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ROTATIONAL PERIOD DETERMINATION AND TAXONOMIC CLASSIFICATION FOR ASTEROIDS 417 SUEVIA, 554 PERAGA, AND 747 WINCHESTER

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CCD photometric observations of three main-belt asteroids were made between 2022 January and March in order to measure their rotation periods and define their taxonomic class. The observations used instrumentation available at our two observatories.

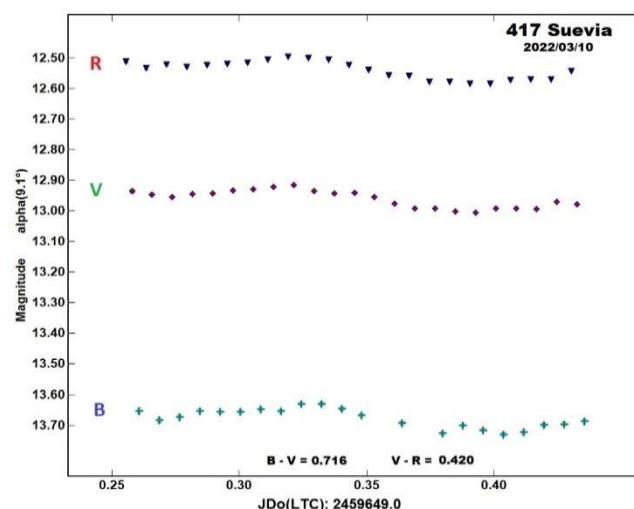
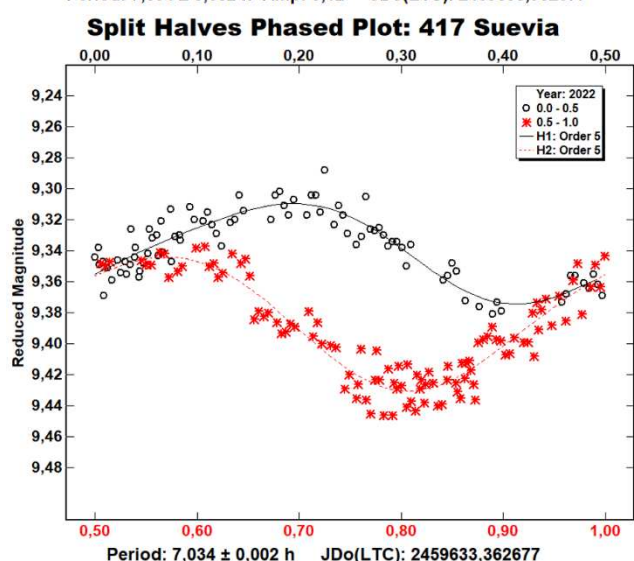
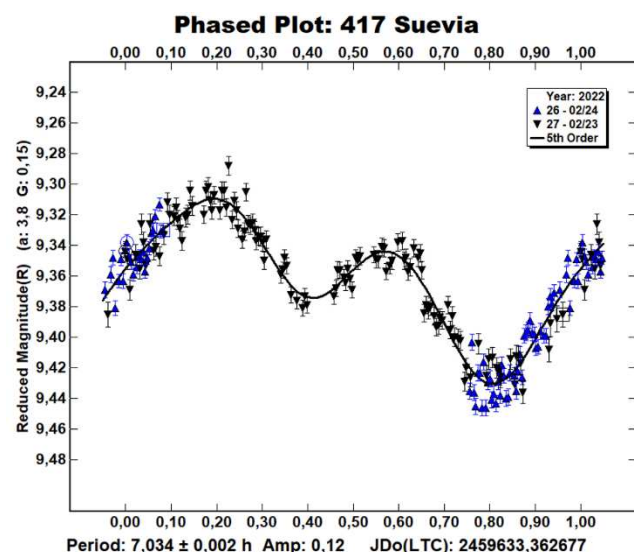
CCD photometric observations of three main-belt asteroids were carried out in 2022 January and March at the Osservatorio Astronomico Margherita Hack (A57) and Osservatorio Astronomico Hypatia (L62). The Osservatorio Astronomico Margherita Hack is equipped with a 0.35-m *f*/8.25 Schmidt-Cassegrain telescope, an SBIG ST10 XME CCD camera, and Johnson-Cousins BVRc photometric filters. The pixel scale was 1 arcsec when binned at 2×2 pixels. The Osservatorio Astronomico Hypatia is equipped with a 0.25-m *f*/5.6 Ritchey-Chretien telescope and a Moravian G2-8300 CCD camera having the pixel scale of 0.81 arcsec at 1×1 binning, and Rc photometric filter. Data processing and analysis were done with *MPO Canopus* (Warner, 2021). All images were calibrated with dark and flat field frames using *Astroart 6.0* and *MaximDL*. Table I shows the observing circumstances and results.

417 SUEVIA was discovered at Heidelberg on 1896 May 6 by M.F. Wolf. It is a main-belt asteroid with a semi-major axis of 2.800 au, eccentricity 0.135, inclination 6.65 deg, and orbital period of 4.69 years. Its absolute magnitude is $H = 9.56$ (JPL, 2022; MPC, 2022).

In this case, our observations were conducted in two steps. The first step consisted in collecting 192 data points during two nights on 2022 Feb 23 and 24. The period analysis shows a bimodal solution for a rotational period $P = 7.034 \pm 0.002$ h with an amplitude $A = 0.12 \pm 0.02$ mag. The split-halves plot let us resolve the potential ambiguity between monomodal and bimodal solution by showing that the two halves of the 7.034 h solution are not superimposable. This makes the bimodal solution much more probable. As a further check, we consulted the asteroid lightcurve database (LCDB; Warner et al., 2009) and found three previously reported periods: Barucci et al. (1992, 7.034 h), Fauvaud and Fauvaud (2013, 7.020 h), and Martikainen et al. (2021, 7.0185 h). The period we found seems to be in good agreement with those previous results.

Number	Name	2022 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E.	Amp	A.E.	Grp
417	Suevia	02/22	192	3.37	152	-6	7.034	0.002	0.12	0.014	MBA
554	Peraga	01/13	391	6.53	103	1	13.715	0.002	0.18	0.01	MBA
747	Winchester	03/01	513	5.46	168	14	9.418	0.002	0.13	0.016	MBA

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



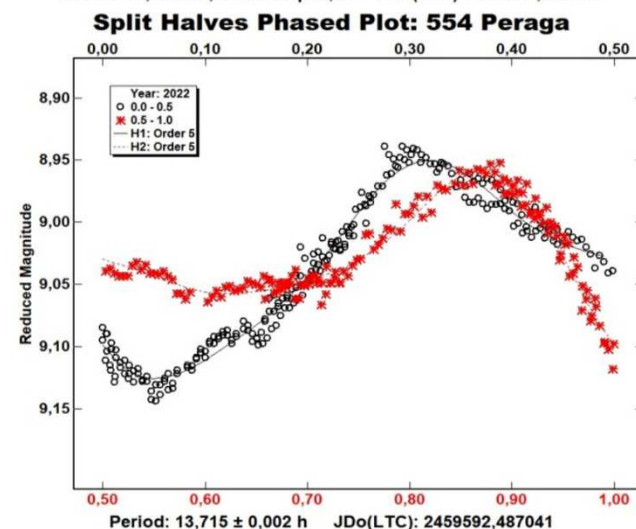
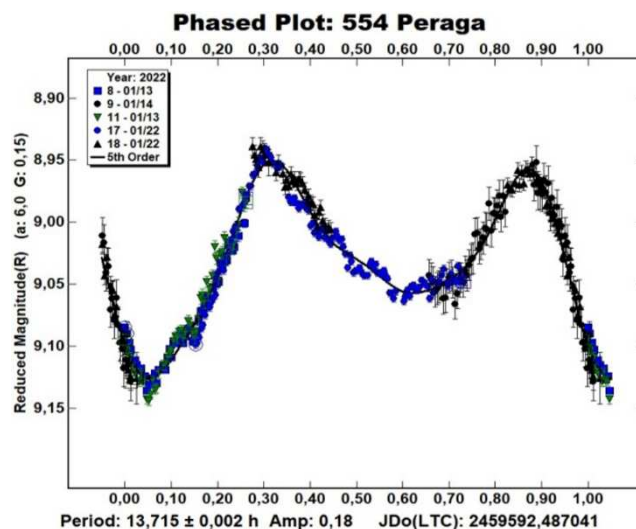
In the second step, we collected further 67 data points in one night using B, V, and Rc filters. This allowed us to determine the color indexes $(V-R) = 0.420 \pm 0.005$ and $(B-V) = 0.716 \pm 0.008$. These values are consistent with a medium albedo M-type taxonomic class

(Shevchenko and Lupishko, 1998) and in good accordance with the previously published results in the LCDB. The albedo of 0.1637 (Warner, B.D. et al., 2009) is also consistent with a taxonomic class of type M (Shevchenko and Lupishko, 1998).

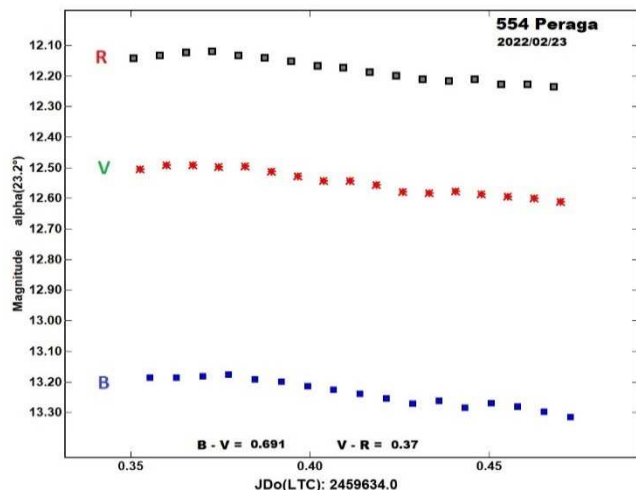
554 Peraga was discovered on 1905 Jan 8 at Heidelberg by P. Gotz. It was chosen from the list of lightcurve photometry opportunities in the *Minor Planet Bulletin* (Warner et al., 2022). It is a main-belt asteroid with a semi-major axis of 2.375 au, eccentricity 0.1519, inclination 2.935 deg, and orbital period of 3.66 years. Its absolute magnitude is $H = 9.13$ (JPL, 2022; MPC, 2022).

We consulted the asteroid lightcurve database (LCDB; Warner et al., 2009) and found five previous calculated periods: Scaltriti and Zappala (1979, 13.63 h), Behrend (2004web, 13.707 h; 2006web, 13.7 h), Higgins et al. (2007, 13.7128 h), and Stephens (2007, 13.71 h).

Our observations were again conducted in two steps. The first consisted of collecting 391 data points during three nights from 2022 Jan 13-22. The period analysis shows a bimodal solution for the rotational period with $P = 13.715 \pm 0.002$ h and an amplitude $A = 0.18 \pm 0.01$ mag. The split-halves plot resolved the potential ambiguity between a monomodal and bimodal solution by showing that the two halves of the 13.715 h solution are not superimposable. This makes the bimodal solution much more probable. The period we found seems to be in good agreement with the previous results.

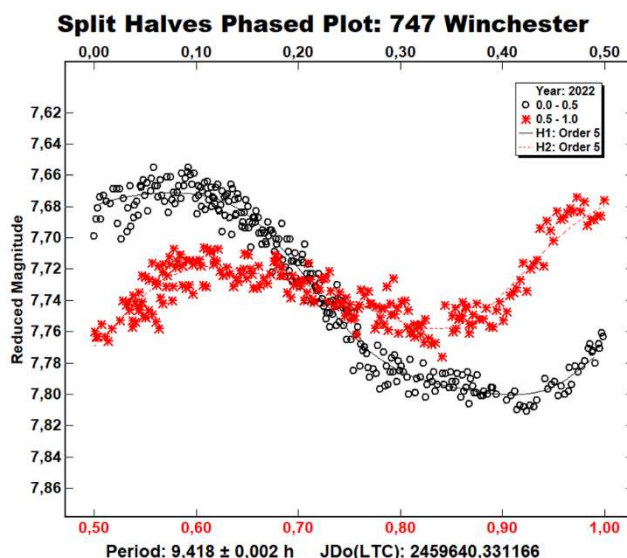
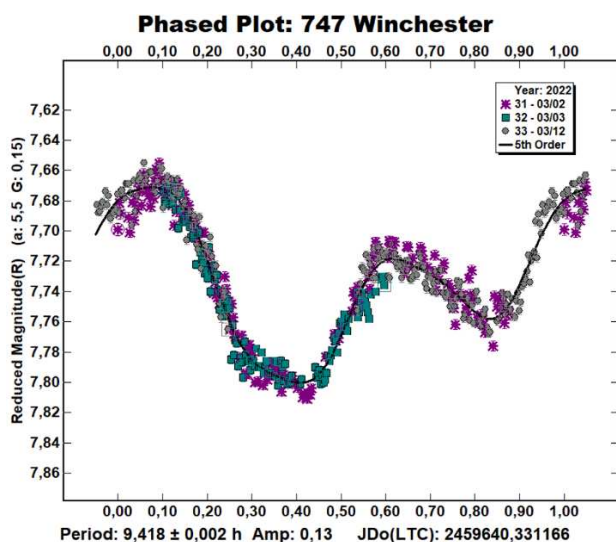


In the second step, we collected an additional 51 data points in one night using filters B, V and Rc. This allowed us to determine the color indexes $(V-R) = 0.37 \pm 0.004$ and $(B-V) = 0.691 \pm 0.005$. These values are consistent with a low albedo C-type taxonomic class (Shevchenko and Lupishko, 1998) and in good accordance with the previously published results in the LCDB. The albedo of 0.044 (Warner, B.D. et al., 2009) is also consistent with a taxonomic class of type C (Shevchenko and Lupishko, 1998).

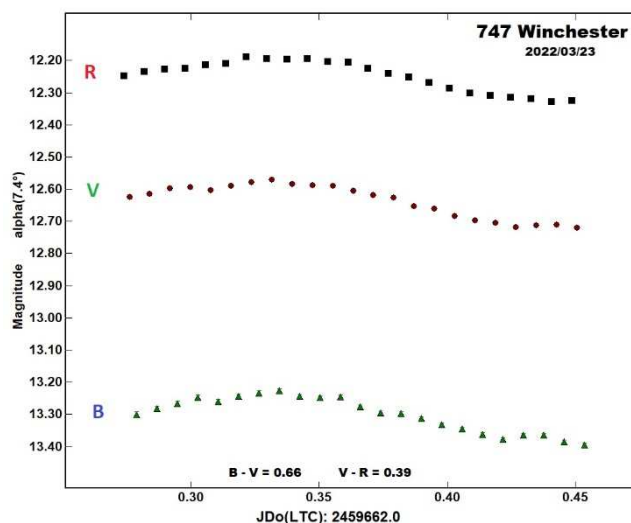


747 Winchester was discovered at Winchester on 1913 Mar 7 by J. H. Metcalf. It is a main-belt asteroid with a semi-major axis of 3.001 au, eccentricity 0.339, inclination 18.22 deg, and orbital period of 5.2 years. Its absolute magnitude is $H = 7.84$ (JPL, 2022; MPC, 2022).

Keeping with the method mentioned above, the first of two steps of observations collected 513 data points from 2022 Mar 2-12. Period analysis shows a bimodal solution with $P = 9.418 \pm 0.002$ h and amplitude $A = 0.13 \pm 0.02$ mag. The split-halves plot shows that the bimodal solution is the most probable. We found at least three previous results in the LCDB (Warner et al., 2009) in good agreement with ours: Warner (2007, 9.4146 h), Pilcher (2010; 9.414 h), and Āurech et al. (2011; 9.414 h).



In the second step, we collected further 69 data points in one night using filters B, V and Rc. This allowed us to determine the color indexes $(V-R) = 0.39 \pm 0.02$ and $(B-V) = 0.66 \pm 0.02$. These values are consistent with a low albedo C-type taxonomic class (Shevchenko and Lupishko, 1998) and in good accordance with the previously published results in the LCDB. The albedo value of 0.0435 (Warner et al., 2009) is also consistent with a taxonomic class of type C (Shevchenko and Lupishko, 1998).



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LIGHTCURVE ANALYSIS OF THREE MAIN BELT ASTEROIDS: 2265 VERBAANDERT, 3787 AIVAZOVSKIJ, AND 4528 BERG

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2265 Verbaandert was imaged on seven nights between 2022 Feb 13 and 2022 Apr 03. A period of 2.8143 ± 0.0001 hours and amplitude of 0.105 magnitude are reported. 3787 Aivazovskij was imaged five nights between 2022 Jan 06 and 2022 Feb 07. A period of 2.9532 ± 0.0001 hours and amplitude of 0.191 magnitude are reported. 4528 Berg was imaged on eight nights from 2022 Apr 07 to 2022 May 07. A period of 3.5630 ± 0.0001 hours and amplitude of 0.345 magnitude are reported.

Photometric measurements of three main-belt asteroids were performed by first author Wiley at the Live Oaks Observatory near Pontotoc, Texas (MPC V62). Images were taken with a 0.36m f/7.2 corrected Dall-Kirkham telescope, SBIG Aluma 3200 CCD, and no filter. Nightly ephemeris positions were obtained from the Minor Planet Center. Exposure time of all images was 180 seconds. The image scale was 1.094 arcseconds/pixel binned 2×2 . Images were calibrated with bias ($N = 100$), dark ($N = 30$) and flat frames ($N = 21$) in *MaxIm DL*. Flat images were taken using a full spectrum LED panel. Alignment, plate solving, and data reduction were performed using *Tycho Tracker* (Parrott, 2021). Comparison stars (five minimum) were picked from *Tycho Tracker*'s "Find Comp Stars" which presents those stars in the FOV ($19.6^\circ \times 13.3^\circ$) with suitable comp stars similar in color to the Sun, typically $0.55 < B-V < 0.90$. Clear instrumental magnitudes are converted to Sloan r' (SR) magnitudes using the Atlas All-Sky Reference Catalog (Tonry et al., 2018) within *Tycho Tracker*. (Two runs are exceptions as noted below.) Fourier analysis was used to find the periods. For each asteroid an initial search was conducted for periods between one and eight hours to investigate aliases. A final step size between one and four hours with 30,000 steps was used to determine the periods and amplitudes. A fit order = 6 was used for 2265 Verbaandert while a fit order = 4 was used for both 3787 Aivazovskij and 4528 Berg. Figures were made in *MPO Canopus* (Warner, 2010) to conform to the Minor Planet Bulletin format by F. P. using ALCDEF files generated in *Tycho Tracker*.

2265 Verbaandert (1950 DB) was discovered by Sylvain J.V. Arend at the Observatoire royal de Belgique. It is a carbonaceous mid-main-belt (9105) asteroid of 12 km in diameter (JPL, 2022). Waszczak et al. (2015) estimated a rotation period of 2.990 ± 0.0006 hours based on sparse photometric data.

Verbaandert was imaged over seven nights in 2022 from late February, late March and early April; see Table I for details. Fourier analysis in *Tycho Tracker* and a fit order of 6 reported a new period of 2.8143 ± 0.0001 hours with an amplitude of 0.105 magnitude (Fig. 1). Photometric precision averaged 0.008 magnitude. Fitting a 2.8143-hour period to data from the existing ALCDEF yielded the