

THE MINOR PLANET BULLETIN

BULLETIN OF THE MINOR PLANETS SECTION OF THE
ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

VOLUME 53, NUMBER 1, A.D. 2026 JANUARY-MARCH

1.

LIGHTCURVE ANALYSIS OF MAIN-BELT ASTEROID 665 SABINE OBSERVED IN 2020 AND 2021

Ian Sherman, James Imamura, R. Scott Fisher
University of Oregon
Willamette Hall 1371 E 13th Ave #130
Eugene, OR 97403 USA
iss@uoregon.edu

Masayuki Itoh, Iku Karukome, Shunku Kataoka
Kobe University
Kobe Hyōgo, JAPAN

(Received: 2025 August 25)

We analyzed data of asteroid 665 Sabine captured in 2020 at Pine Mountain Observatory (PMO) and 2020 and 2021 at Nishi Harima Astronomical Observatory (NHAO). We find an amplitude of 0.30 ± 0.01 magnitudes and a period consistent with 4.294 ± 0.001 hours.

665 Sabine is a main-belt asteroid discovered in 1908 by W. Lorenz with an orbital inclination of 14.7° , semi-major axis of 3.1443 A.U., a diameter of 51.09 km, and eccentricity of 0.1723 (JPL, 2025b). Results from the LCDB indicate 665 Sabine has an absolute magnitude of $H = 8.93$, rotation period of 4.294 ± 0.001 h, an amplitude range of 0.27 to 0.45 mag, and an albedo of 0.3547 (Michałowski et al., 2006; Tedesco et al., 2002; Vereš et al., 2015).

Observations were conducted over three nights: 2020 Aug 16 at PMO, and 2020 Aug 24 and 2021 Nov 11 at NHAO. PMO used a 0.35 m $f/7.2$ PlaneWave CDK14 telescope paired with an Andor F9000 CCD (3056×3056 resolution, 0.96 arcsec/pix scale) using Sloan g' filters and 60 s exposures for a total of 169 image frames (PMO, 2025). NHAO employed a 0.60 m $f/12$ Cassegrain reflector with an SBIG STL-1001E CCD (1024×1024 resolution, 0.70 arcsec/pix scale) using Johnson V filters and 30 s exposures for a total of 145 image frames in 2020 and 359 frames in 2021 (NHAO, 2025). All image files were calibrated with flat, dark and bias corrections prior to analysis.

We measured the magnitude of 665 Sabine and the field's comparison stars using *AstroImageJ* (Collins et al., 2017). Candidate comparison stars were chosen using data from GAIA DR2 accessed via the *IRSA Catalog* (Gaia, 2016; Gaia, 2018; NASA/IPAC, 2025). Measurements were transformed into SDSS g' magnitudes using literature conversions from the relevant photometric systems (Jester et al., 2005; Carrasco and Bellazzini, 2023). In total, eighteen comparison stars were identified for the PMO 2020 Aug 16 data, seven for the NHAO 2020 Aug 24 data, and nine for the NHAO 2021 Nov 7 data.

Three primary sources contributed to the total magnitude uncertainty which we combined in quadrature: (1) observational counting statistics from the photometry of 665 Sabine, (2) magnitude conversions across the three employed filter sets (Carrasco and Bellazzini, 2023; Jester et al., 2005; Shevchenko et al., 2021), and (3) the one σ spread of residuals between measured and cataloged magnitudes of field comparison stars (Gaia, 2018). We find an average magnitude error of 0.083 g' mag for the 2020 PMO data, and 0.064 and 0.069 g' mag for the 2020 and 2021 NHAO data respectively.

Using Python and ephemerides from the Horizons system, we generated lightcurves for the three datasets based on the following initial conditions: Aug 16 at 00:00:00 UTC was selected as the phasing zero-point; light travel time was subtracted from each UTC timestamp; and magnitude offsets, extracted from the Horizons system using the standard IAU H-G formalism and transformed into g' , were applied relative to the PMO dataset (JPL, 2025a).

Due to the sparsity of our 2020 data and the significant time gap between our initial and final observations, extracting a reliable period from the composite lightcurve required the development of a dedicated epoch-folding routine in line with the procedures outlined by Larsson (1995). We first composited the two 2020 datasets and broadly sampled within ten σ of the literature period of 4.294 ± 0.001 h (Michałowski et al., 2006), using a step size of 0.00001 h. At each trial period, the magnitude data were binned into twenty phase intervals, weighted proportionally to counts per bin, and folded accordingly.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
665	Sabine	2020 08/16-08/24	*3.8, 4.4	326	8	4.291	0.002	0.30	0.01	MB
665	Sabine	2021 11/07	5.6	40	17					

Table I. Observing circumstances and results. 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). Grp is the asteroid family/group (Warner et al., 2009). Measurements of Period, Amp and their errors taken across both lines.

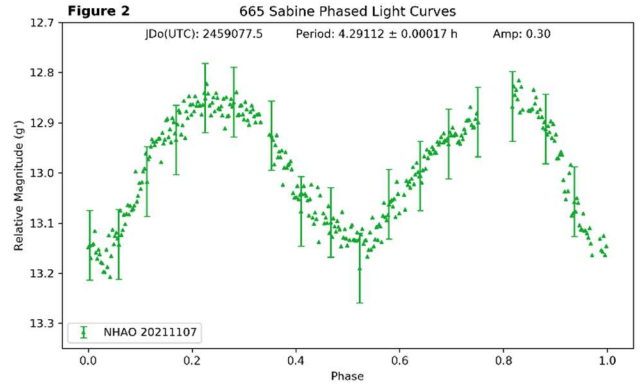
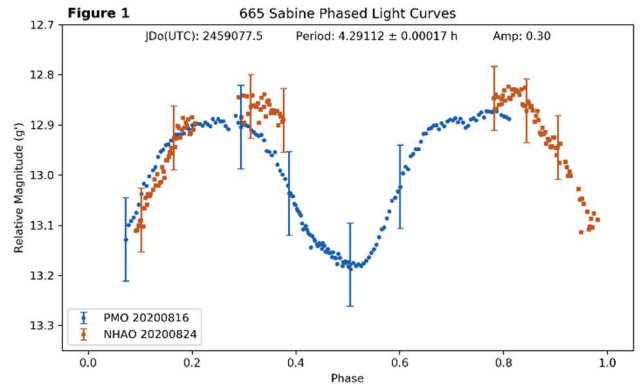
For each trial, we calculated the normalized residuals and their σ about 665 Sabine's mean magnitude. The best-fit candidate, 4.29126 h, was identified as the period that maximized the residual spread across the sampled range. Incorporating the 2021 dataset to improve phase coverage, we performed a second composite fold over a narrower period range to focus on behavior within a single rotation cycle. This allowed us to refine the period estimate to 4.29112 h and produce the lightcurves seen in Figure 1 and 2. However, the necessity of spanning all three lightcurves over a 448-day baseline introduces a cycle-count ambiguity of ± 0.002 h (Sterken, 2005). As a result, we report a synodic period for 665 Sabine of 4.291 ± 0.002 h from our observations. This period is consistent with the literature values reported by Michalowski.

To demonstrate the effect of cycle-count uncertainty over long time baselines, we also folded all three datasets across a three- σ range around the literature value. This yielded four synodic periods that modeled the data comparably well: 4.29112 ± 0.00017 h, 4.29286 ± 0.00017 h, 4.29458 ± 0.00017 h, and 4.29635 ± 0.00018 h with uncertainties derived from a Monte Carlo shuffle test permuted 5000 times per candidate. Each period corresponds to an additional complete rotation cycle over the 448-day span and cannot be uniquely distinguished without further observations. A recently published period for 665 Sabine of 4.29407 ± 0.00005 h agrees with one of these results within three σ but does not agree with our reported synodic period (Shevchenko et al., 2021).

We constructed three models – a 6th-degree polynomial, a 2nd-order Fourier fit, and a spline with a smoothing factor of 0.003 – to evaluate the amplitude of the binned, composite lightcurve. Our binning approach inherently reduced noise, and we measured amplitudes as the maximum difference between local extrema in each fit. We report an amplitude of $\Delta g' = 0.30 \pm 0.01$ magnitudes, calculated as the average of the three models as well as the amplitude given from the raw, binned data, with the uncertainty given by the standard deviation about the mean.

Acknowledgements

We thank Alton Luken, Head of Operations at PMO, for his invaluable support and stewardship of the observatory, Riley Monsrud for leading the collection of this data, and the Roundhouse and Heising-Simons Foundations for their generous support keeping PMO active. Thank you to Dr. Jun Takahashi and the University of Hyogo for their facilitation of NHAO. The codebase used in the analysis of this data is accessible on GitHub at: <https://github.com/iss-uoregon/asteroids>. This work has made use of data from the European Space Agency Gaia mission, processed by the Gaia Data Processing and Analysis Consortium. We thank the Solar System Dynamics group at the Jet Propulsion Laboratory for maintaining and providing access to the JPL Horizons On-Line Ephemeris System and the JPL Small-Body Database. Special thanks to Brian Warner and the MPB and LCDB teams. This project makes use of the python language interpreter along with several supporting packages which are made freely available: *pandas* (pandas, 2025), *Matplotlib* (Hunter, 2007), *Astropy* (Astropy, 2022), *NumPy* (Harris et al., 2020), *SciPy* (Virtanen et al., 2020), and *Astroquery* (Ginsberg et al., 2019).



References

- Astropy Collaboration (2022). “The Astropy Project: Sustaining and Growing a Community-oriented Open-source Project and the Latest Major Release (v5.0) of the Core Package.” *ApJ* **935**, 167.
- Carrasco, J.M.; Bellazzini, M. (2023). “Photometric relationships with other photometric systems.” *Gaia data release 3 documentation*, Section 5.5.1.
- Collins, K.A.; Kielkopf, J.F.; Stassun, K.G.; Hessman, F.V. (2017). “AstroImageJ: Image Processing and Photometric Extraction for Ultra-Precise Astronomical Light Curves.” *AJ* **153**, 77-89.
- Gaia Collaboration (2016). “The Gaia Mission.” *A&A* **595**, A1.
- Gaia Collaboration (2018). “Gaia Data Release 2. Summary of the contents and survey properties.” *A&A* **615**, A1.
- Ginsberg, A.; Sipőcz, B.M.; Brasseur, C.E.; Cowperthwaite, P.S. and 30 colleagues (2019). “astroquery: An Astronomical Web-querying Package in Python.” *AJ* **157**, 98-104.
- 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, C.R.; Millman, K.J.; van der Walt, S.J.; Gommers, R. and 22 colleagues (2020). “Array programming with NumPy.” *Nature* **585**, 357-362.
- Hunter, J.D. (2007). “Matplotlib: A 2D Graphics Environment.” *Computing in Science & Engineering* **9**, 90-95.