A New Program for Rotational Characterization of Near-Earth Objects

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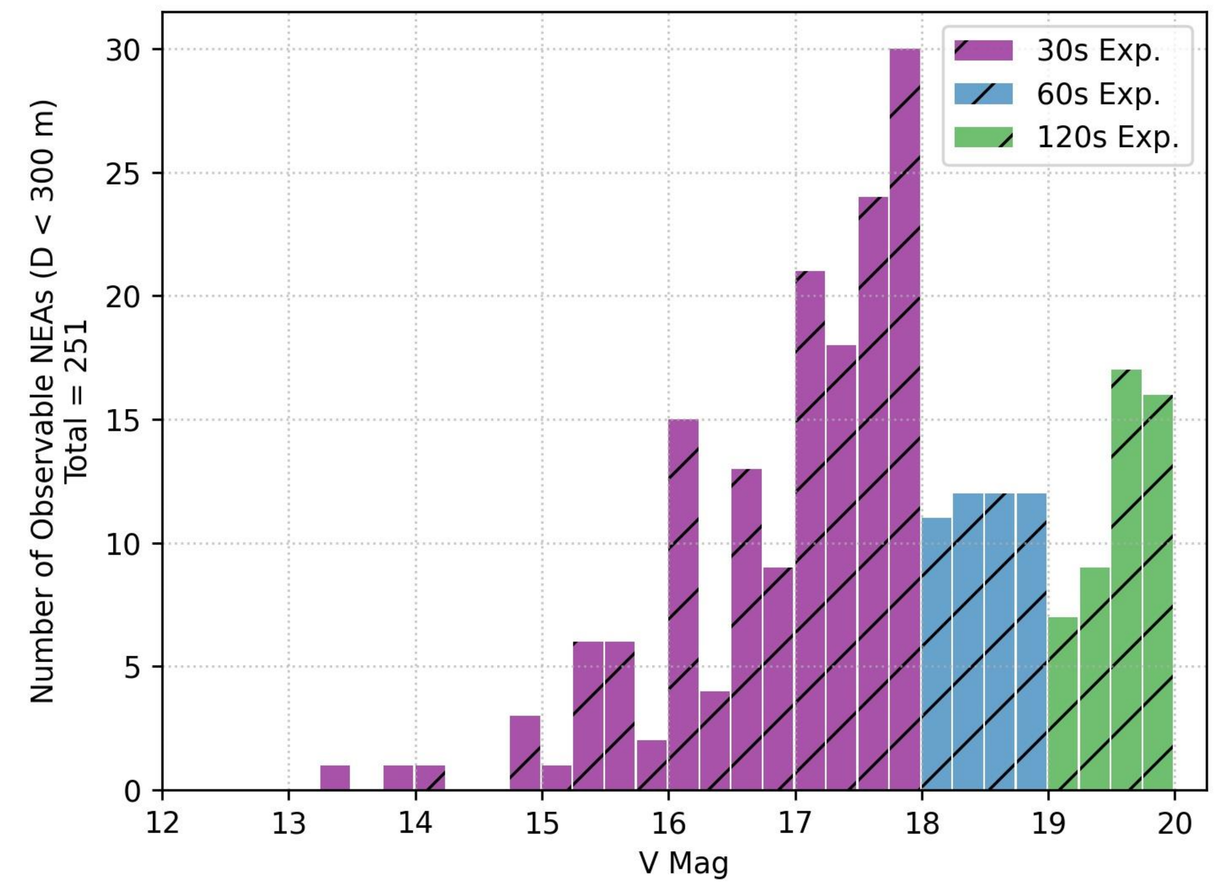
Background and Goals

Motivation

- The discovery of near-Earth objects (NEOs) continues to outpace their characterization
- As Vera Rubin Observatory and NEO Surveyor come online in the near future, this problem will become more apparent

Goals

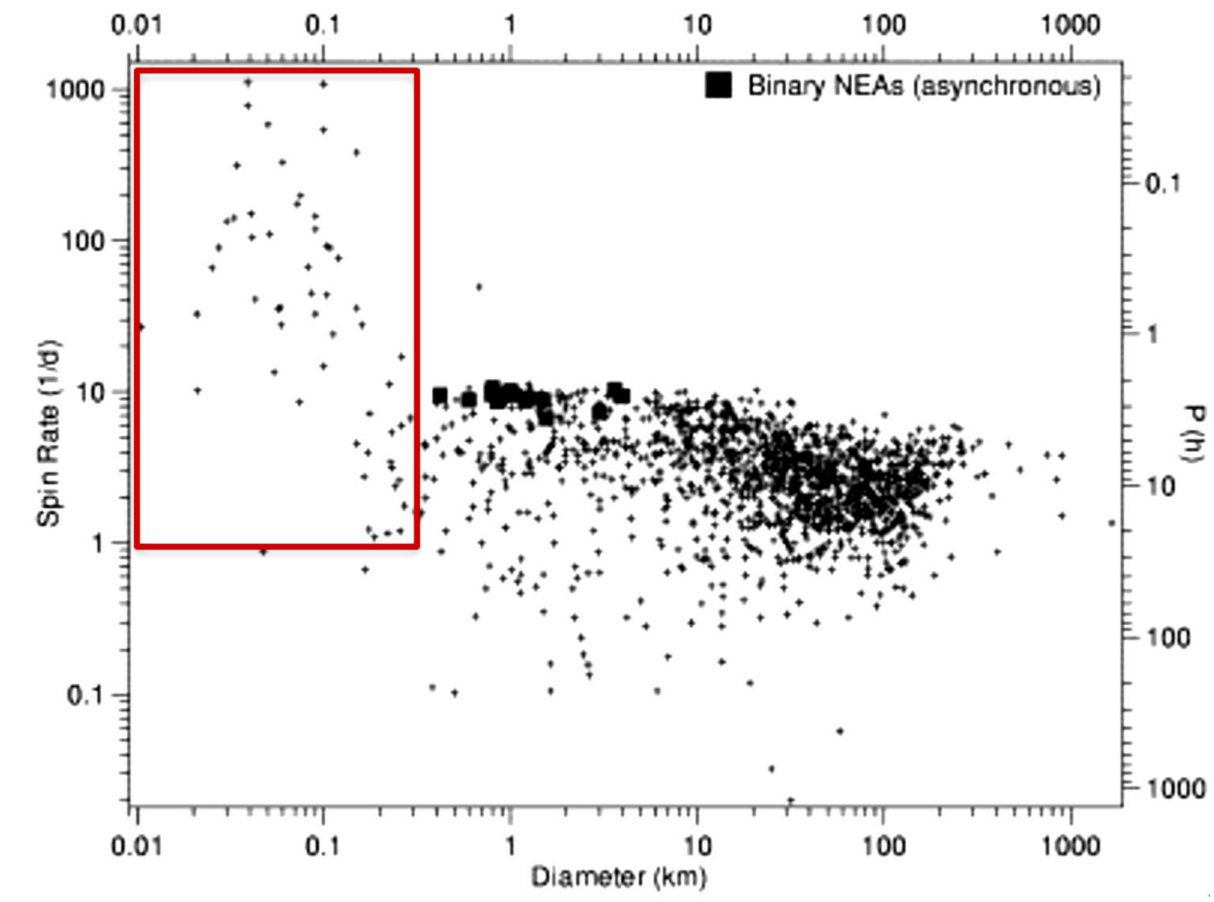
- This is a new NASA Planetary Defense Coordination Office grant focused on:
  - Support of Goldstone Radar (GSSR) observations which can benefit from initial optical characterization
  - Determination of NEO rotational information including binary fraction for NEOs smaller than 300 m
  - Support of IAWN campaigns



Target magnitude versus the number of NEOs known to be observable during program period of performance (as of May 2024). Newly discovered NEOs will be added to this with time.

Support of other NEO Characterization Programs

- This program will focus on determining rotation rates of GSSR-targeted NEOs
- Photometric observations to support IAWN campaigns, as needed

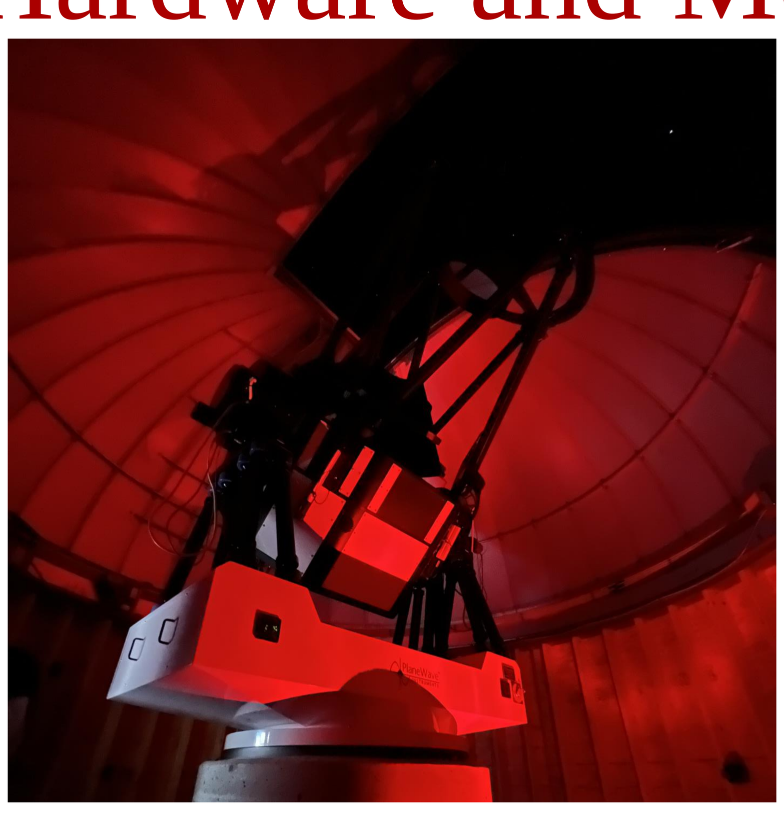


Spin rate versus NEO diameter from Pravec et al. 2006. This program will focus on targets smaller than 300 m (red box inset)

Search for Small Binaries

- The binary fraction of NEOs with diameters larger than 300 m was determined to be ~15% (e.g. Pravec et al. 2006)
- This program will attempt to explore this fraction for D < 300 m NEOs

Hardware and Methods



Planewave PW1000

- 1 m, f/4.2 telescope
- 43 x 33 arcmin field of view
- 0.73” px^{-1} plate scale
- Sky background is 21.6 mag $arcsec^{-2}$
- Limiting magnitude of ~20 with SNR of 10
- Located in Tucson, AZ

KESTREL

(Keen-Eyed Spectroscopy Telescope for Reflectance, Emission, and Lightcurves)

- 0.61 m, f/4.3 telescope
- 18 x 17 arcmin field of view
- 1” px^{-1} plate scale
- Sky background is ~22 mag $arcsec^{-2}$
- Limiting magnitude of ~18.5 with SNR of 10
- Located in Australia

Observation Cadence

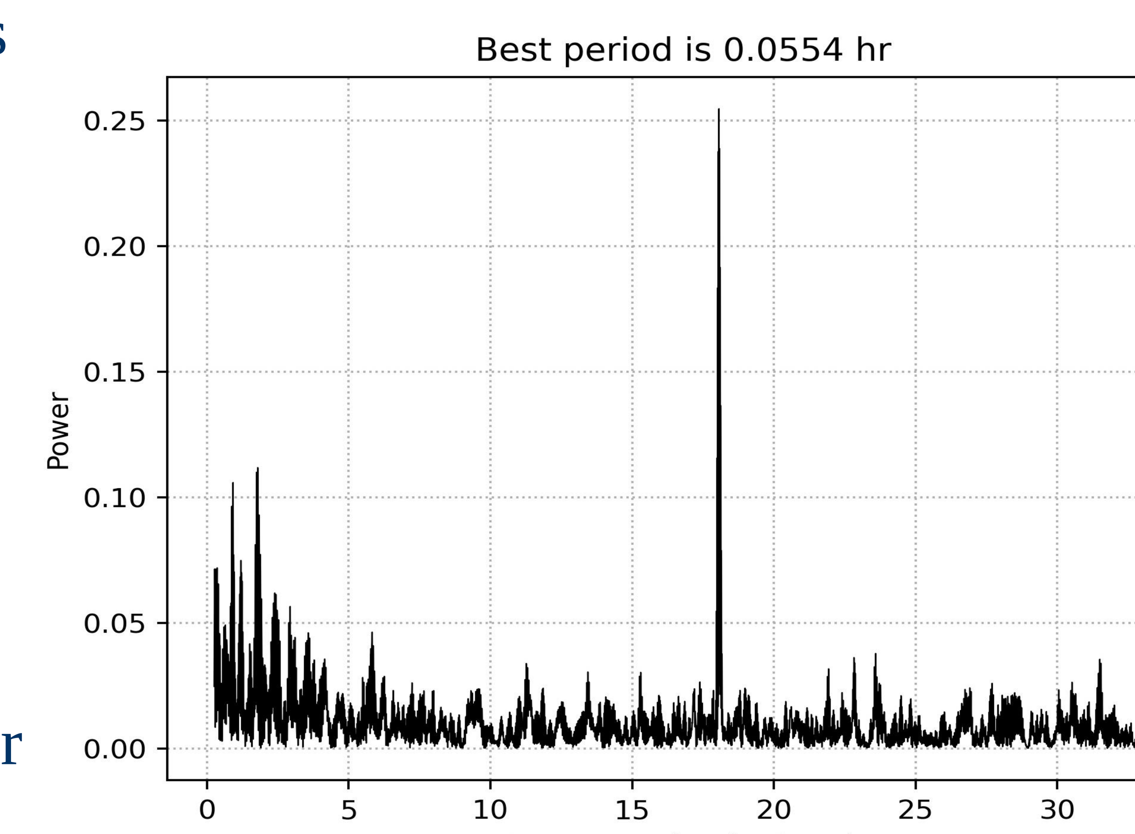
- Observe GSSR published target list ahead of scheduled radar observations
- Observe smaller NEOs in the 2 weeks around new Moon
- Identifying new binaries requires ~5 consecutive nights to search for longer orbital periods
- Full access to telescopes allows improved capabilities
- KESTREL can be used to observe southern hemisphere targets, as needed

Photometric Extraction

- Custom Python pipeline to perform in-frame photometry
- Can produce calibrated Sloan or Gaia G band magnitudes
- Ephemeris-based object identification

Period Estimation

- Python periodogram routine using Lomb-Scargle method (Lomb 1978, Scargle 1982)
- Canopus can also be used for Fourier-based period estimates (Warner 2006; Harris et al. 1989)
- Distance modulus correction for close-approach NEOs
- Phase-wrapping asteroid lightcurves resolves period ambiguities

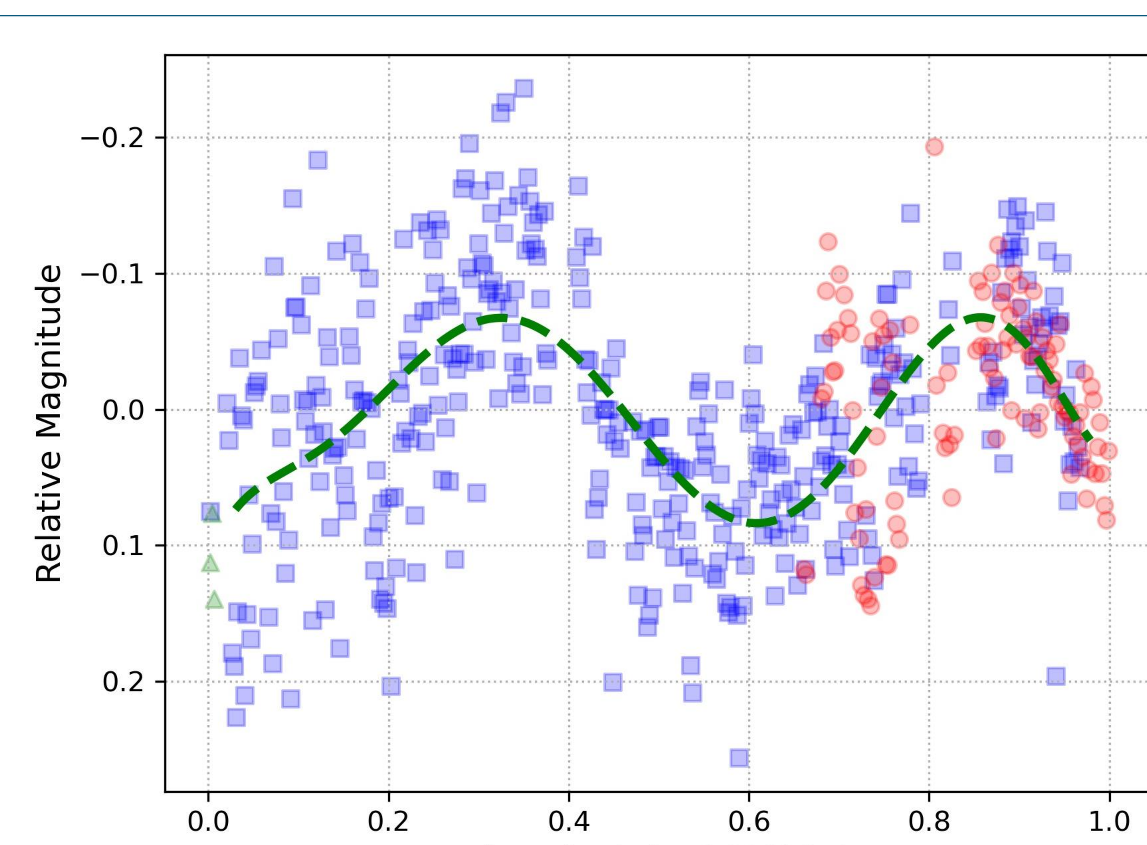


Lomb-Scargle Periodogram for observations of NEO 2025 BB2 (D~23m). Periods between 0.03 to 5 hrs are shown with a strong peak at the 0.0554 hr. period (199.4 s)

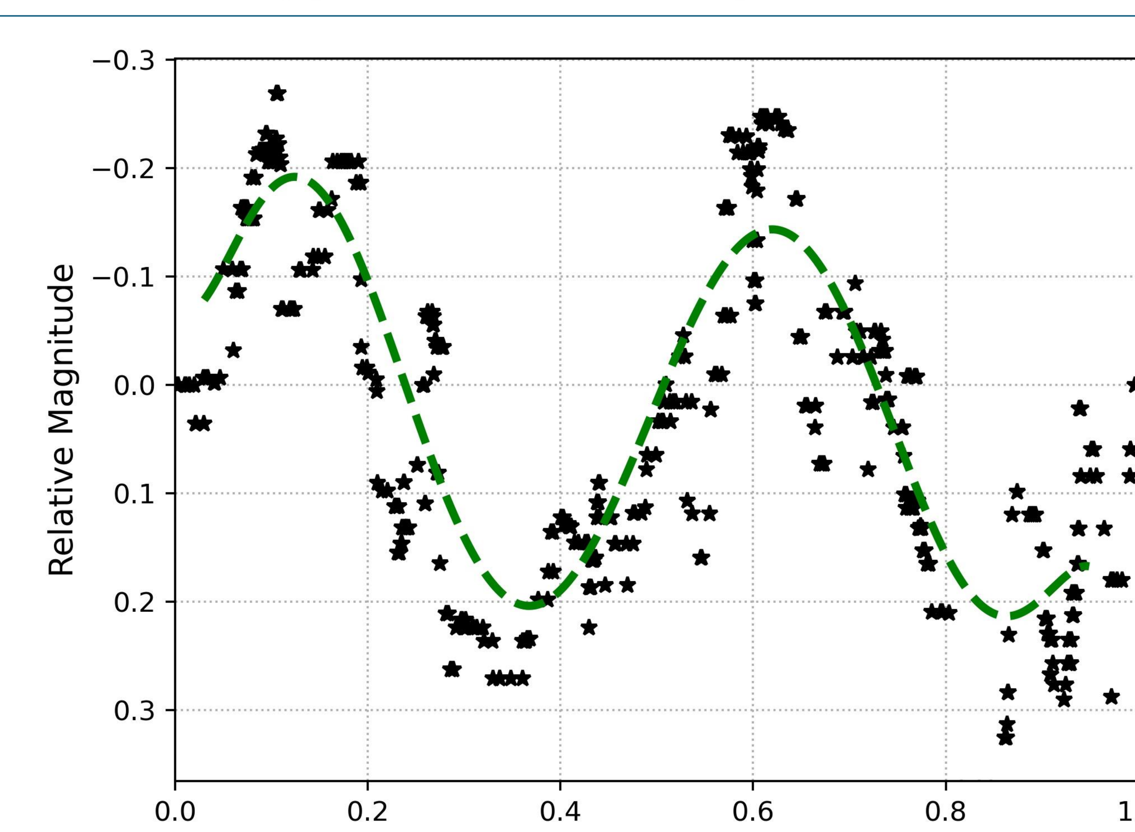
Results

- Phase-wrapped lightcurves help confirm period estimates
- We performed a short observing campaign that helped improve data collection techniques
  - Lessons learned on best exposure times and updates needed for processing frames with highly streaked stars
- Our techniques were confirmed by comparing to periods reported by other programs for the same objects (e.g., 2025 BB2 shown right)

References: Pravec, P., 56 colleagues, 2006. Photometric survey of binary near-Earth asteroids. Icarus 181, 63-93, Lomb N. R. 1976 *Ap&SS* **39** 447, Scargle J. D. 1982 *ApJ* **263** 835. Warner, B.D., 2006. A practical guide to lightcurve photometry and analysis (Vol. 300). New York: Springer.. Harris, A.W., Young, J.W., Bowell, E., et al., 1989. Photoelectric observations of asteroids 3, 24, 60, 261, and 863. Icarus, 77(1), pp.171-186. Pravec, P. Personal communications, Feb. 1, 2025



Phase-wrapped lightcurve of GSSR target 2018 RC2 (D ~73 m). Increased scatter is from using short exposures to observe the rapidly moving object. Color/shape changes indicate separate rotations of the object.



Phase-wrapped lightcurve of 2025 BB2 across several rotations and two nights (Jan 31 and Feb 01, 2025 UTC). Lightcurve confirms periodogram estimate and agrees with Pravec (personal communications, 2025)