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CCD photometric observations of five main-belt asteroids were obtained at the Center for Solar System Studies (CS3) from 2021 September to 2022 January.

The Center for Solar System Studies (CS3) has nine telescopes which are normally used in program asteroid family studies. The focus is on near-Earth asteroids, Jovian Trojans and Hildas. When a nearly full moon is too close to the family targets being studied, targets of opportunity amongst the main-belt families were selected.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

| Telescope | Camera |
|---|---|
| 0.30-m f/6.3 Schmidt-Cass | SBIG 1001E |
| 0.35-m f/9.1 Schmidt-Cass | FLI Microline 1001E |
| 0.35-m f/9.1 Schmidt-Cass | FLI Microline 1001E |
| 0.35-m f/9.1 Schmidt-Cass | FLI Microline 1001E |
| 0.40-m f/10 Schmidt-Cass | FLI Proline 1001E |
| 0.40-m f/10 Schmidt-Cass | FLI Proline 1001E |
| 0.50-m F8.1 R-C | FLI Proline 1001E |

Table I: List of CS3 telescope/CCD camera combinations.

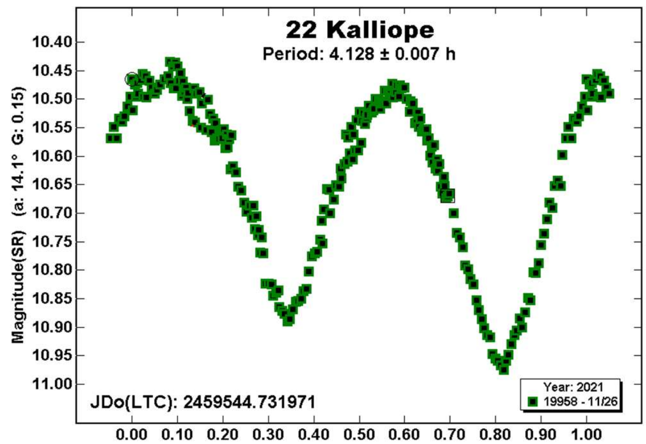
Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs and are "native" magnitudes of the catalog. Those adjustments are usually ≤ ±0.03 mag. The rare greater corrections may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction.

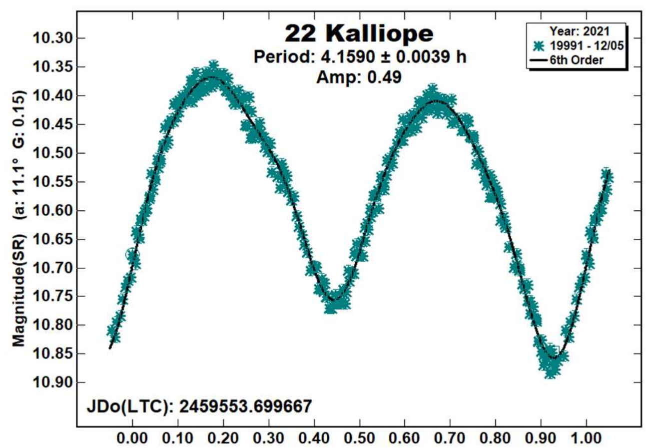
The Y-axis values are ATLAS SR "sky" magnitudes. The two values in the parentheses are the phase angle (a) and the value of *G* used to normalize the data to the comparison stars used in the earliest session. This, in effect, made all the observations seem to be made at a single fixed date/time and phase angle, leaving any variations due only to the asteroid's rotation and/or albedo changes. The X-axis shows rotational phase from -0.05 to 1.05. If the plot includes the amplitude, e.g., "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

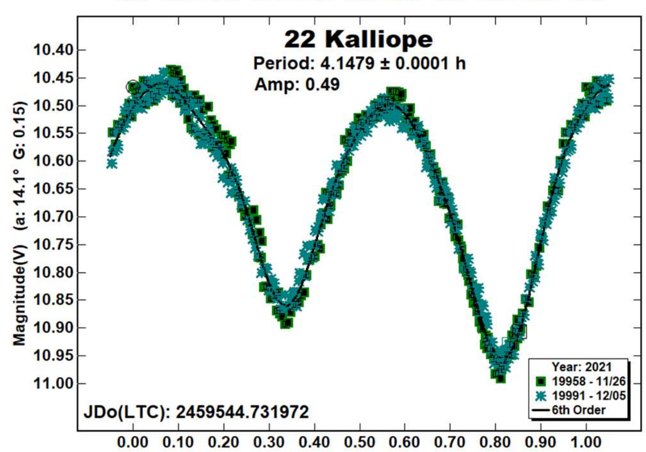
For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the asteroid lightcurve database (LCDB; Warner et al., 2009).

22 Kalliope. At the request of Josef Hanus (private communications) observations of this outer main-belt asteroid were made at CS3. It is a known binary. The times of observations were meant to observe mutual events between the two bodies.

On the first night, 2021 Nov 26, an attenuation seemed to be recorded and was near the predicted time. However, the attenuation was too shallow and too short to fit predictions based on accurate modeling. The cause for the attenuation was attributed to an artifact during star subtraction as the asteroid passed a star three magnitudes fainter. The Fates could not have been much less kind.



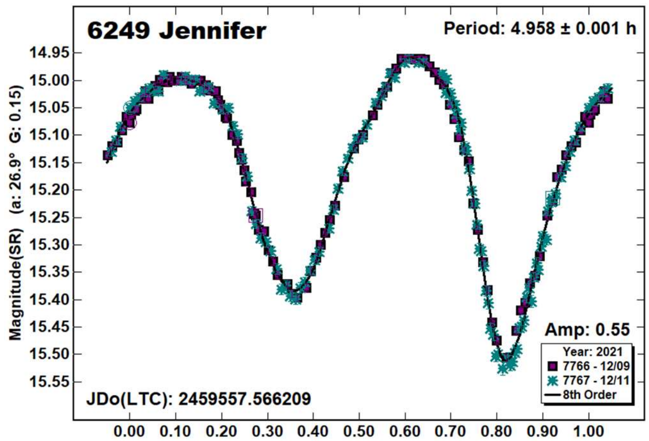



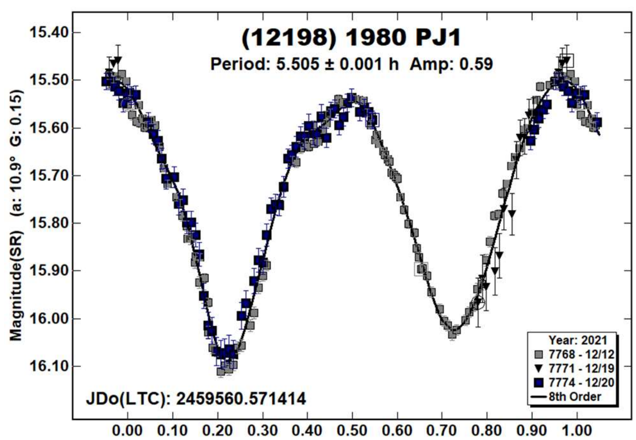
Follow-up observations on 2021 Dec 5 showed no attenuations, but the observations were made outside any predicted events so nothing unusual was expected.

Combining the two sets allowed finding a more accurate and precise synodic rotation period of 4.1479 h. This fits well with the many previous results found in the LCDB.

6249 Jennifer. This member of the Hungaria dynamical group has been observed many times in the past (Warner 2015 and references therein), each time reporting a period near 4.96 h. The results found this year are in good agreement.

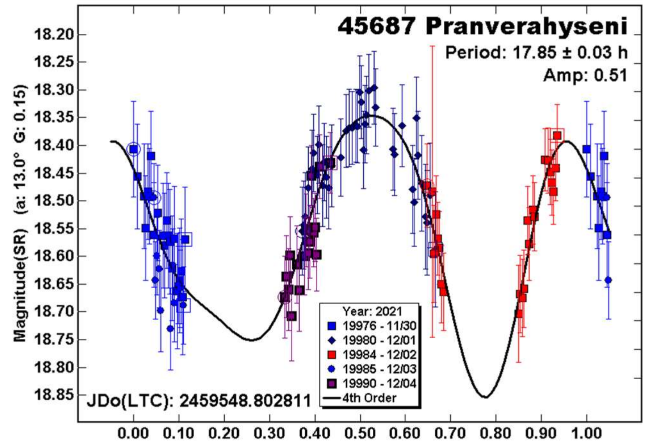



(12198) 1980 PJ1. The estimated diameter of this Mars-crosser (family 9103 in the LCDB) is 3 km. Carreño et al. (2019) reported a period 5.494 h. There were no other periods listed in the LCDB. The results using the 2021 data obtained at CS3 are in good agreement with Carreño et al. (2019).



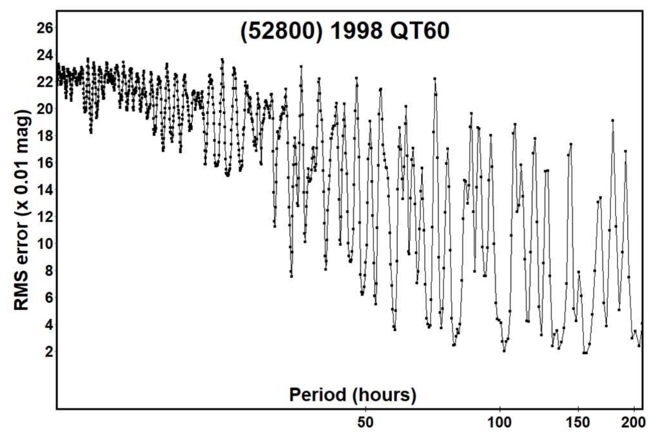

45687 Pranverahyseni. Observations were made at the request of its namesake, Pranvera Hyseni, a student at the University of Santa Cruz, who founded the organization *Astronomy Outreach of Kosovo* and is a leading advocate of amateur astronomy in her native country. The lightcurve was used to link a point in the curve to any changes in the asteroid's spectrum during rotation.

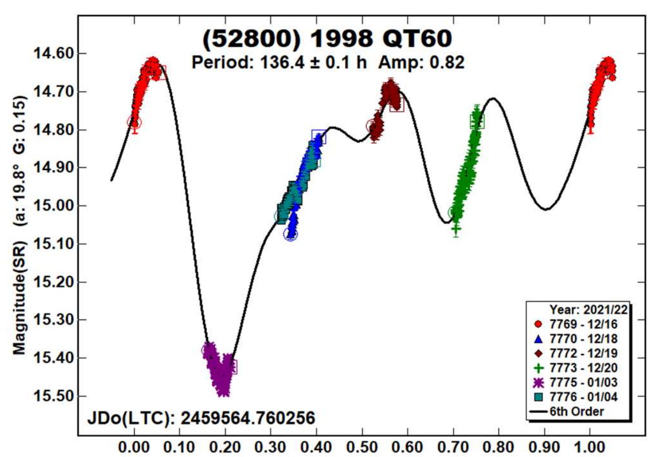
There were no previous results for a period in the LCDB. Masiero et al. (2021) used WISE data to find an estimated $D$ = 13.14 km. Using $H$ = 15.84 gave $p_V$ = 0.039. This was a difficult target, being about SR = 18.55 mag. Fortunately, the amplitude was large enough to overcome the noise and, based the modest phase angle and amplitude, a bimodal solution was very likely (Harris et al., 2014).




(52800) 1998 QT60. There were no previously-reported rotation periods in the LCDB for this Mars-crosser. With large gaps between successive sessions, it was fully expected that there would be numerous potential periods due to rotational aliasing, which is when the actual number of rotations over the total span of the data set is not known.

Different solutions presented themselves depending on the number of orders in the Fourier analysis. Using 4th and 6th orders found similar results for a somewhat symmetrical bimodal lightcurve. The true period may be tens of hours from what's reported here. At the least, it's been established that the asteroid is tumbling and so is a place with continuously restless days and nights.



| Number | Name | 2021/mm/dd | Phase | $L_{PAB}$ | $B_{PAB}$ | Period(h) | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|
| 22 | Kalliope | 11/26-12/05 | 14.1,11.1 | 97 | 7 | 4.1479 | 0.0001 | 0.49 | 0.03 |
| 6249 | Jennifer | 12/31-12/31 | *20.3,19.7 | 0 | 0 | 4.958 | 0.001 | 0.55 | 0.02 |
| 12198 | 1980 PJ1 | 12/12-12/20 | 10.9,15.7 | 68 | 3 | 5.505 | 0.001 | 0.59 | 0.01 |
| 45687 | Pranverahyseni | 11/30-12/04 | 13.0,12.1 | 101 | -19 | 17.85 | 0.03 | 0.51 | 0.05 |
| 52800 | 1998 QT60 | 12/16-01/04 | 19.9,7.5 | 106 | 12 | [T]136.4 | 0.1 | 0.82 | 0.03 |

Table II. Observing circumstances and results. [T]Dominant period for a tumbling asteroid. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extremum 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).

Acknowledgements

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References

Carreño, A.; Arce, E.; Fornas, G.; Mas, V. (2019). "Eleven Main-belt Asteroids and One Near-Earth Asteroid Lightcurves at Asteroids Observers (OBAS) - MPPD: 2017 May - 2019 Jan." *Minor Planet Bul.* **46**, 200-203.

Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Harris, A.W.; Young, J.W.; Contreiras, L.; Dockweiler, T.; Belkora, L.; Salo, H.; Harris, W.D.; Bowell, E.; Poutanen, M.; Binzel, R.P.; Tholen, D.J.; Wang, S. (1989). "Phase relations of high albedo asteroids: The unusual opposition brightening of 44 Nysa and 64 Angelina." *Icarus* **81**, 365-374.

Harris, A.W.; Pravec, P.; Galad, A.; Skiff, B.A.; Warner, B.D.; Vilagi, J.; Gajdos, S.; Carbognani, A.; Hornoch, K.; Kusnirak, P.; Cooney, W.R.; Gross, J.; Terrell, D.; Higgins, D.; Bowell, E.; Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.

Masiero, J.R.; Mainzer, A.K.; Bauer, J.M.; Cutri, R.M.; Grav, T.; Kramer, E.; Pittichova, J.; Wright, E.L. (2021). "Asteroid Diameters and Albedos from NEOWISE Reactivation Mission Years Six and Severn." *Plan. Sci. J.* **2**, id.162.

Tonry, J.L.; Denneau, L.; Flewelling, H.; Heinze, A.N.; Onken, C.A.; Smartt, S.J.; Stalder, B.; Weiland, H.J.; Wolf, C. (2018). "The ATLAS All-Sky Stellar Reference Catalog." *Astrophys. J.* **867**, A105.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2021 August. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2015). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 March-June." *Minor Planet Bul.* **42**, 267-276.

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## COLLABORATIVE ASTEROID PHOTOMETRY OF SIX MAIN-BELT ASTEROIDS

Stephen M. Brincat
Flarestar Observatory (MPC 171)
Fl.5/B, George Tayar Street,
San Gwann SGN 3160, MALTA
stephenbrincat@gmail.com

Charles Galdies
Znith Observatory
Naxxar NXR 2217, MALTA

Martin Mifsud
Manikata Observatory
Manikata MLH 5013, MALTA

Kevin Hills
Tacande Observatory
El Paso, La Palma, SPAIN

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Synodic rotation periods of six main-belt asteroids were derived from photometric observations obtained from 2021 July 21 through November 2 from three observatories situated in Malta and one from Spain. We provide lightcurve rotation periods for (1713) Bancilhon, (2232) Altaj, (2458) Veniakaverin, (6681) Prokopovich, (6787) 1991 PF15, and (18863) 1999 RC191.

Photometric observations of six asteroids were carried out from four observatories located on the Maltese mainland and another located on the island of La Palma, Spain. Observations of asteroids for (1713) Bancilhon, (2232) Altaj, (2458) Veniakaverin, (6681) Prokopovich, and (6787) 1991 PF15 were obtained from the Maltese observatories, while the data for (18863) 1991 RC191 were obtained from Spain. Our observatories used the configurations shown in Table 1. All of our images were dark subtracted and flat-fielded.

All telescopes and cameras were controlled remotely over the internet either from a location near each telescope via *Sequence Generator Pro* (Binary Star Software) or through remote programing for the La Palma Observatory. Photometric reduction, lightcurve construction and analyses were derived through *MPO Canopus* software (Warner, 2017) where differential aperture photometry was used. The Comparison Star Selector (CSS) feature of *MPO Canopus* was used to select comparison stars of near-solar color. Our magnitude measurements were based on the ATLAS catalogue through the Red (r) bandpass.