

Photometric Follow-Up of **LSST** Ultra-Fast Rotators in the Main Asteroid Belt

PREPARING FOR A DECADE OF EXCITING DISCOVERIES

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Chandler, S. Greenstreet

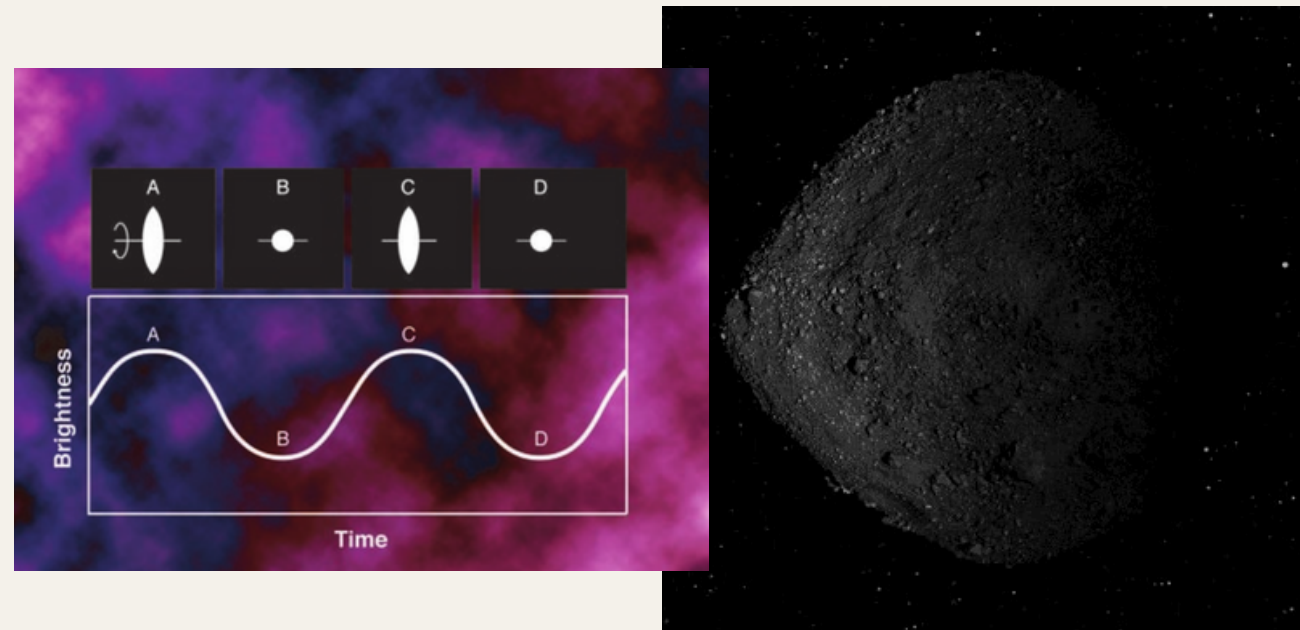
What can we learn from

How Asteroids Reflect Light?

Lightcurves

(rotation-driven brightness changes)

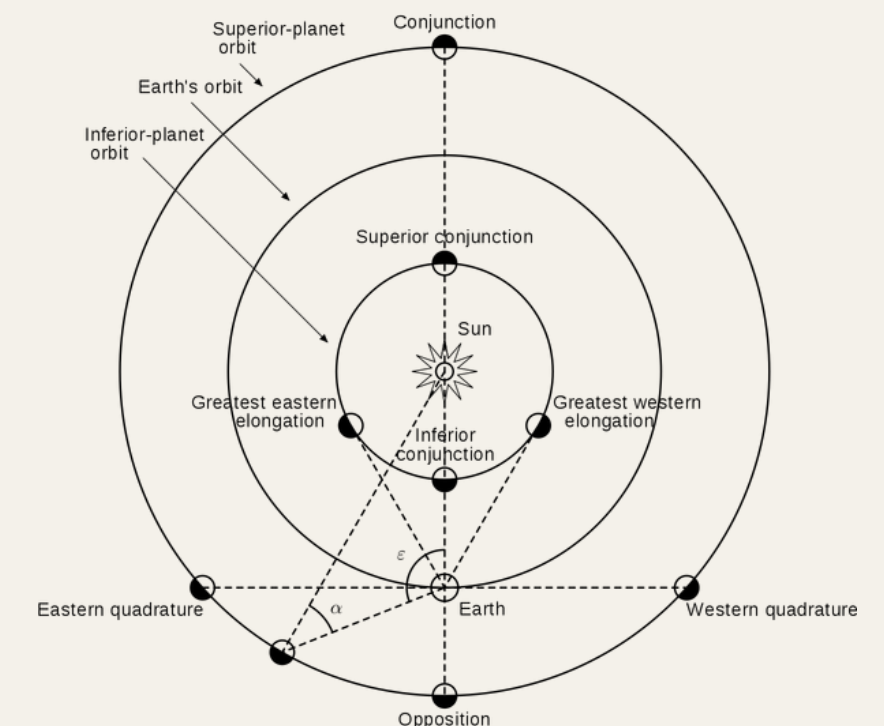
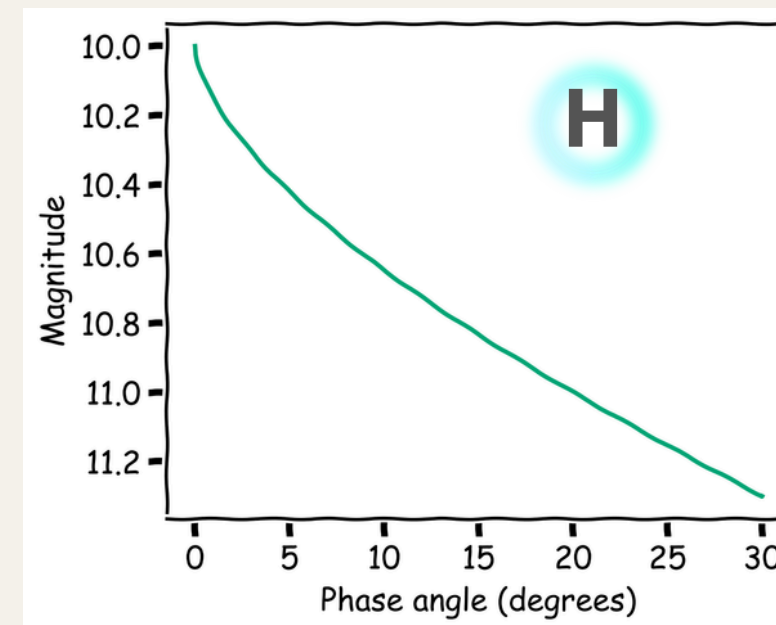
- Show how brightness varies with time
- Reveal rotation period, shape, and surface features



Phase Curves

(geometry-driven brightness changes)

- Show how brightness changes with phase angle (angle between Sun–asteroid–Earth)
- Related to surface properties: albedo, roughness, composition



Data Previews

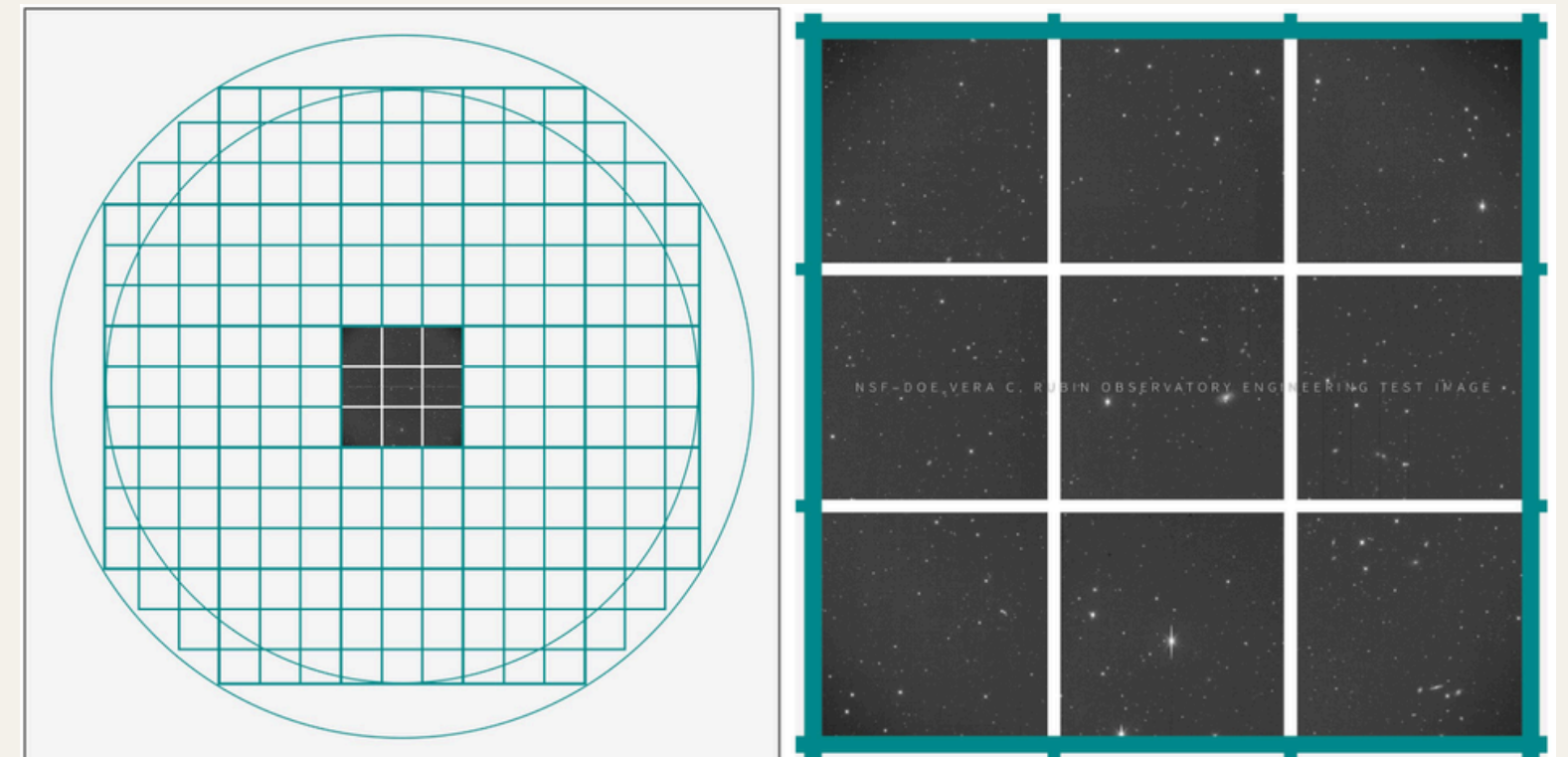
DP0: Data Preview 0 is the first of three data previews during the period leading up to the start of Rubin Observatory Operations.

DP0.2: simulated LSST-like data products containing extragalactic and galactic objects.

DP0.3: simulated Solar System objects.

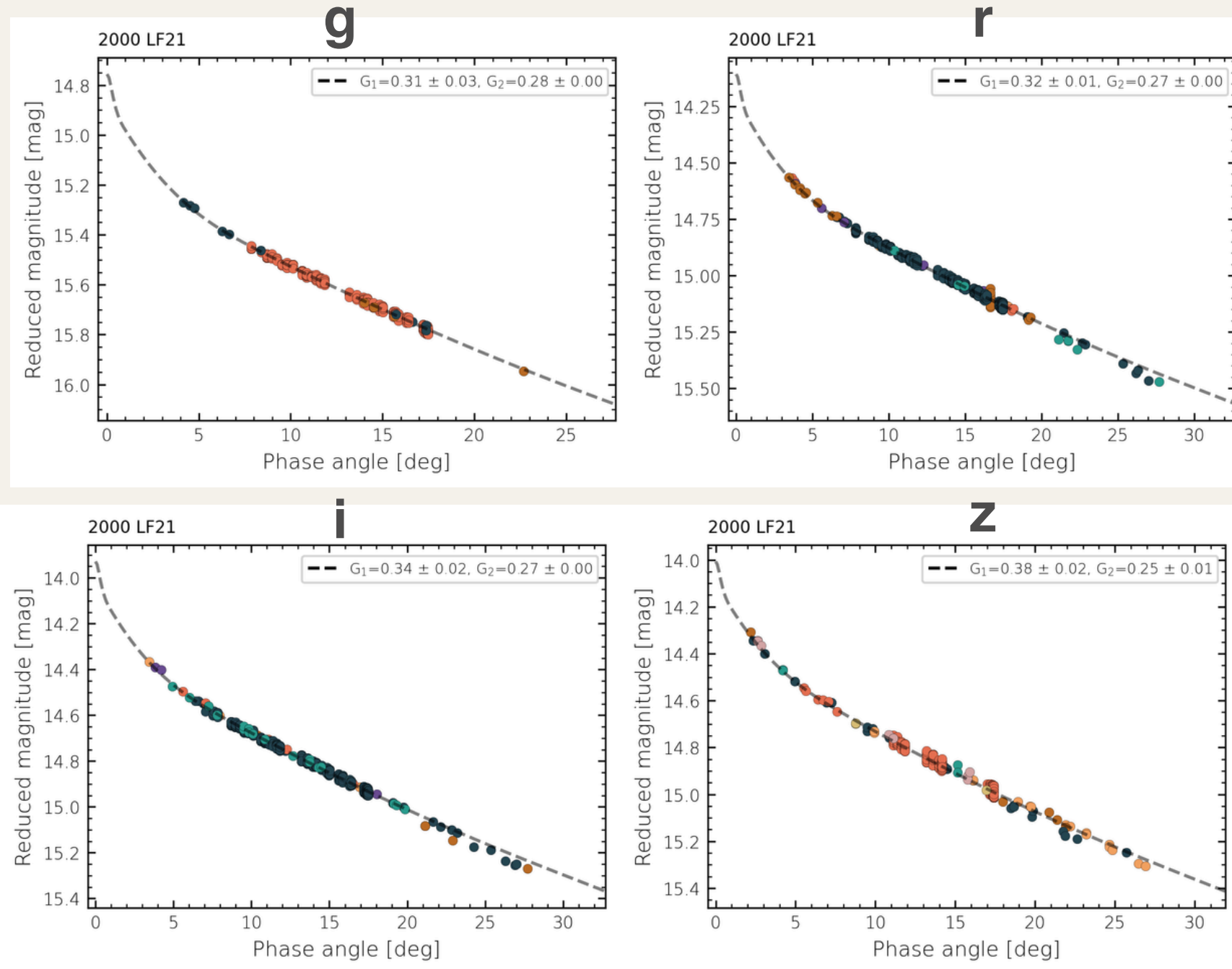
DP1: Data Preview 1 is the first of three data previews during the period leading up to the start of Rubin Observatory Operations.

- Perform with the comissioning camera (subset of the bigger LSST camera)
- The campaign was conducted between October and December 2024 (2 months of observations)

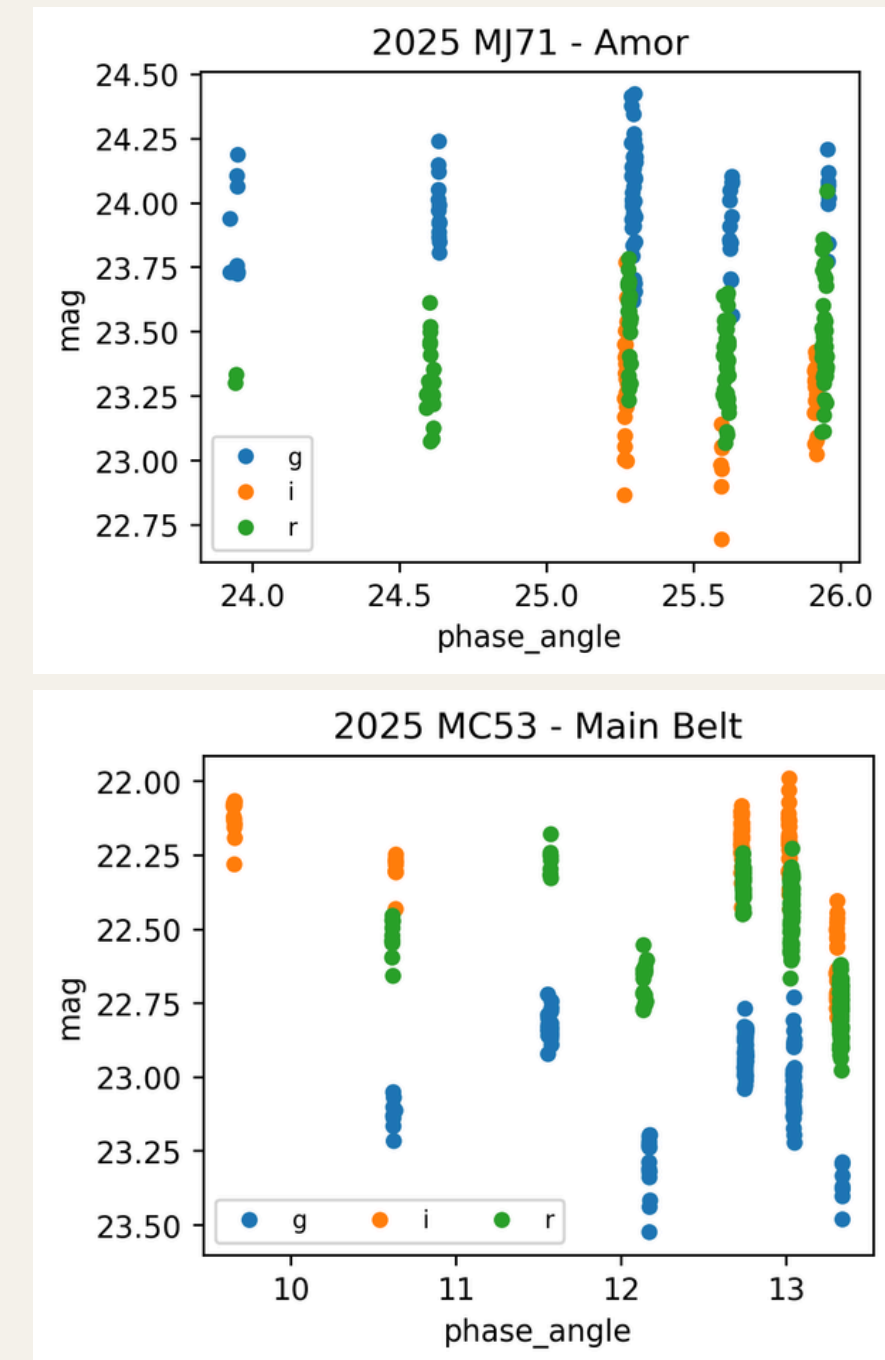


Data Previews

DP0.3



DP1



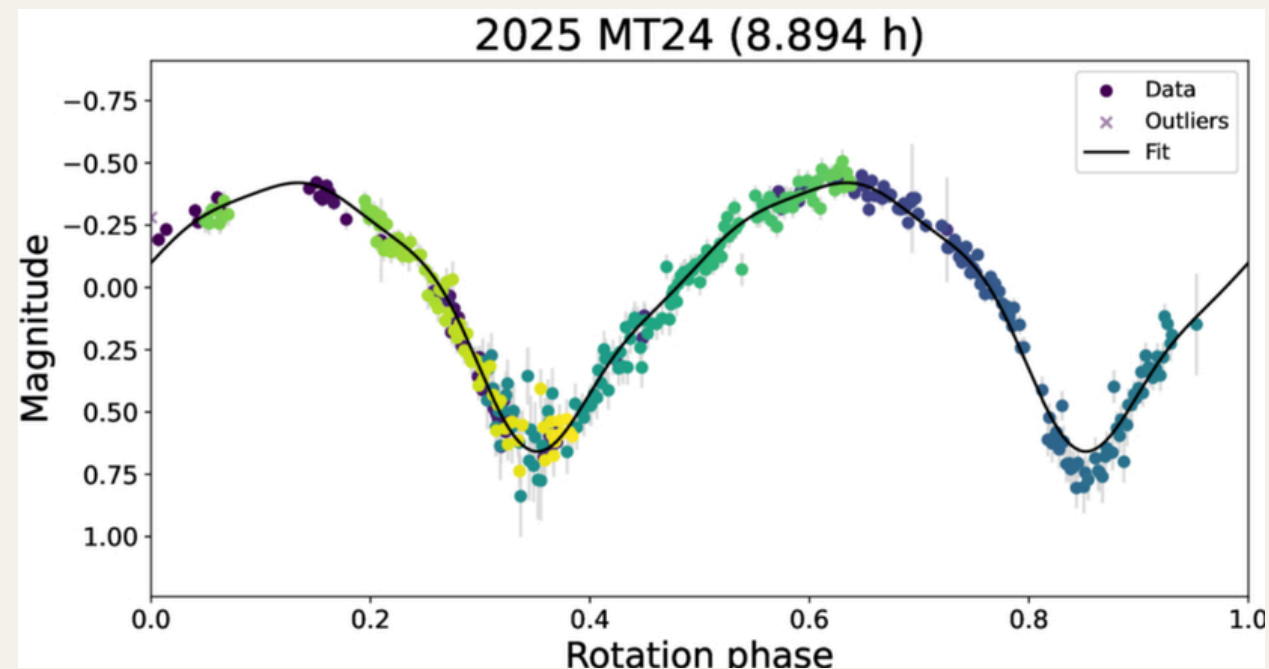
The Rubin First Look (RFL)

- 1185 images taken with LSSTCam
- 24 deg² in the area near M49
- 9 nights beginning on 2025 April 21 and ending 2025 May 5

Sarah Greenstreet et al. 2026:

↳ They model lightcurves and derive rotation periods and colors for the ~2000 discovered asteroids.

↳ They found 19 superfast rotators with periods shorter than the 2.2 hr spin barrier.



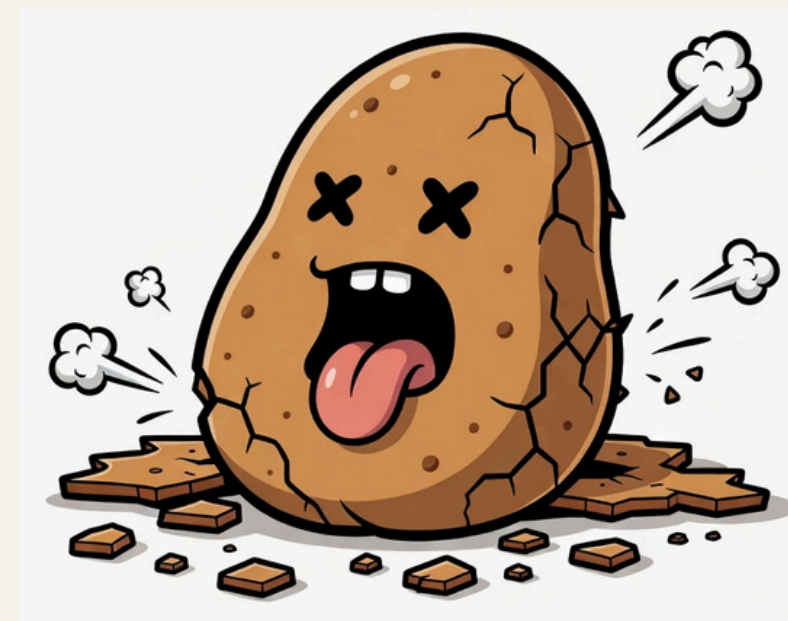
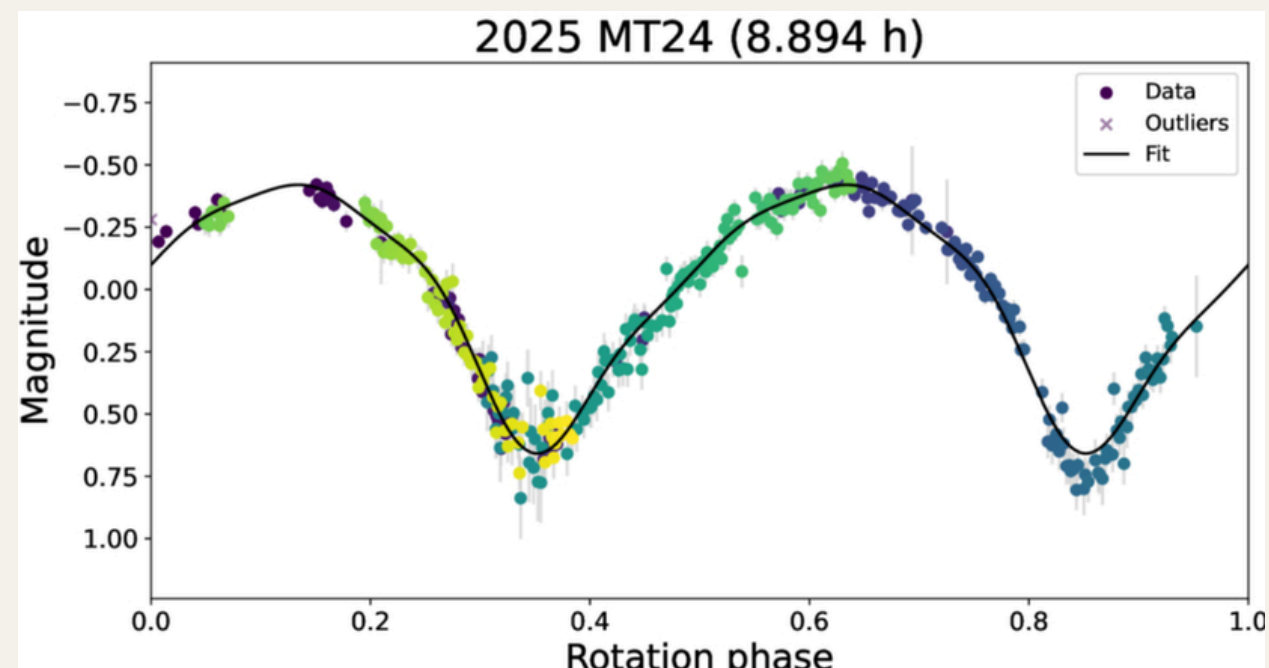
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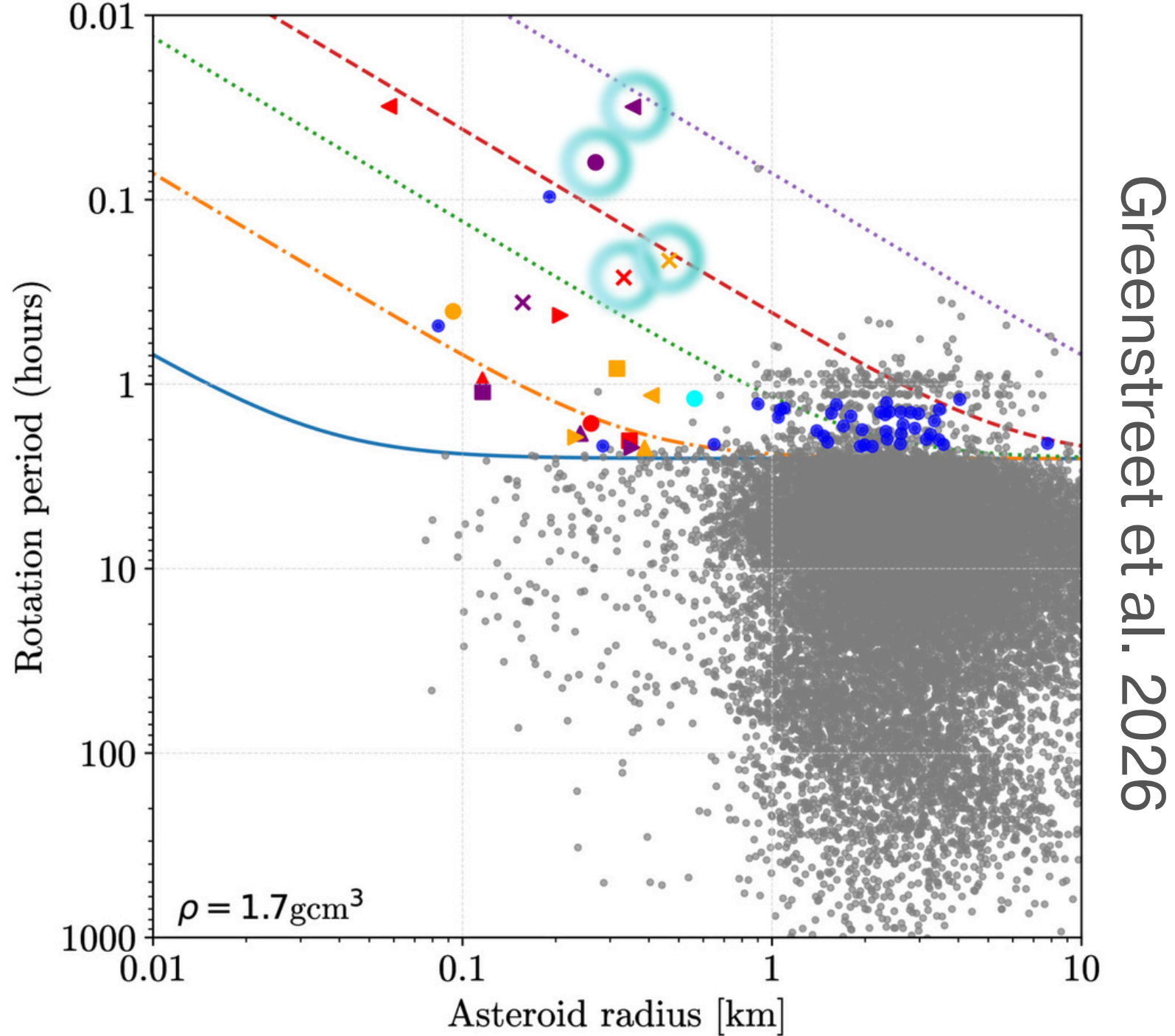
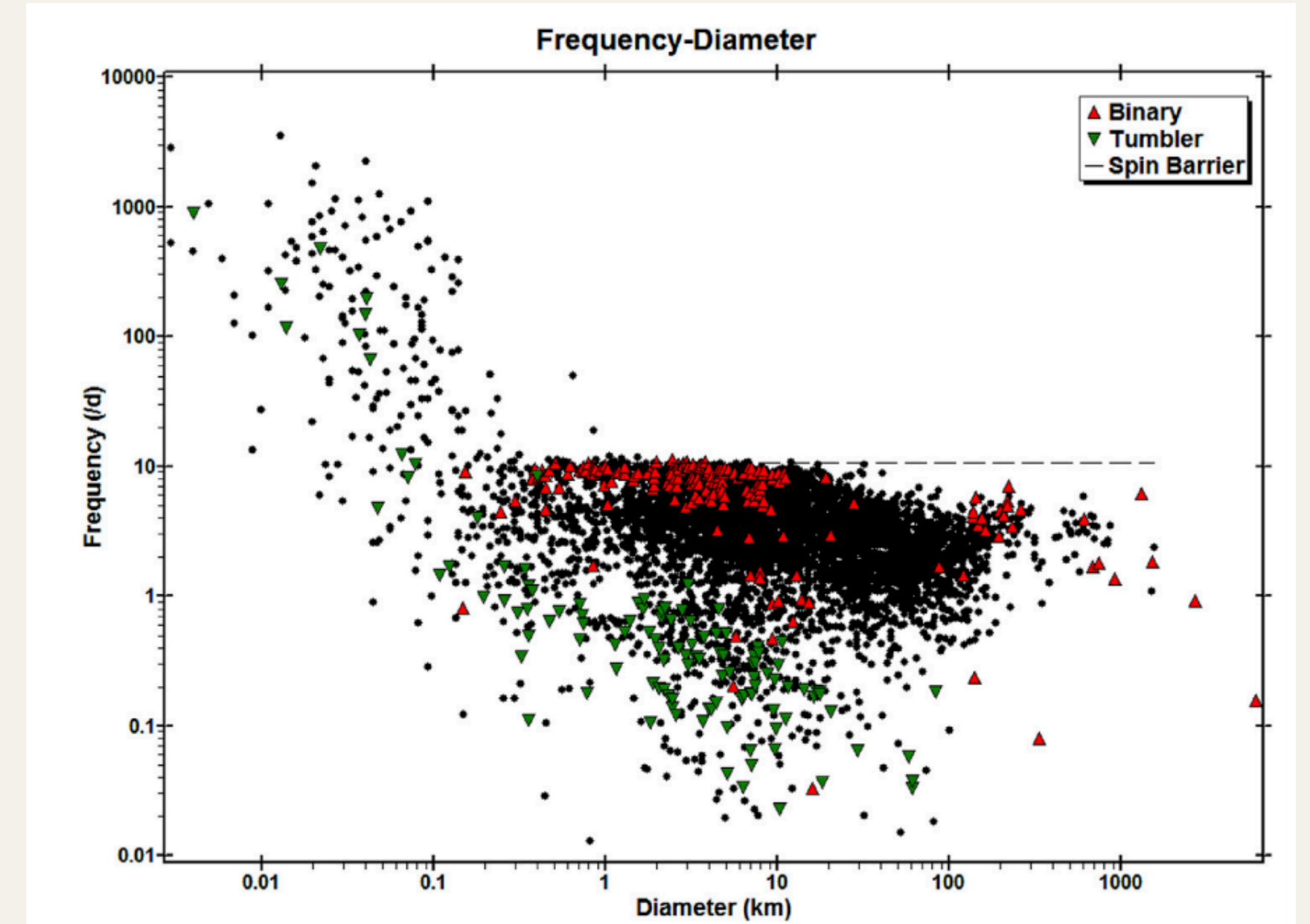
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↳ *critical spin period at which self-gravity and centrifugal acceleration are balanced*

Asteroid size vs. rotation period

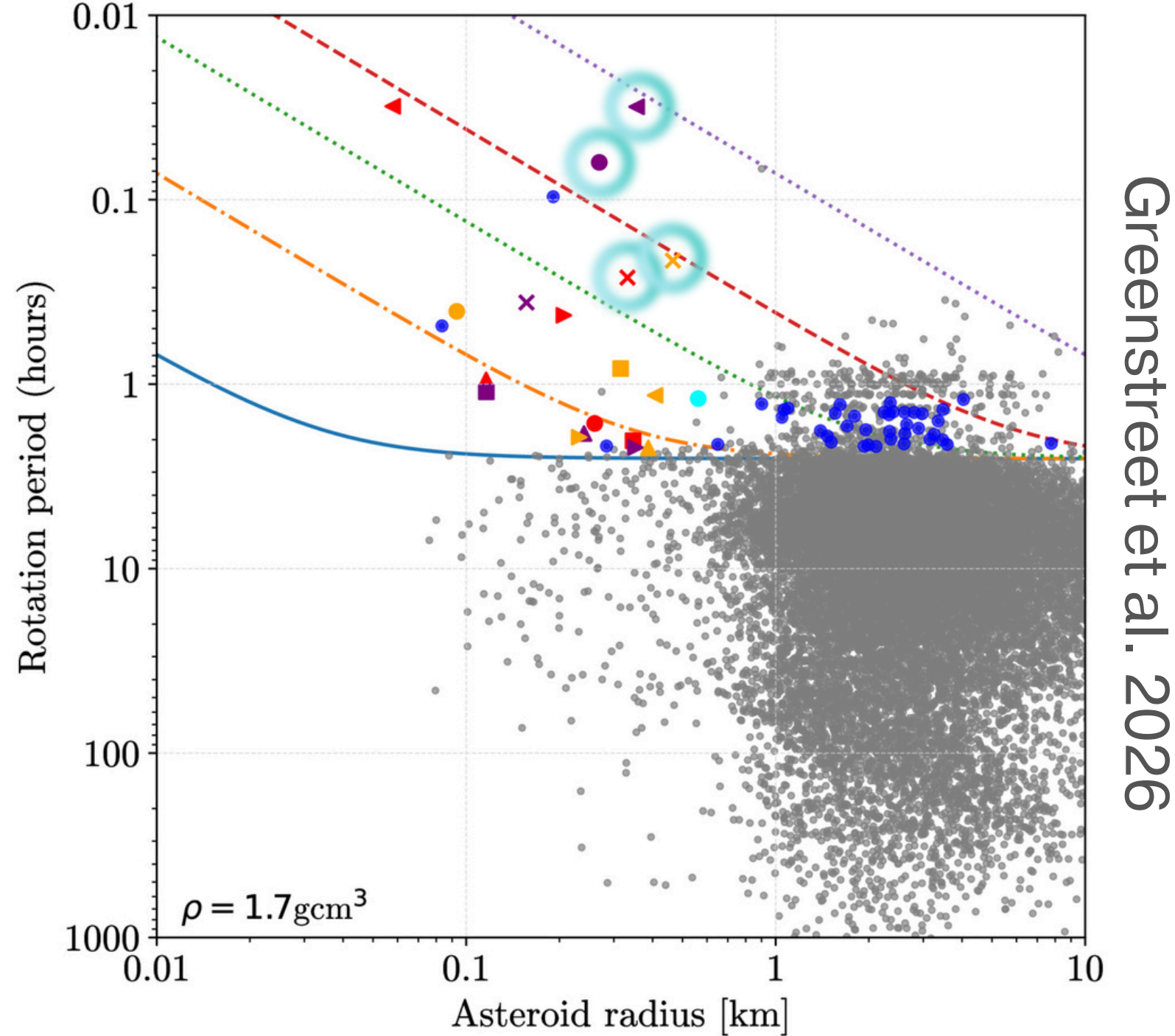
Carbognani (2017)



Greenstreet et al. 2026

— Cohesion: 1 Pa	■ 2025 MF76	▶ 2025 MP47
- - Weak Lunar Coh.: 100 Pa	× 2025 MG56	● 2025 MU15
⋯ Strong Lunar Coh.: 3k Pa	◀ 2025 MJ71	▲ 2025 MU24
- - Clay Coh.: 30k Pa	▶ 2025 MJ79	■ 2025 MU8
⋯ Rock Coh.: 10M Pa	● 2025 MK41	× 2025 MV71
• Numbered Objects	▲ 2025 MM37	◀ 2025 MX44
• Rel. Known Fast Rotators	■ 2025 MM81	▶ 2025 MX50
• 2025 MA45	× 2025 MN25	● 2025 MZ78
▲ 2025 ME68	▶ 2025 MN45	

Asteroid size vs. rotation period



- 2025 MN45
 - P ~1.88 min, D ~ 710 m
- 2025 MK41
 - P ~3.78 min, D ~ 540 m
- 2025 MV71
 - P ~13 min, D ~ 930 m
- 2025 MG56
 - P ~16 minutes, D ~ 660 m

Difficult to explain under current asteroid formation models, as they would require a very high degree of internal cohesion to prevent disintegration due to rotational forces

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▲ 2025 ME68	◀ 2025 MN45	

Belfast - Queen's University Belfast

LSST Solar System First Data Sprint

The **goal** of this work is to photometrically *follow-up* on these
Rubin super-fast rotators:
2025 MN45, 2025 MK41, 2025 MV71 and 2025 MG56



Simone Ieva
Bryce Bolin
Colin Orion Chandler
Sarah Greenstreet



Our project:

1

Characterise the rotational lightcurves, verify rotational periods through targeted, dense photometric observations, reducing *aliasing* in periodograms and validating the fast rotation rates.

2

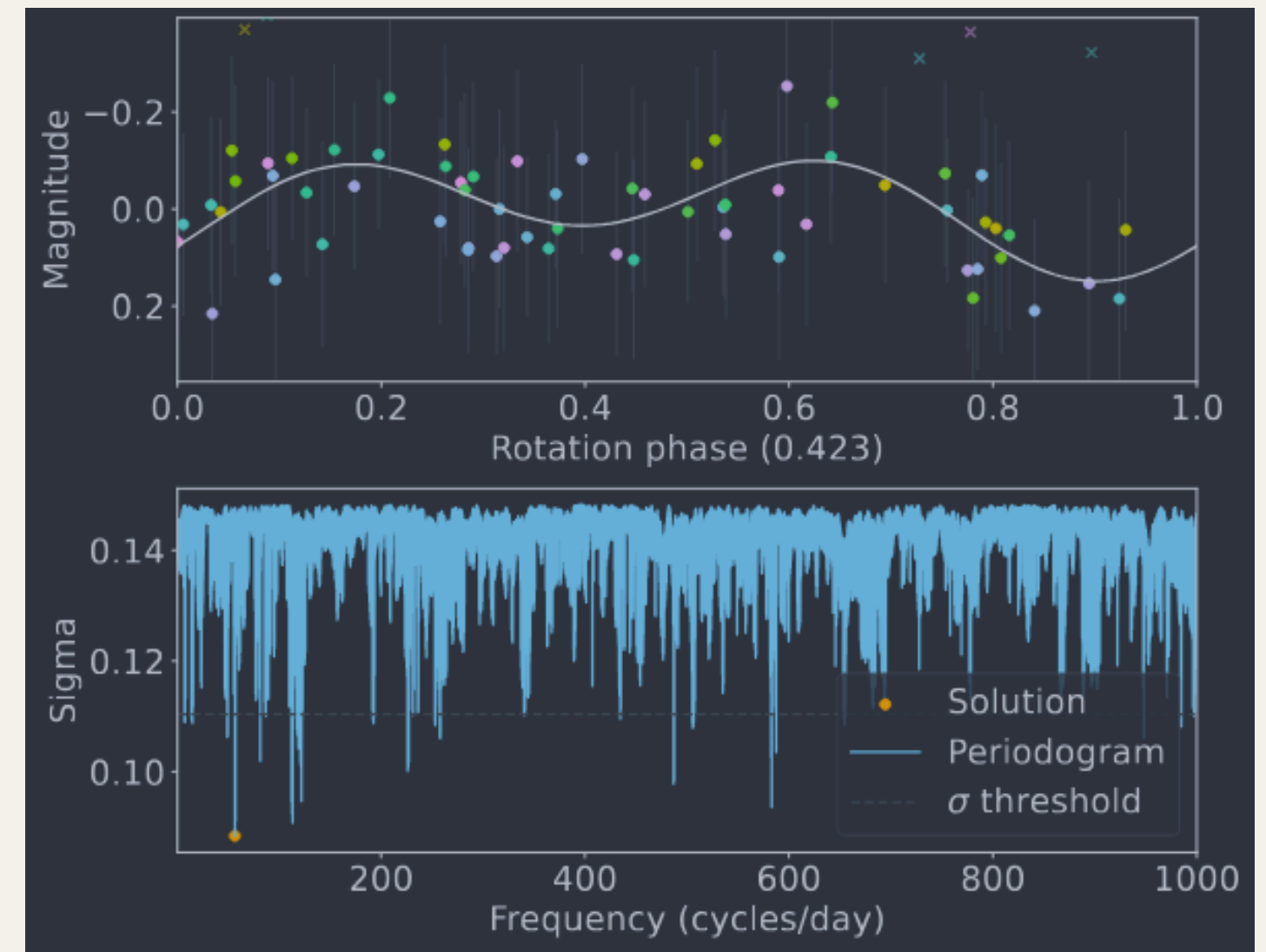
Observations obtained at opposition (small phase angles) will be combined with LSST data (taken at phase angles of 10-20°) to derive more *reliable absolute magnitudes*.

more accurate size estimates

confirm their positions in spin-barrier plots

whether such large cohesive strengths are truly required

2025 MJ79



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1

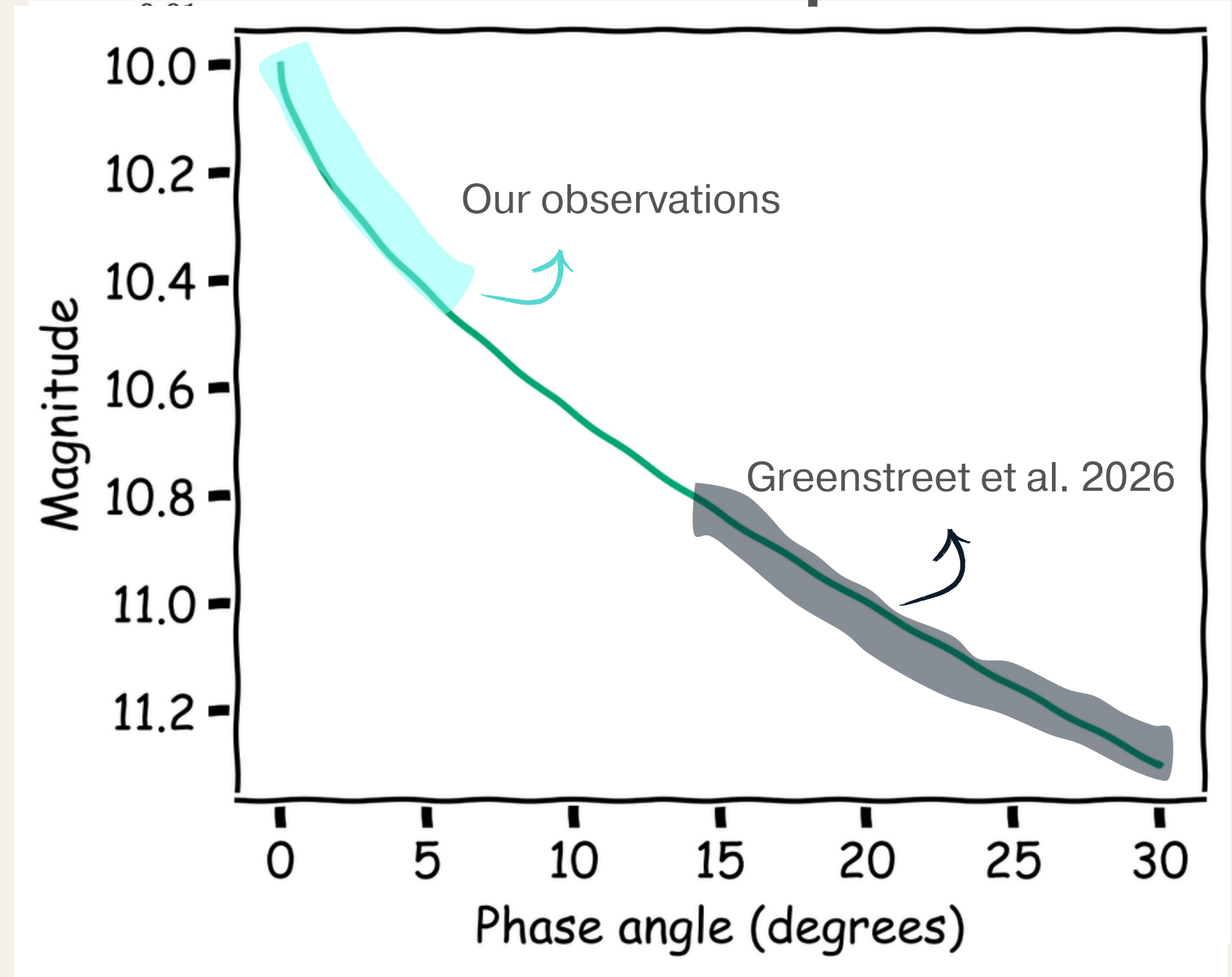
Characterise the rotational lightcurves, verify rotational periods through targeted, dense photometric observations, reducing *aliasing* in periodograms and validating the fast rotation rates.

2

Observations obtained at opposition (small phase angles) will be combined with LSST data (taken at phase angles of 10-20°) to derive more *reliable absolute magnitudes*.

- more accurate size estimates
- confirm their positions in spin-barrier plots
- whether such large cohesive strengths are truly required

Remember the phase curves!



$$d = \frac{1329}{\sqrt{p_v}} 10^{-0.2H}$$

Bowell et al. 1989



SALT proposal

- Instrument setup: SALTICAM full-frame mode, 2×2 binning, FAST readout (14 s).
- Observations: 4 targets, ~1 hour of imaging per target.
- Exposure times: 20–120 s, yielding 26–105 frames per target.
- Overheads: 600 s acquisition + 8–14 s per filter change.
- Total observing time: ~4210 s (~70 min) per target; ~4.7 h for all targets.
- Calibration: Standard calibration frames required.
- Expected performance: S/N \approx 35–111 (SALTICAM Simulator v1.11).

PI: Dagmara Oszkiewicz

Object (alternative designation)	hours of RA	Deg of Dec	V (mag)	sky motion ("/min)	Rotational period (min)	Exp. time (sec)	Filter	expected S/N
2025 MN45	21	-31	22.1	0.58	1.88	20	Clear	46
2025 MG56	20	-00	22.7	0.56	16	25	Clear	28
2025 MK41	00	-06	22.3	0.65	3.78	20	Clear	35
2025 MV71	19	-26	21.6	0.51	13	20	Clear	64

Asteroids to be observed, along with RA, Dec and V magnitude at the nearest opposition, rotational period, exposure time and expected S/N for SALTICAM.



Gemini proposal

PI: Bryce Bolin

We will obtain optical **spectroscopy** and **photometry** with $\text{SNR} > 30$, providing $>3\sigma$ confidence in the classification of our four fast-rotator asteroid targets. The resulting spectral types will constrain their bulk density and cohesive strength.

- Spectroscopy (GMOS-N / GMOS-S)
- Long-slit mode, R150 + GG455, $R \sim 300$
- Coverage: 450–1000 nm (up to ~ 1100 nm)
- 1.0" slit, 2×2 binning, $\lambda_c = 700$ nm
- 4×1200 s (ABBA pattern) $\rightarrow \text{SNR} \sim 20 \rightarrow$ rebinned to ~ 30
- Dark time, IQ70 / CC50 / SB50, airmass < 1.2
- G2V standard star calibration (5 s exposures)
- 1.8 h per target (+0.4 h standards)

Spectroscopy



Gemini proposal

PI: Bryce Bolin

We will obtain multi-band lightcurve photometry of these rapidly rotating asteroids with periods of 2–15 minutes. Short exposures and filter cycling are required to sample full rotations and mitigate lightcurve effects on color measurements (DeMeo & Carry 2013).

- Photometry (GMOS g,r,i,z)
- SNR > 20–30 for $V \sim 22$ asteroids
- 20 s exposures, fast readout, 2×2 binning
- 20 images per filter (g, r, i, z)
- Sensitive to lightcurves (0.05–0.2 mag)
- Rotation periods down to ~2 min
- 0.9 h per visit, 2 visits per target
- Calibration: Pan-STARRS field stars
- Scheduled with spectroscopy, avoid crowded fields

Photometry



VLT proposal

PI: Simone Ieva

FORS2 Observations

We propose 6 hours of FORS2 imaging (split between July and August 2026)

Observational Strategy

We will obtain ~ 1 hour of on-target imaging per visit using FORS2 in R band with 30 s exposures and 2×2 binning. Targets ($V \sim 21.5\text{--}23$) are observed under dark-time conditions near new moon, requiring large-aperture sensitivity.

Performance & Requirements

We expect $\text{SNR} \geq 30$ under conservative conditions (airmass ≤ 1.2 , seeing $\leq 1.0''$, PWV = 30 mm, moon phase 0.3). Total time includes acquisition overheads, leading to a 6-hour request, ideally within ± 7 days of new moons (July 14 and August 12, 2026).

Independent Verification of Asteroid Rotation Periods: Lightcurve Analysis Pipeline

Goal: Determine asteroid rotation periods and lightcurve amplitudes from Rubin First Look photometry and compare them with published values.

Data Preparation

- Rubin First Look dataset (~343,000 observations)
- Individual asteroid lightcurves extracted and stored as separate files
- JPL Horizons queried for each epoch:
 - Heliocentric distance (r)
 - Topocentric distance (Δ)
 - Phase angle (α)
- Data organized for multi-night and multi-filter analysis

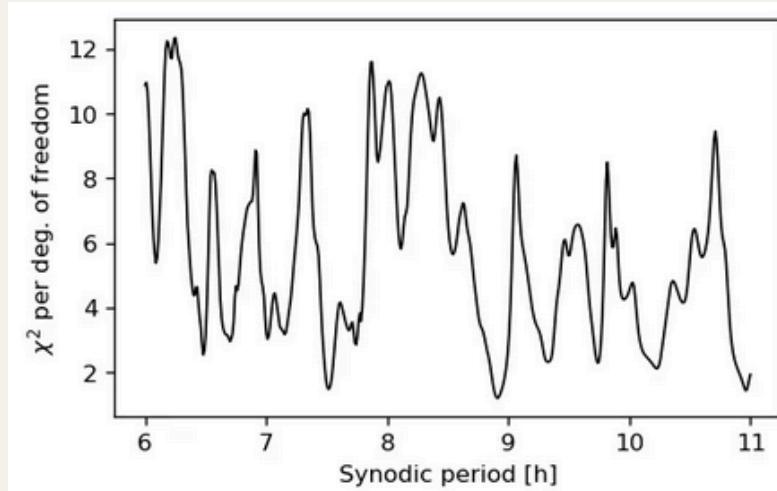
Analysis Tools

- Python-based implementation of Perfit (Kwiatkowski et al. 2009)
- Pandas, NumPy, SciPy, Astropy
- Automated processing of Rubin lightcurve data

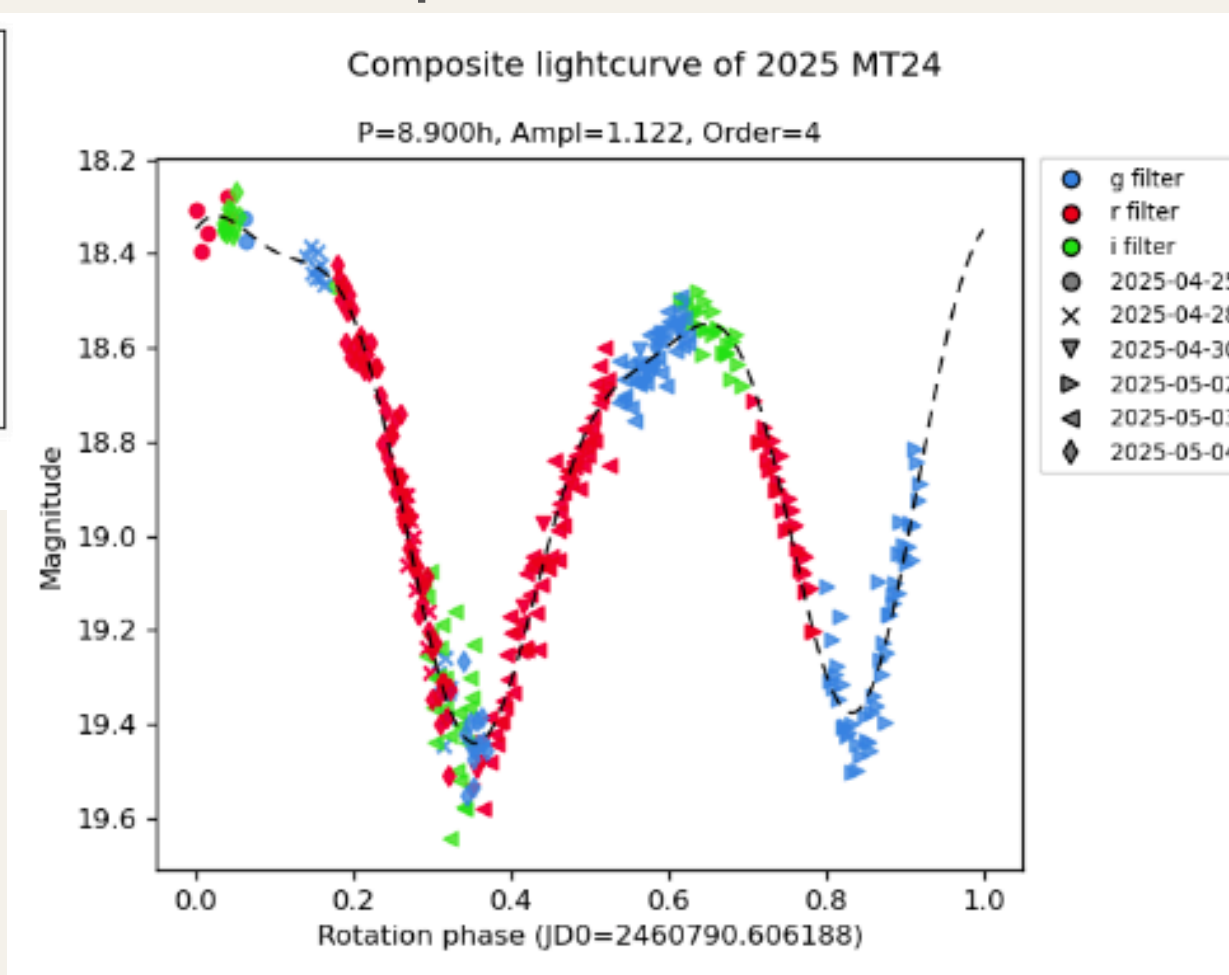
Independent Verification of Asteroid Rotation Periods: Comparison with Published Lightcurves

Case Study: 2025 MT₂₄

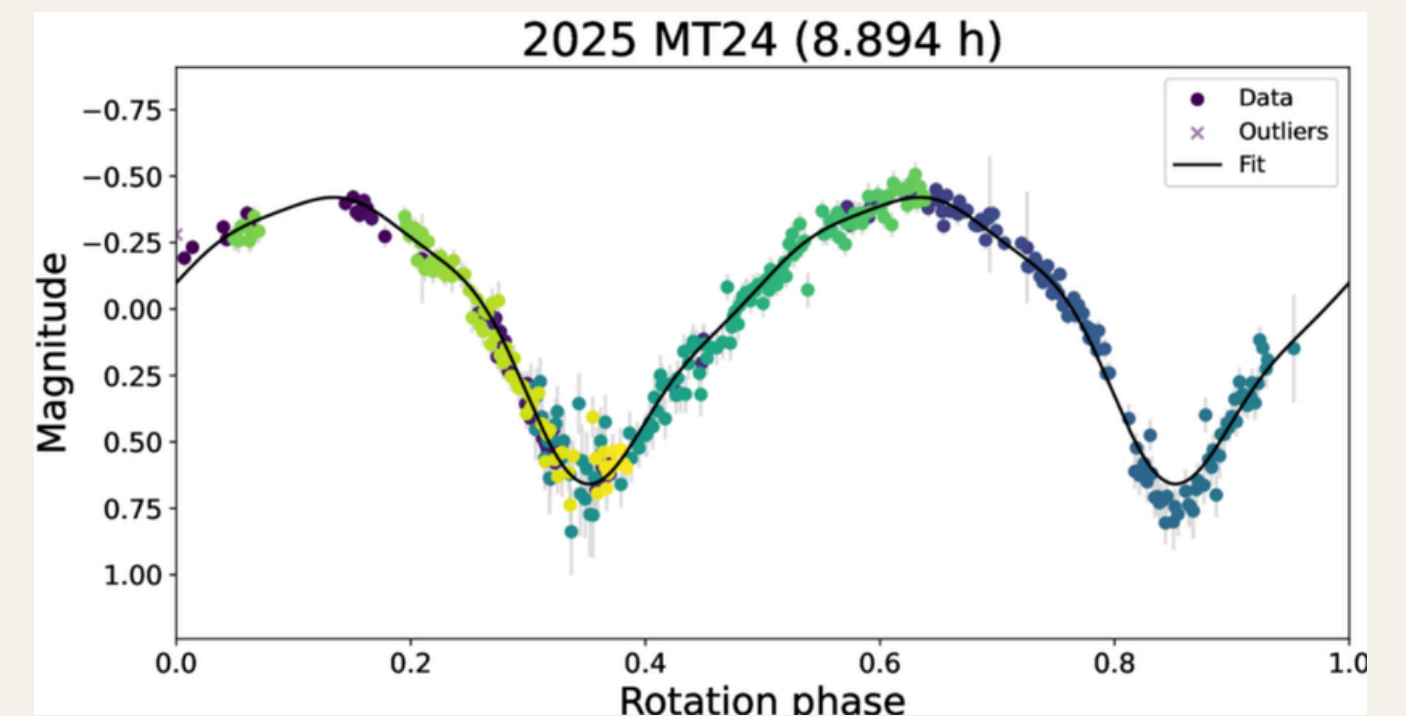
- Periodogram shows multiple minima, but a clear global minimum is identified
- Best-fit rotation period: $P=8.900$ h
- Excellent agreement with the published value



Stefanowska et al. (in prep)



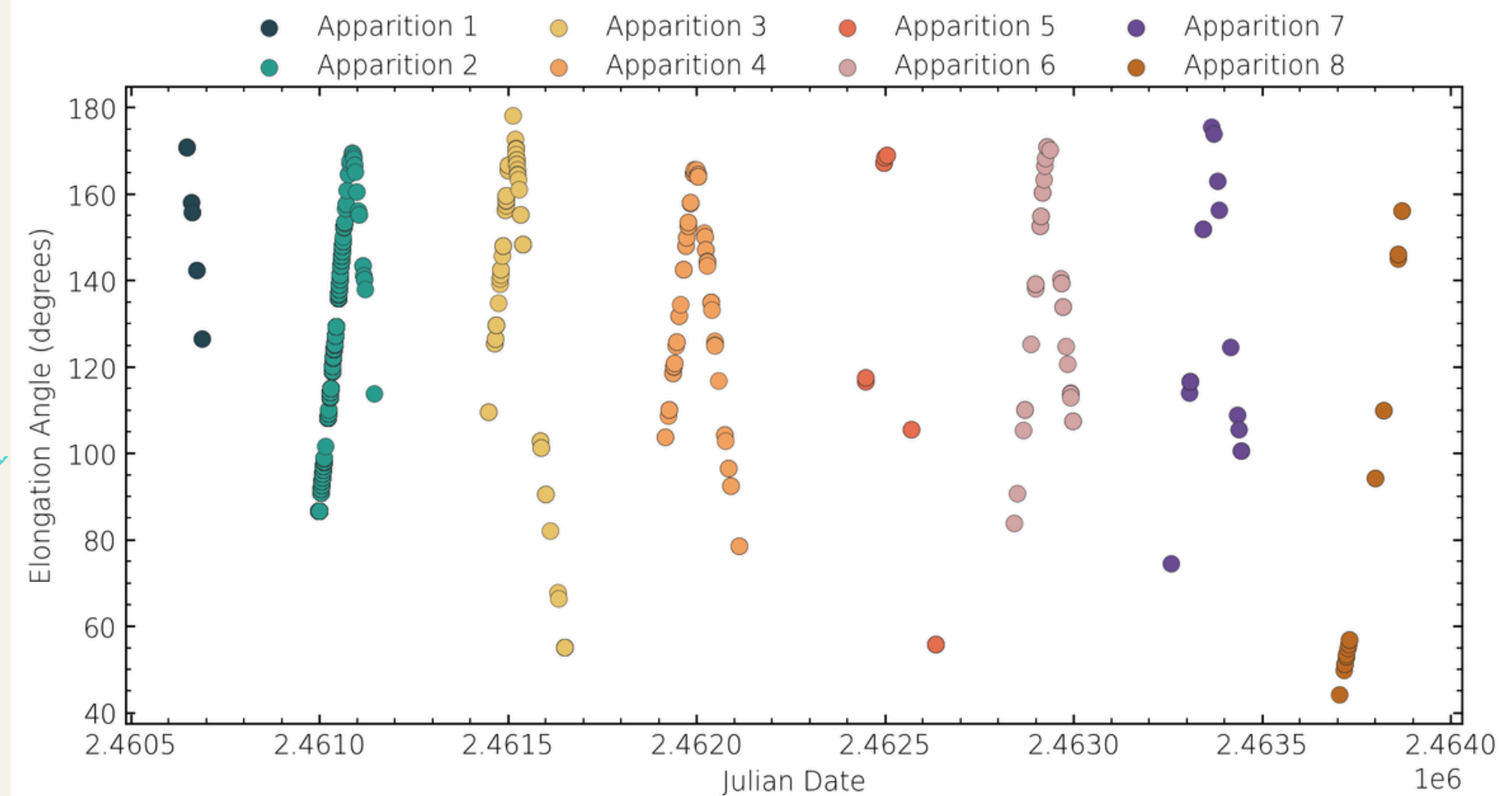
Greenestreet et al. (2026)



Previous Contribution to Fink: sfHG1G2: Phase-Curve Modeling for Asteroids

- Simultaneous G1 and G2 fit across all apparitions.
- H_i for each opposition (N)
- Fit includes N+2 free parameters: global G1 and G2 and mean H value reported per photometric band.

The data were split into different oppositions using solar elongation information obtained from the JPL Horizons system through the Python astroquery package



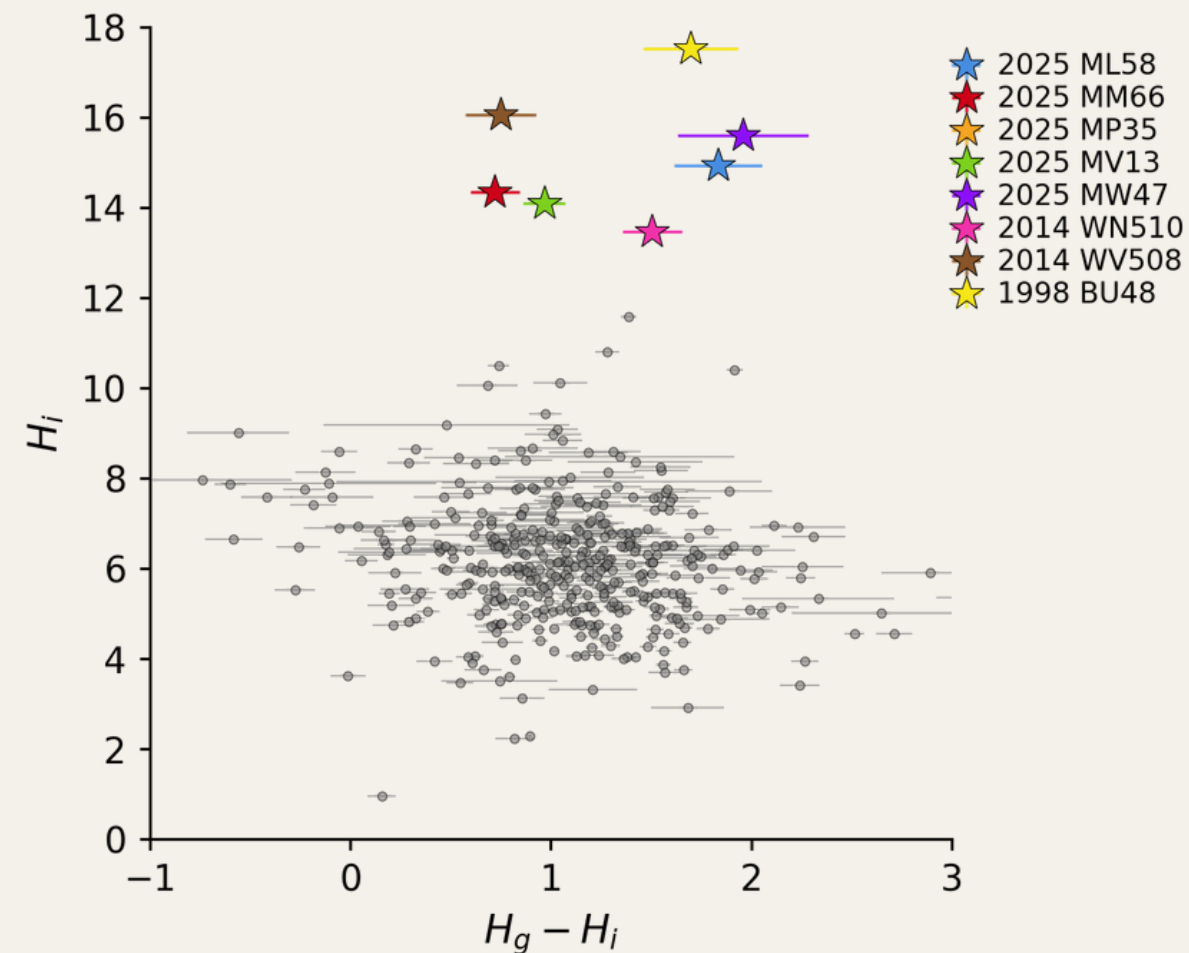
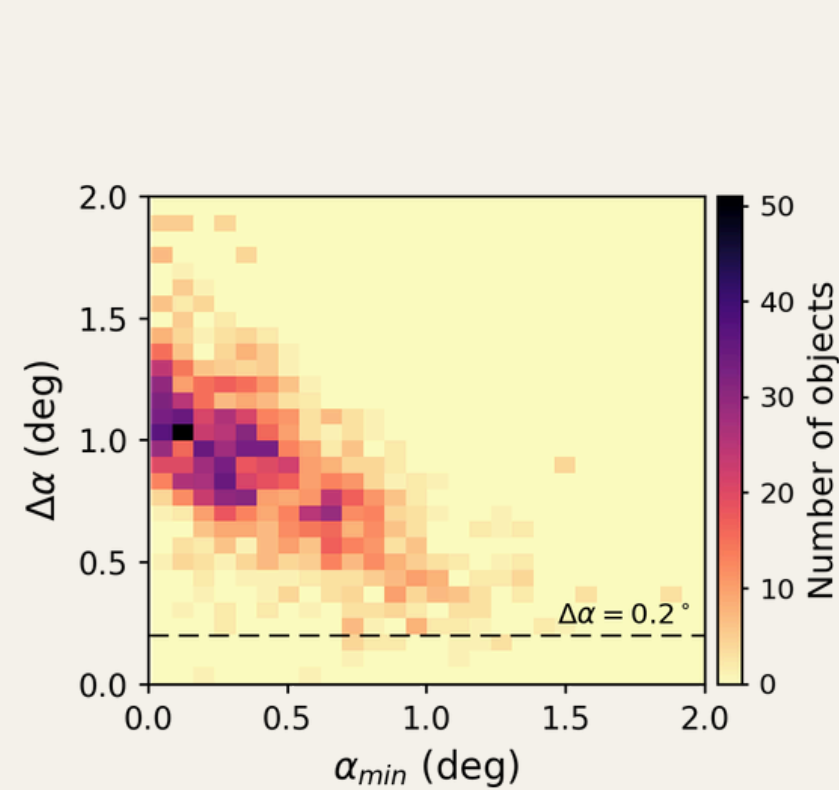
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- Apparition identification currently relies on ephemerides from JPL Horizons.
- The associated **computational cost** prevents deployment at the scale of $\sim 150,000$ Solar System objects.
- Future development: derive apparitions directly from available Fink geometry parameters (e.g., elongation angle)

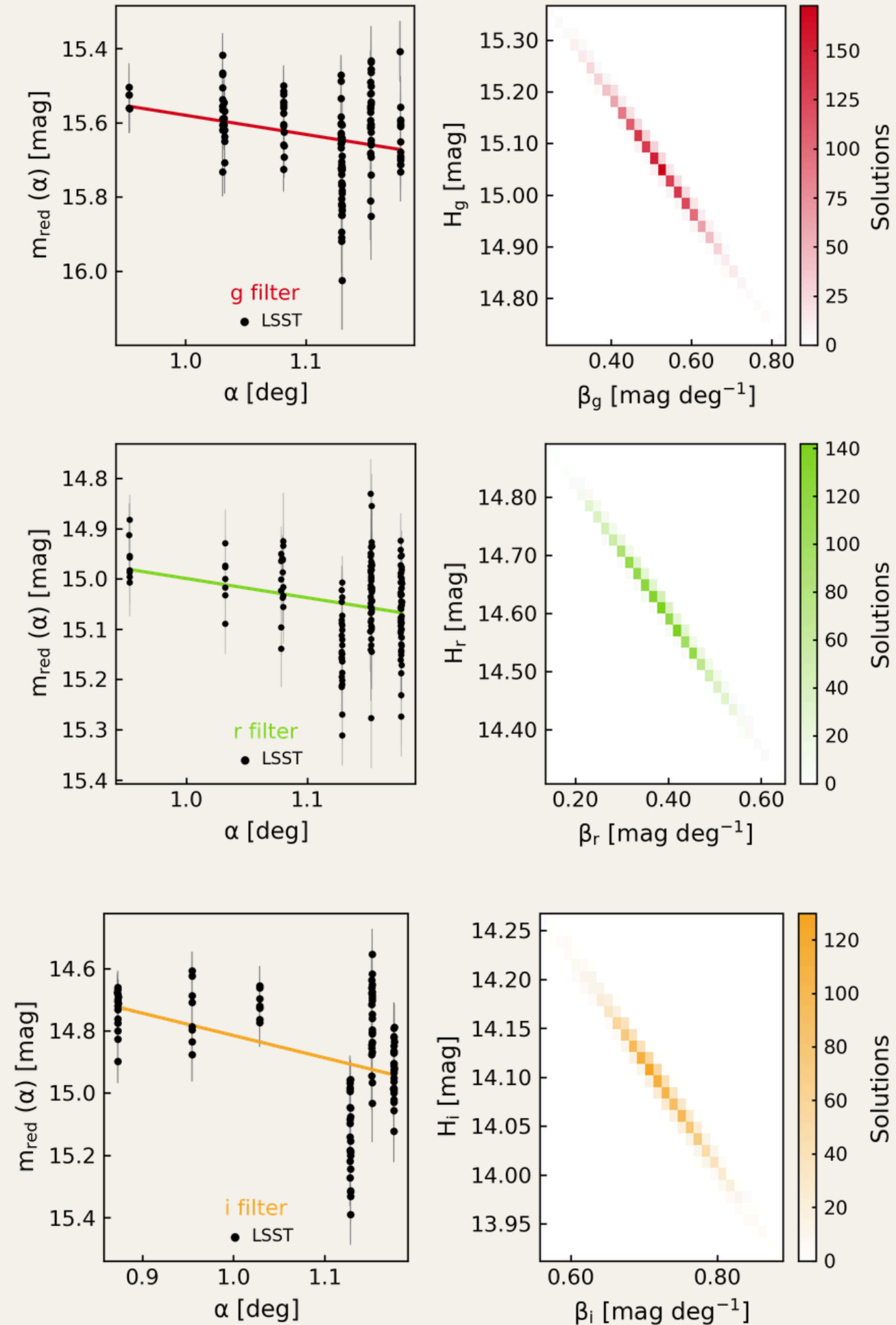


Early Results from RFL Data

- First RFL measurements incorporated into our TNO phase-curve database.
- Extends photometric coverage at faint magnitudes.
- Provides an early glimpse of the LSST small-body science return.



2025 MV13



Key Takeaways

TASKS:

- Verify the **rotational periods** through targeted, dense photometric observations.
- Constrain **absolute magnitudes, size estimates** and **colors**.
- Verify positions in the spin-barrier plot and assess the need for large **cohesive strengths**.

SENT PROPOSALS:

- SALT (DDT) - PI: Dagmara Oszkiewicz
- GEMINI (Queue 2025B) - PI: Bryce Bolin
- ESO (DDT) - PI: Simone Ieva



Gracias!