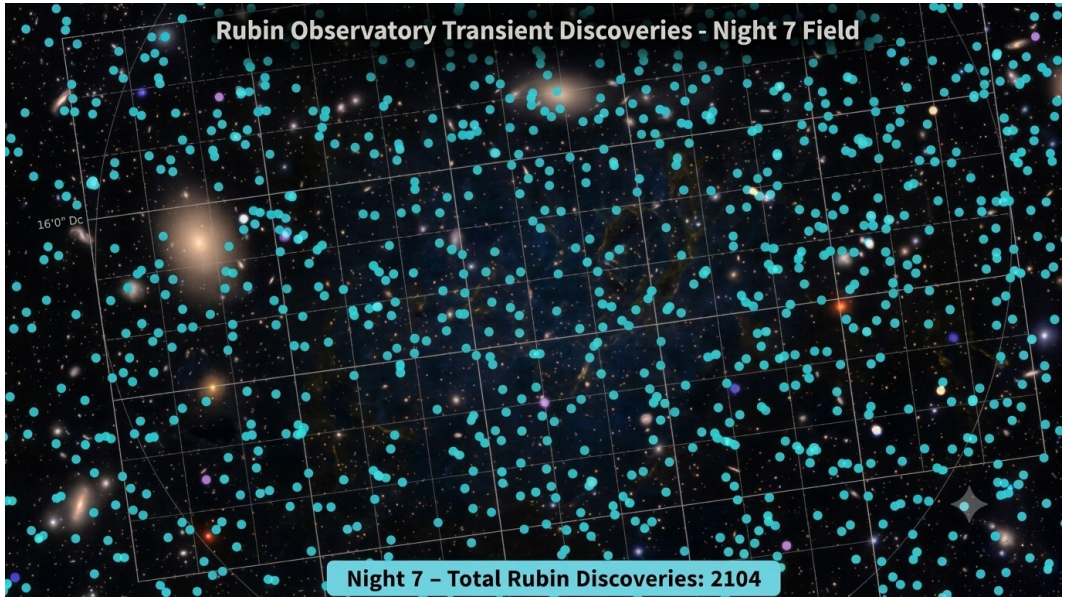
Extracting Asteroid Physical Properties from Vera C. Rubin Observatory Science Validation Survey Data:

Rotational Periods - Colors - Taxonomies

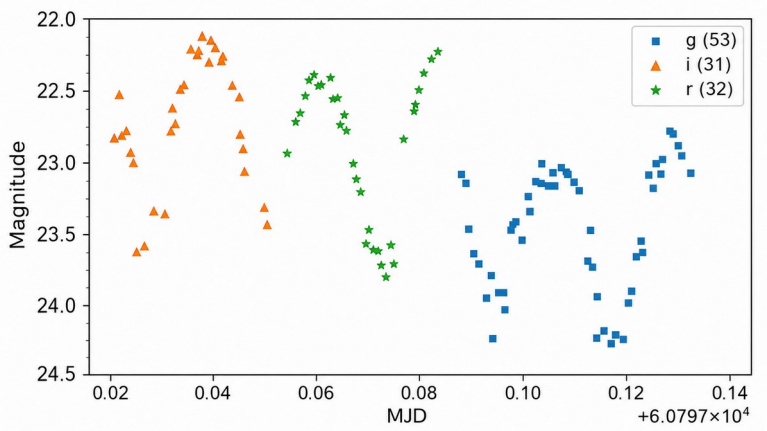


Valerio Carruba, Sarah Greenstreet, Maria Mastropietro, Safwan Aljbaae, Gabriel Caritá, Rita C. Domingos, Mariela Huaman, Mansur Bala, Robson D. Z. Pedroso, Eduardo Delfino

UNESP – São Paulo State University, LIneA – Laboratório Interinstitucional de e-Astronomia

3rd LSST@LATAM Meeting, November 2-6, 2026

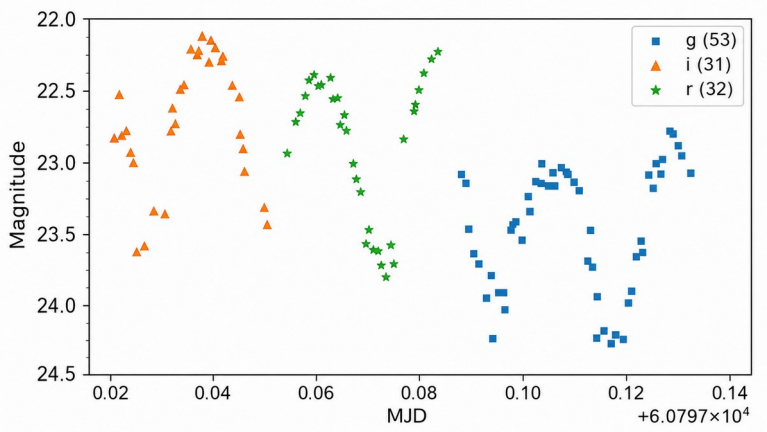
From Rubin First Look to Science Validation

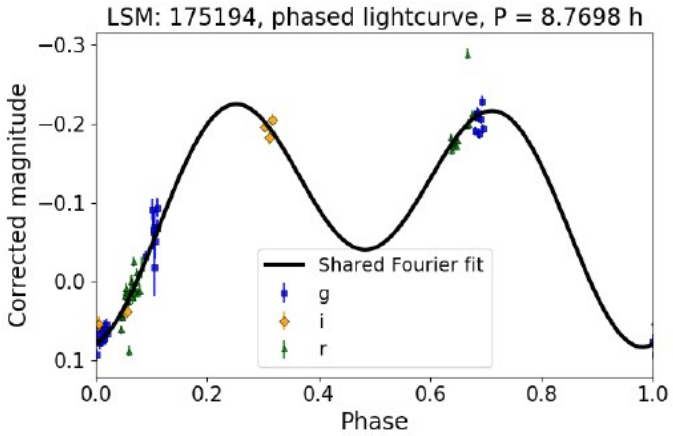


Rubin First Look (Greenstreet et al. 2026)

- **Dense sampling**
- **Complete phase coverage**
- **Direct physical characterization**

From Rubin First Look to Science Validation





Rubin First Look (Greenstreet et al. 2026)

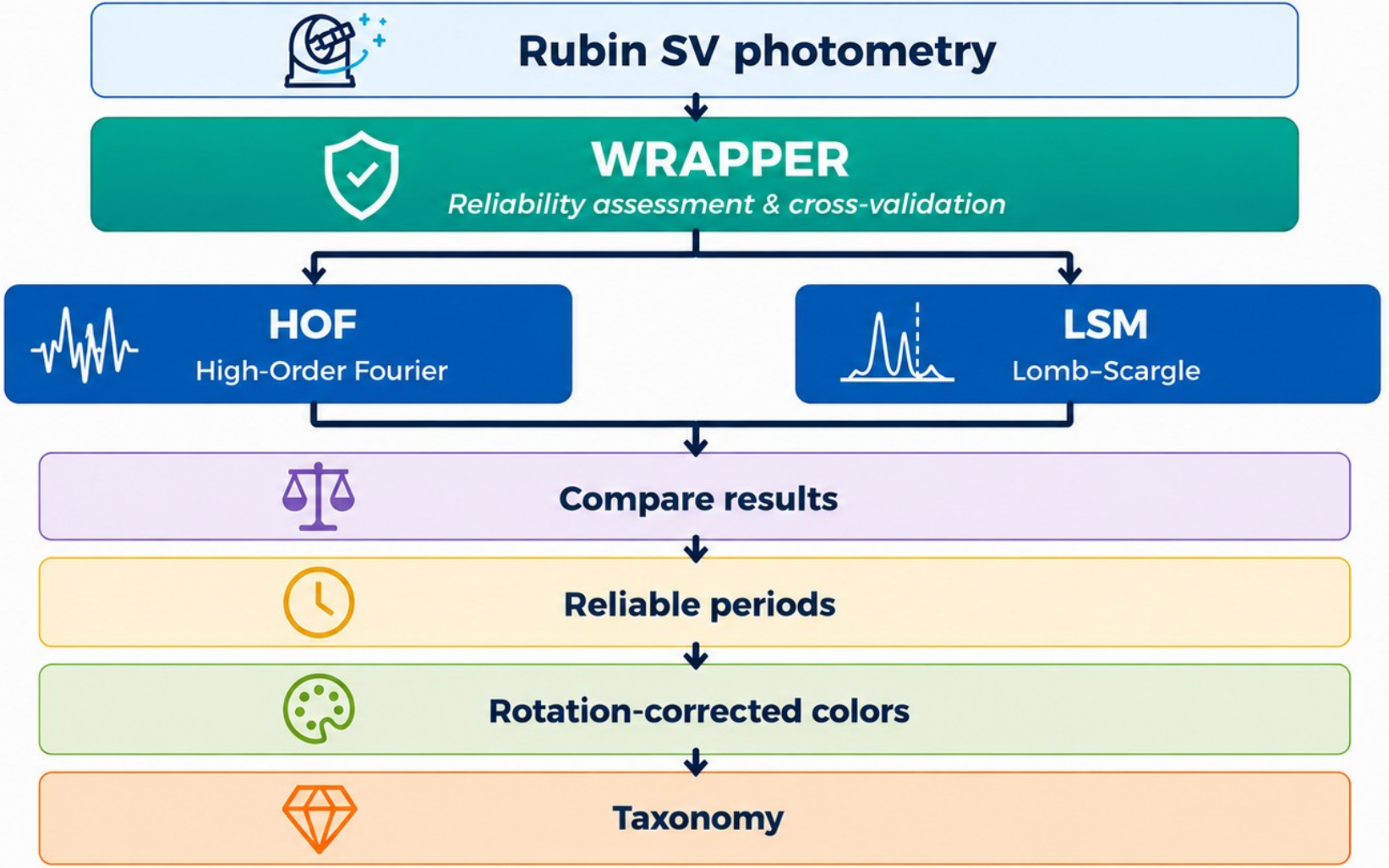
- **Dense sampling**
- **Complete phase coverage**
- **Direct physical characterization**

Rubin Science Validation (this work)

- **Sparse sampling**
- **Incomplete phase coverage**
- **Cross-validated physical characterization**

Can we reliably characterize asteroids from sparse SV observations?

Methodology Overview



Two independent period-search methods

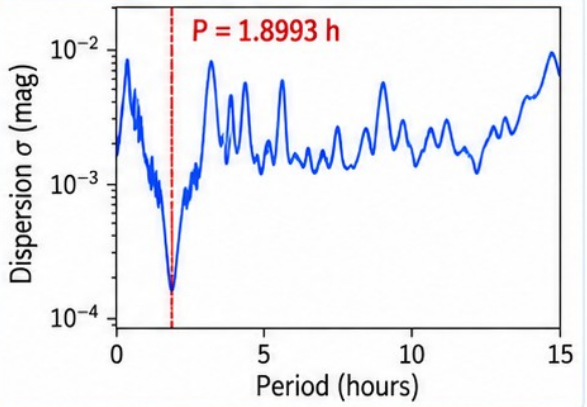
Characteristic	High-order Fourier (HOF)	Lomb–Scargle (LSM)
Period determination	Fit a high-order Fourier series to the light curve $m(t) = \sum_{k=1}^{N} \left[A_k \sin(k\omega t) + B_k \cos(k\omega t)\right]$	Compute Lomb–Scargle periodogram $P(\omega) = \frac{1}{2\sigma^2}\left[\frac{\left(\sum y \cos\omega(t-\tau)\right)^2}{\sum \cos^2\omega(t-\tau)} + \frac{\left(\sum y \sin\omega(t-\tau)\right)^2}{\sum \sin^2\omega(t-\tau)}\right]$
Fourier order	Variable, 2 – 6 (selected using BIC)	Fixed, 2 (fundamental and first harmonic)
Phase-angle effects	Explicitly modeled $m(\alpha) = m_0 + \beta\alpha + \sum_{k=1}^{N} \left[A_k \sin(k\omega t) + B_k \cos(k\omega t)\right]$	Different correction procedure (linear phase-angle term removed before period search)
Band treatment	Simultaneous fit with photometric offsets between bands $m_b(t) = m_0 + C_b + \sum_{k=1}^{N} \left[A_k \sin(k\omega t) + B_k \cos(k\omega t)\right]$	Median normalization per band $m'_b(t) = m_b(t) - \mathrm{median}(m_b)$
Main advantage	Flexible light-curve modeling (more complex shapes)	Computational efficiency (robust and fast)

Why use two independent methods?

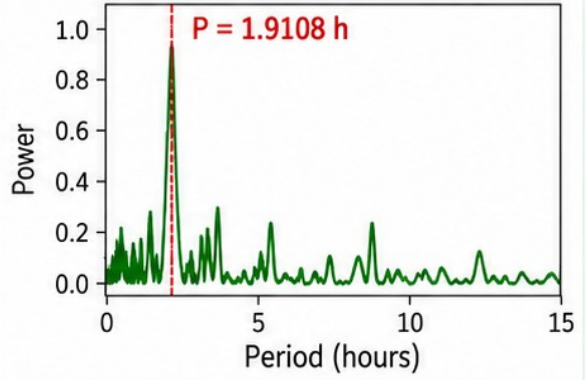
- Sparse sampling can introduce aliases and harmonic ambiguities.
- HOF and LSM make different assumptions and may identify different candidate periods.
- Agreement between complementary approaches increases confidence in the adopted solution.

The wrapper compares the independent period estimates to identify reliable rotational periods.

HOF periodogram (2026 DO14)



LSM periodogram (2026 DO14)



Wrapper reliability criteria: selecting reliable periods

HOF and LSM period estimates

1. **Valid period estimate?** At least one method returns a period.
2. **Sufficient coverage?** ≥ 30 observations in at least two of the g, r, i bands.
3. **Significant amplitude?** Light-curve amplitude $A > 0.1$ mag.
4. **Period agreement?** When both periods are available: $\Delta P/P < 10\%$.

Reliable rotational period

Criterion	Requirement	Notes
1. Successful period determination	At least one of the two methods (HOF or LSM) returns a valid rotational period.	Allows inclusion of objects for which only one method provides a reliable solution.
2. Photometric coverage	≥ 30 observations in at least two of the g, r, i photometric bands.	Ensures adequate sampling for rotation-corrected colors and taxonomic classification.
3. Significant rotational amplitude	Fitted light-curve amplitude $A > 0.1$ mag.	Rejects solutions with very small amplitudes, which may be dominated by photometric noise.
4. Period agreement (when both available)	Relative difference < 10%: $\frac{\Delta P}{P} = \frac{\lvert P_{HOF} - P_{LSM} \rvert}{0.5\,(P_{HOF} + P_{LSM})} < 0.10$	Independent agreement between two complementary methods increases confidence in the adopted period.

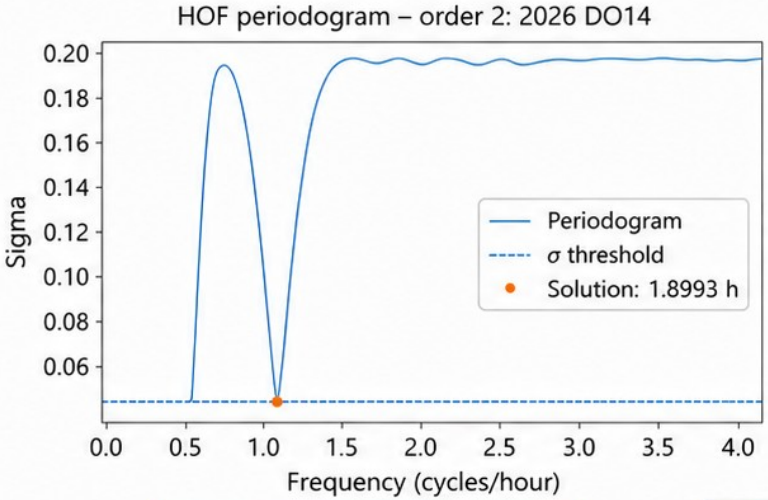
The wrapper combines observational quality and methodological consistency to select reliable rotational periods.

Wrapper framework

Example application: 2026 DO14

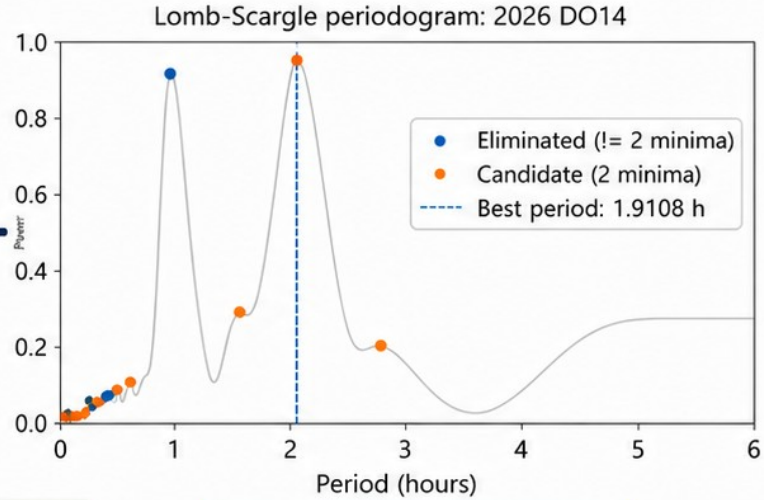
Despite sparse and incomplete phase coverage, two independent methods converge on the same rotation period.

HOF
High-Order Fourier



1.8993 h

LSM
Multiband Lomb–Scargle



1.9108 h

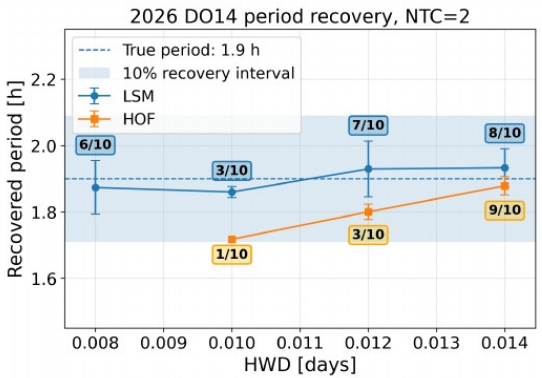
Compare candidate periods

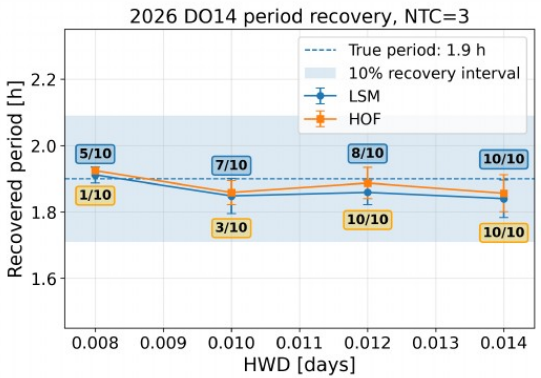
Agreement: $\Delta P/P \approx 0.6\%$

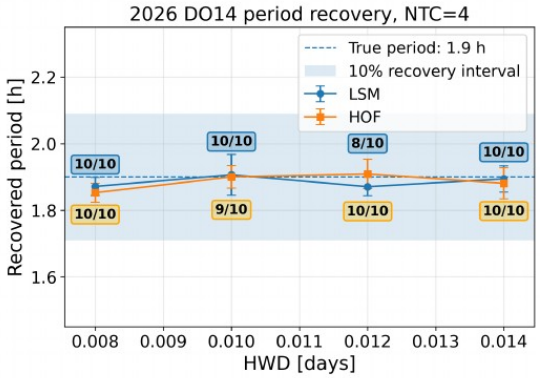
Reliable rotational period → **Rotation-corrected colors** → **Taxonomy**

Agreement between independent methods increases confidence in the derived period and enables subsequent color and taxonomic analysis.

Performance under sparse sampling

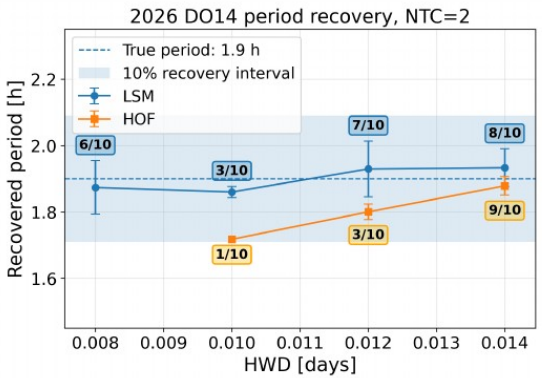


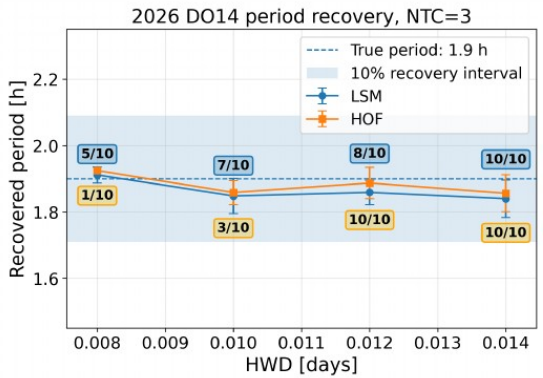


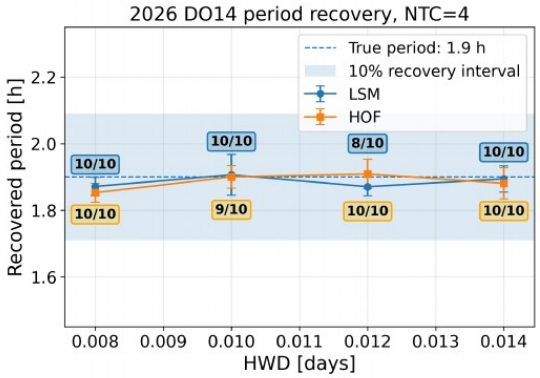


- **NTC: number of temporal clusters**
- **HWD: cluster half-width**

Performance under sparse sampling





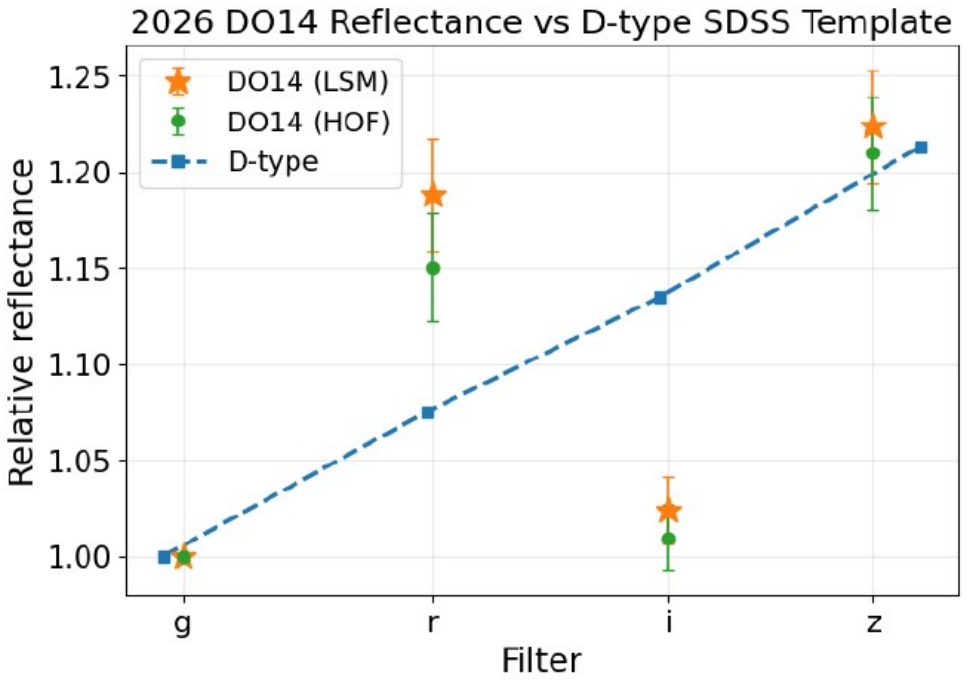


- NTC: number of temporal clusters
- HWD: cluster half-width

- Sparse sampling increases period ambiguity.
- LSM remains more robust than HOF under the tested sparse-sampling conditions.
- Agreement identifies high-confidence solutions.

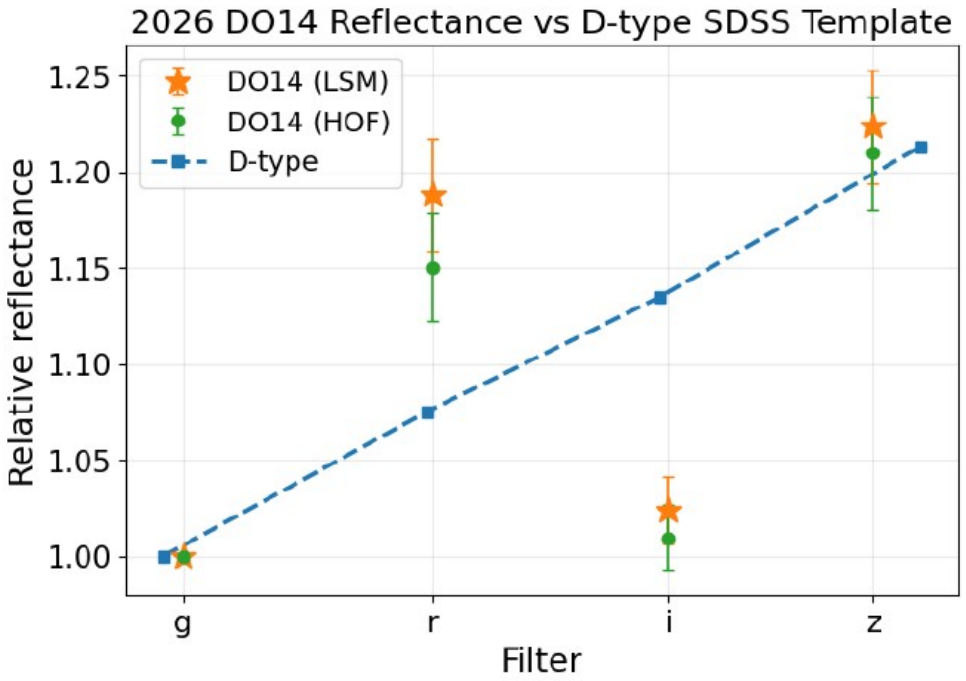
Reliable periods enable accurate color determination

Rotation-corrected colors



- **Rotational variability is removed.**

Rotation-corrected colors



- **Rotational variability is removed.**
- **Mean griz colors are measured consistently.**
- **Photometric reflectance measurements enable taxonomic classification.**

Reliable periods enable accurate griz reflectance spectra

Taxonomic classification: DeMeo & Carry (2013)

Photometric taxonomy

- Based on the DeMeo & Carry (2013) adaptation of the Bus–DeMeo taxonomy to SDSS photometry.
- Uses two quantities derived from the $griz$ filters:
  - gri **spectral slope**, in % per 100 nm.
  - $i - z$ **color index**, sensitive to spectral behavior near 1 μm.
- Taxonomic classes occupy predefined regions in the (gri slope, $i - z$) plane.

From magnitudes to normalized reflectances

- Relative reflectances are obtained by removing solar colors:

$$R_f = 10^{-0.4[(m_f - m_g) - (m_{f,\odot} - m_{g,\odot})]}$$

where m_f are rotation-corrected magnitudes and $m_{f,\odot}$ are solar magnitudes in the corresponding filters.
The reflectance is normalized to the g band ($R_g = 1$).

Color parameters

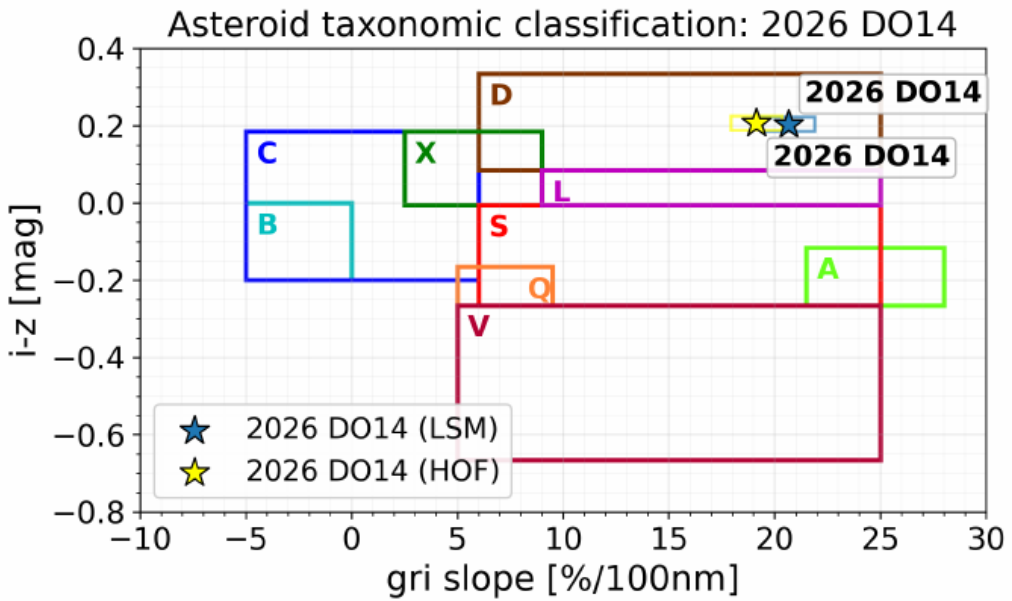
- The ***gri* slope** is obtained from a linear fit to the normalized reflectances in the g, r, i filters as a function of wavelength (expressed in % per 100 nm).
- The $i - z$ **color index** is calculated directly from the rotation-corrected photometric magnitudes:

$$(i - z) = m_i - m_z$$

- The resulting (gri slope, $i - z$) coordinates are compared with the DeMeo & Carry (2013) taxonomic boundaries.

Broadband Rubin colors provide low-resolution spectral information for asteroid classification.

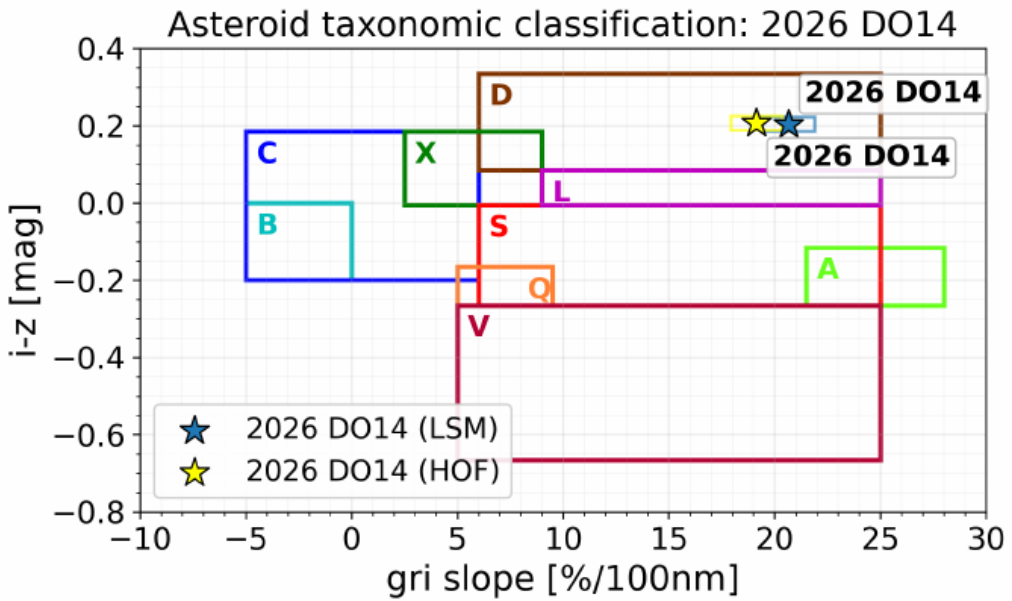
Taxonomic classification: 2026 DO14



LSM: gri_slope = 20.6602, i-z = 0.2037 | Taxonomy = D
HOF: gri_slope = 19.1422, i-z = 0.2066 | Taxonomy = D

- **Rotation-corrected griz colors enable reliable classification.**

Taxonomic classification: 2026 DO14

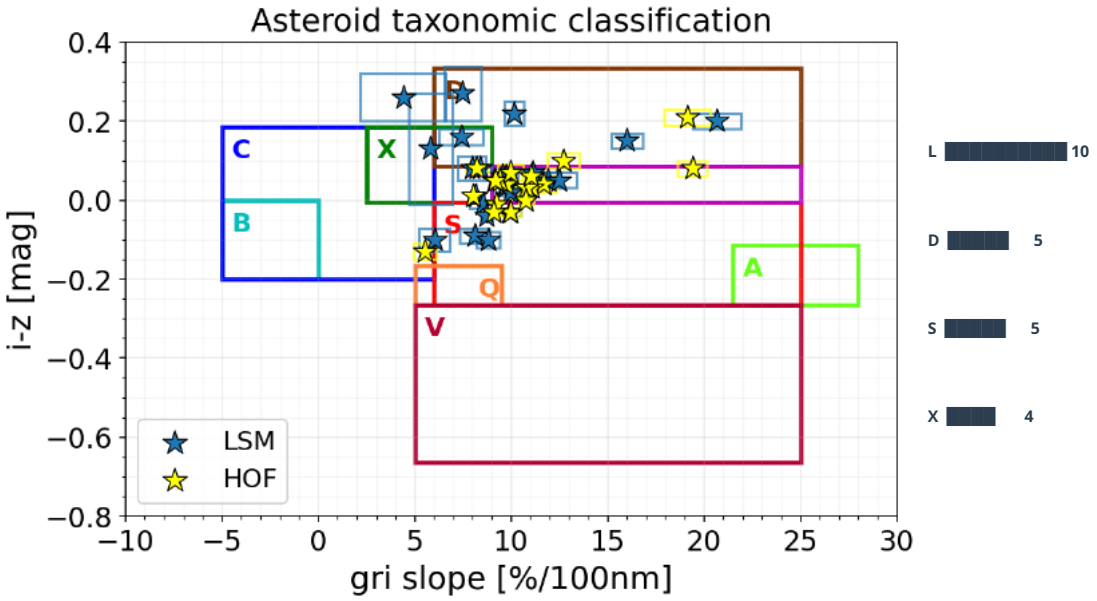


LSM: gri_slope = 20.6602, i-z = 0.2037 | Taxonomy = D
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- **Rotation-corrected griz colors enable reliable classification.**
- **Including the z band extends taxonomic discrimination beyond gri colors.**
- **Derived colors are consistent with established taxonomic templates.**

Sparse Rubin SV observations can recover physically meaningful asteroid taxonomies

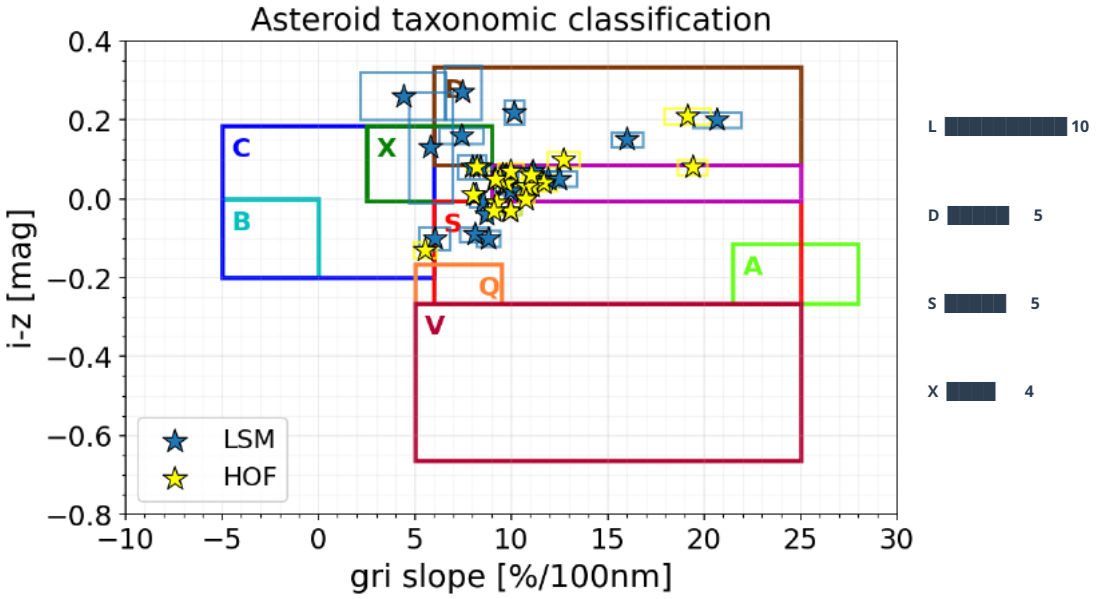
Science Validation sample



Science Validation sample (Carruba et al. 2026)

- 36 asteroids characterized in the published PSS article.
- 24 taxonomic classifications

Science Validation sample

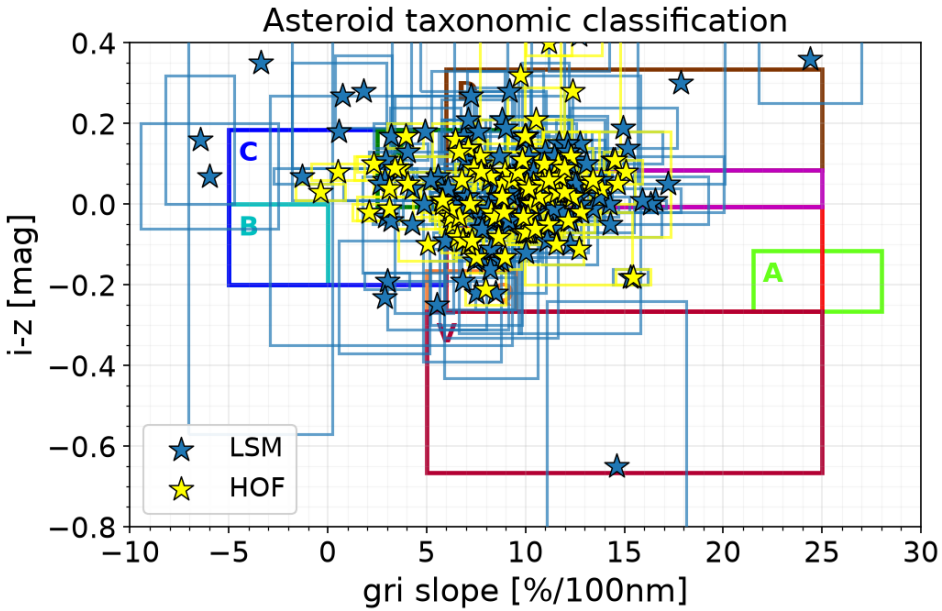


Science Validation sample (Carruba et al. 2026)

- 36 asteroids characterized in the published PSS article.
- 24 taxonomic classifications
- 286 ± 180 observations per asteroid

Sparse Rubin SV data already enable asteroid physical characterization

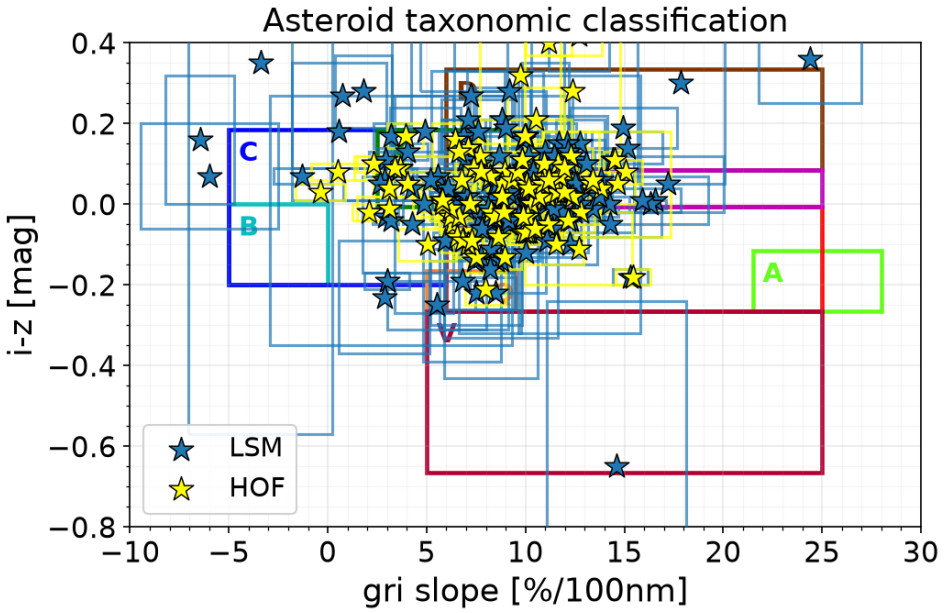
Selected EDP2 results



EDP2 Preliminary results

- 168 asteroids in the selected sample.
- 166 have the colors required for classification.

Selected EDP2 results

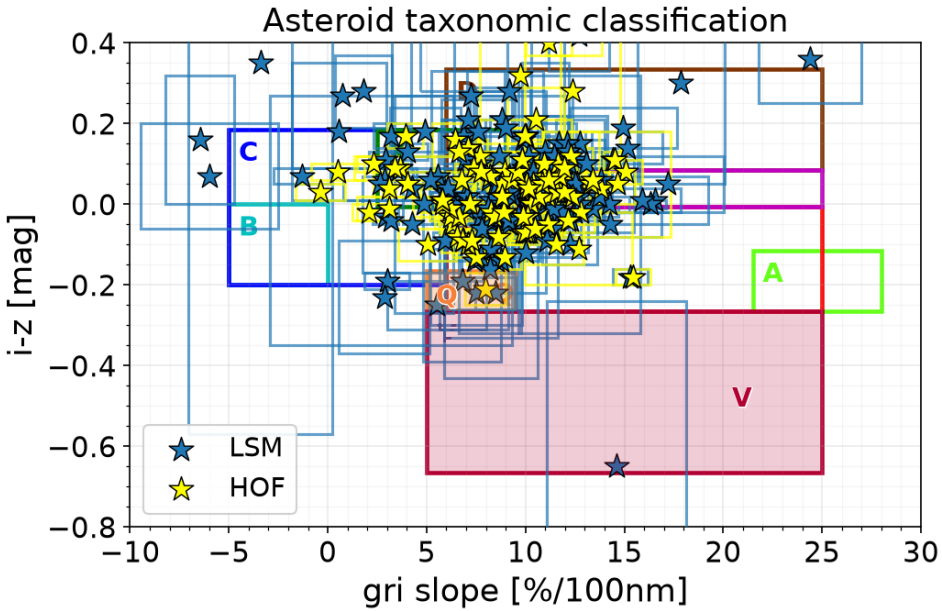


EDP2 Preliminary results

- 168 asteroids in the selected sample.
- 166 have the colors required for classification.
- 154 receive at least one photometric classification (Astron. Nachr., in preparation)

Rotation-corrected colors extend the analysis to a larger EDP2 sample

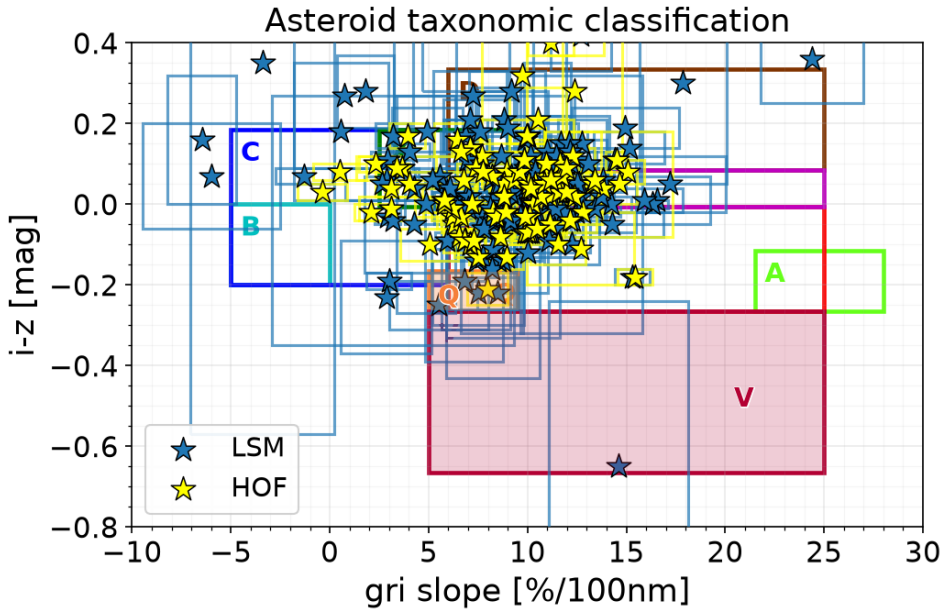
Taxonomic candidates for follow-up



EDP2 selected candidates

- 1 V-type candidate in the middle main belt.
- 4 Q-type candidates.

Taxonomic candidates for follow-up



EDP2 selected candidates

- 1 V-type candidate in the middle main belt.
- 4 Q-type candidates.
- Color uncertainties and period aliases affect individual assignments.

EDP2 photometry identifies compositional candidates for targeted spectroscopy

Conclusions

✓ Period determination

- HOF and multiband Lomb–Scargle provide complementary checks on candidate periods.

✓ Physical characterization

- Rotation-corrected griz colors support photometric taxonomic classification.

Conclusions

✓ Period determination

- HOF and multiband Lomb–Scargle provide complementary checks on candidate periods.

✓ Physical characterization

- Rotation-corrected griz colors support photometric taxonomic classification.

✓ Comparison with EDP2

- Preliminary classifications for 154 asteroids include one V-type and four Q-type candidates.

✓ Rubin future

- The framework can support physical characterization in future LSST releases.

Early Rubin observations enable asteroid physical characterization

Thank you for your attention



Current work

- V. Carruba et al. (2026), Planetary and Space Science, 283, A106350.
- M. Mastropietro, V. Carruba and M. M. Bala (2026), Astronomische Nachrichten, in preparation.

Code availability

- https://github.com/maria-mastropietro/Rubin-Asteroid-Analysis-Pipeline

Contact

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UNESP / LIneA

valerio.carruba@unesp.br

THIRD LSST@LATAM MEETING | 2 NOV 2026

Identification of 21 Superfast Rotators in Rubin LSST Data

Maria Mastropietro

Universidade Estadual Paulista (UNESP)
Faculdade de Engenharia e Ciências (FEG), Guaratinguetá, SP, Brasil

Superfast Rotators

- Rotation period **P < 2.2 h**



Credits: NASA

Superfast Rotators

- Rotation period **P < 2.2 h**
- Rubble piles with **D > 0.2 km** may undergo rotational disruption



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Superfast Rotators

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- Smaller asteroids can rotate faster due to **material strength**



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Superfast Rotators

- Rotation period **P < 2.2 h**
- Rubble piles with **D > 0.2 km** may undergo rotational disruption
- Smaller asteroids can rotate faster due to **material strength**

- Constrain **internal cohesion**



Credits: NASA

Rubin LSST Dataset & Coverage

DATASET

- **Rubin LSST** observations
- Asteroid Institute: April & June 2026
- Sample: **21 asteroids**

Rubin LSST Dataset & Coverage

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PHOTOMETRY

- **191–680** photometric measurements

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- **Rubin LSST** observations
- Asteroid Institute: April & June 2026
- Sample: **21 asteroids**

PHOTOMETRY

- **191–680** photometric measurements



Multiband coverage

Rotation and Taxonomy Analysis

Following Carruba et al. (2026) (based on Greenstreet et al., 2026):

ROTATION PERIOD

- High-Order Fourier (HOF)
- Multiband Lomb–Scargle (LSM)
- Period agreement **< 10%**

$$\frac{|P_{HOF} - P_{LSM}|}{0.5(P_{HOF} + P_{LSM})} < 10\%$$

Rotation and Taxonomy Analysis

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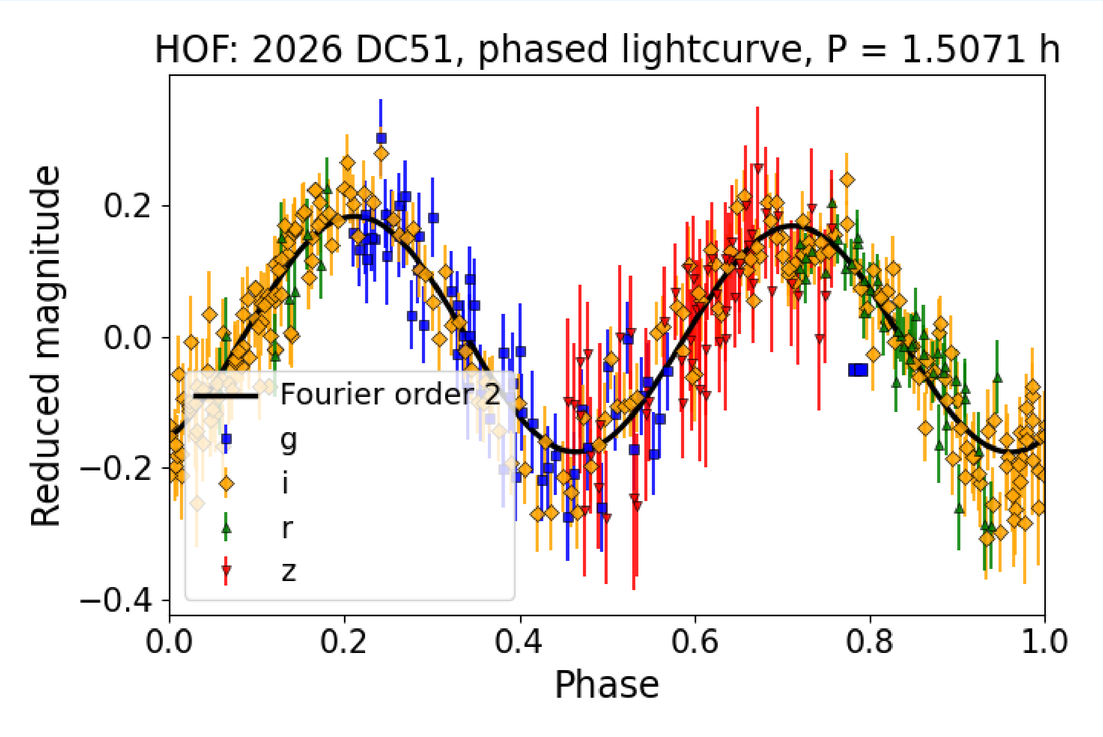
$$\frac{|P_{HOF} - P_{LSM}|}{0.5(P_{HOF} + P_{LSM})} < 10\%$$

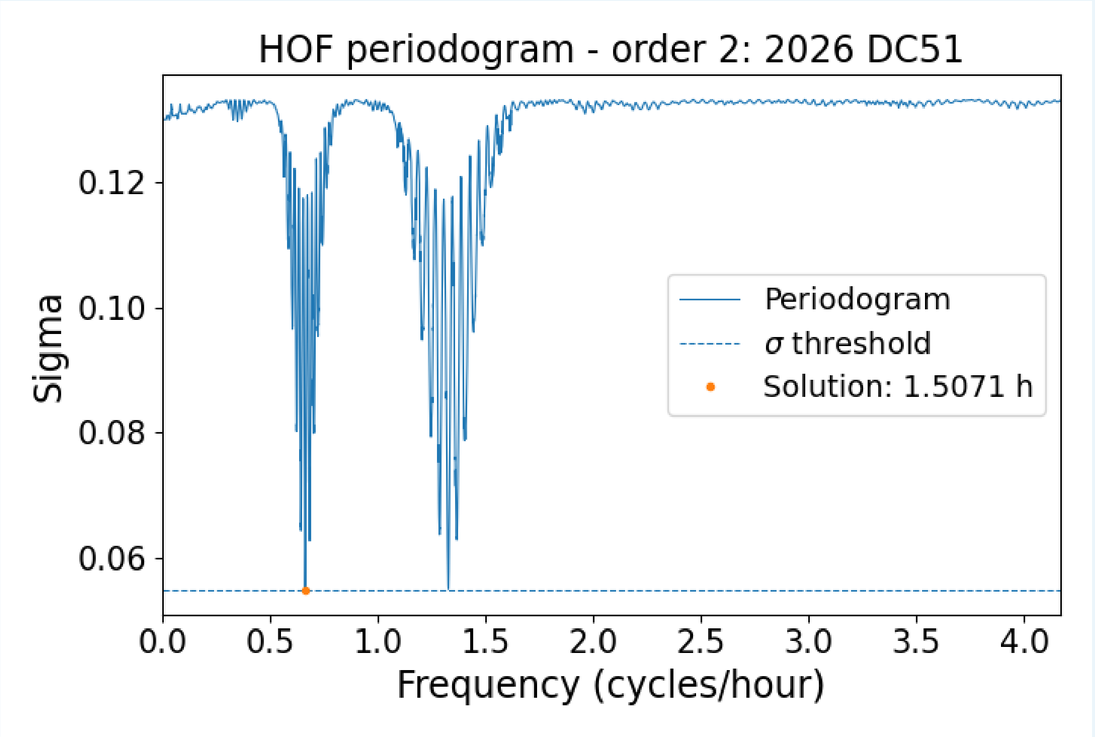
TAXONOMIC CLASSIFICATION

- **gri-slope vs. (i-z)** color diagram
- DeMeo & Carry (2013) boundaries

Example: 2026 DC51 Period Determination

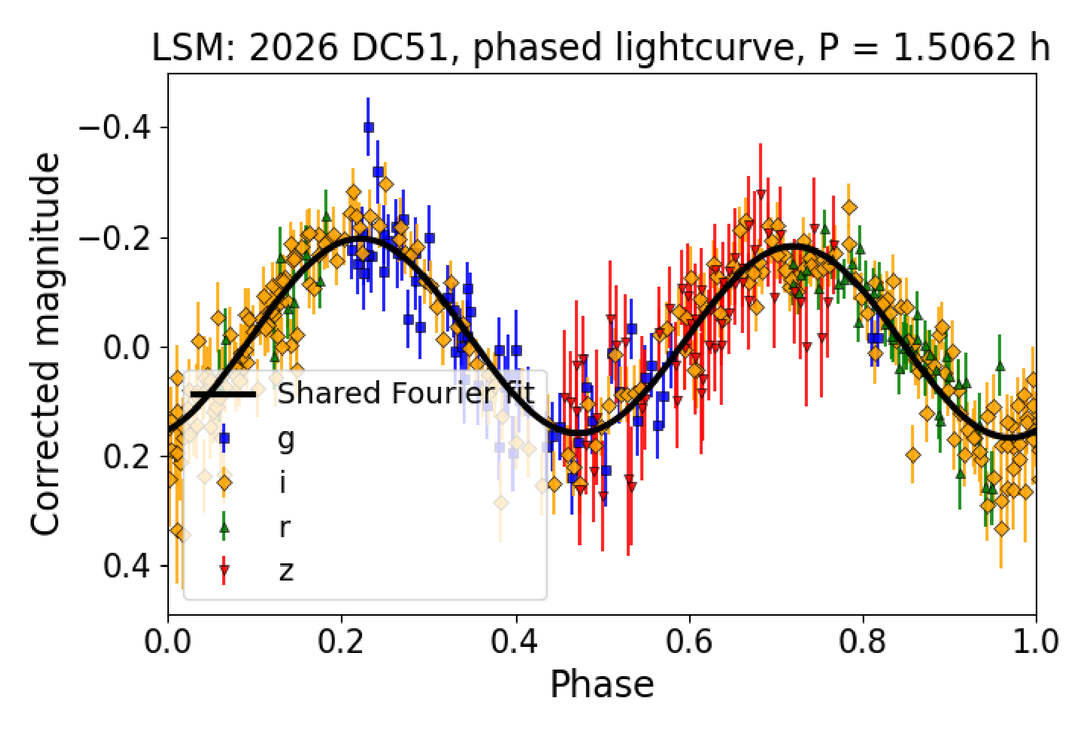
HOF method:

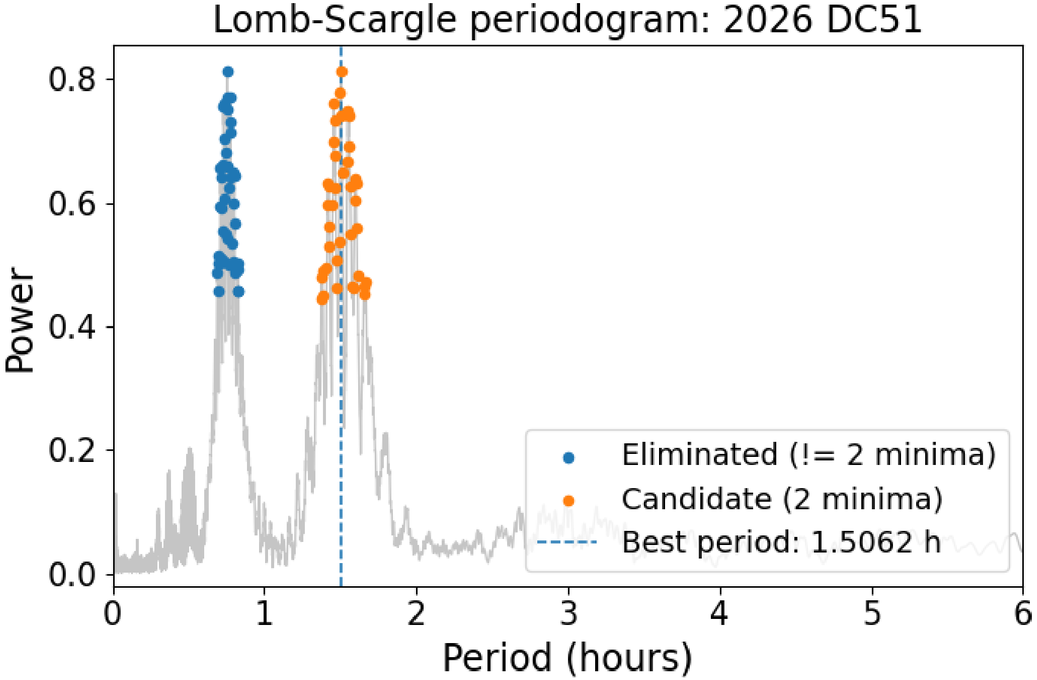




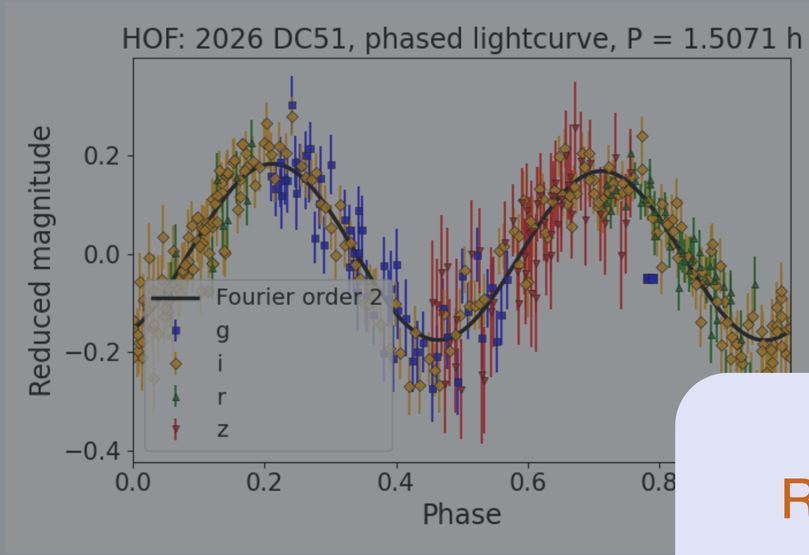
Example: 2026 DC51 Period Determination

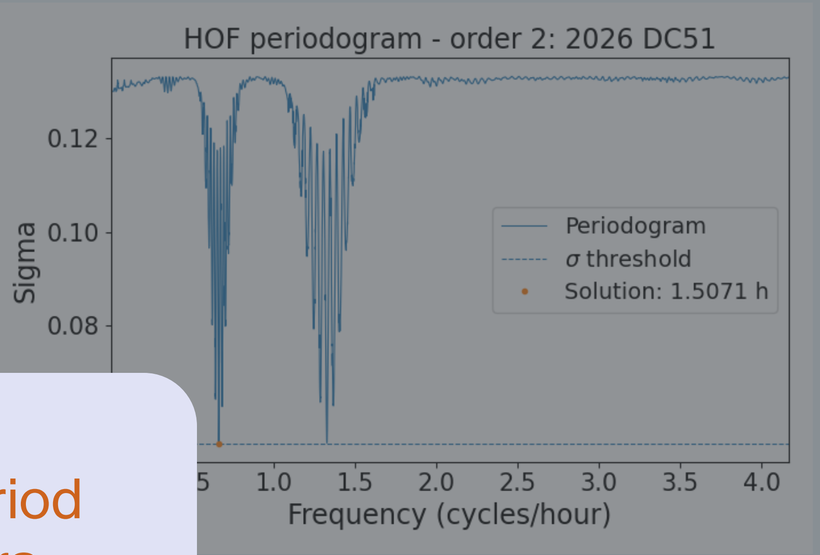
LSM method:



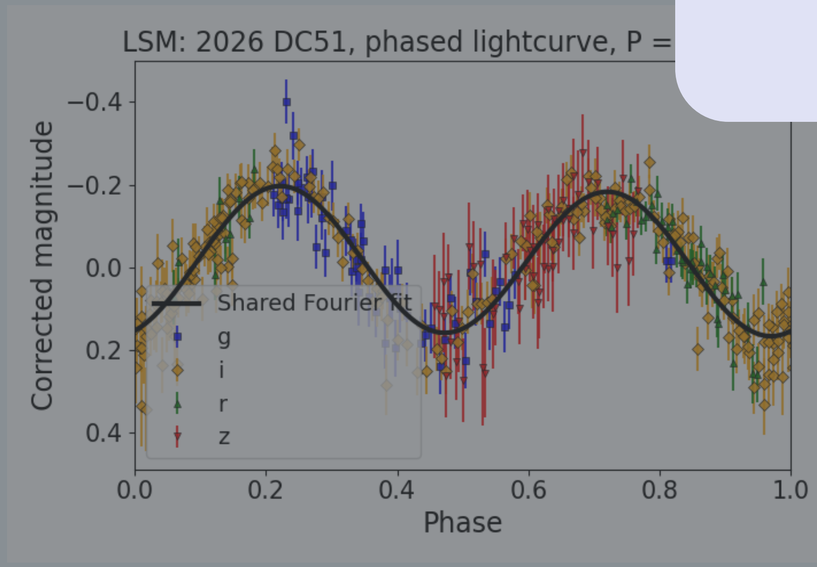


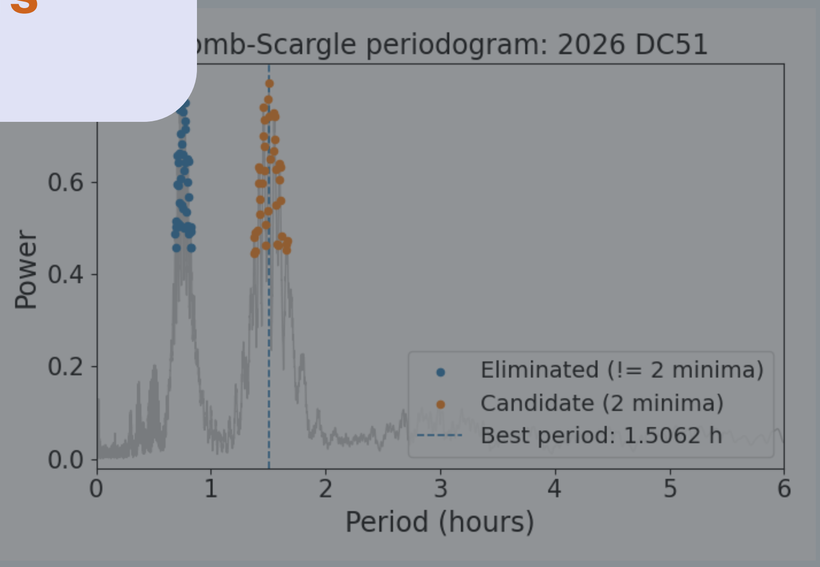
Example: 2026 DC51 Period Determination



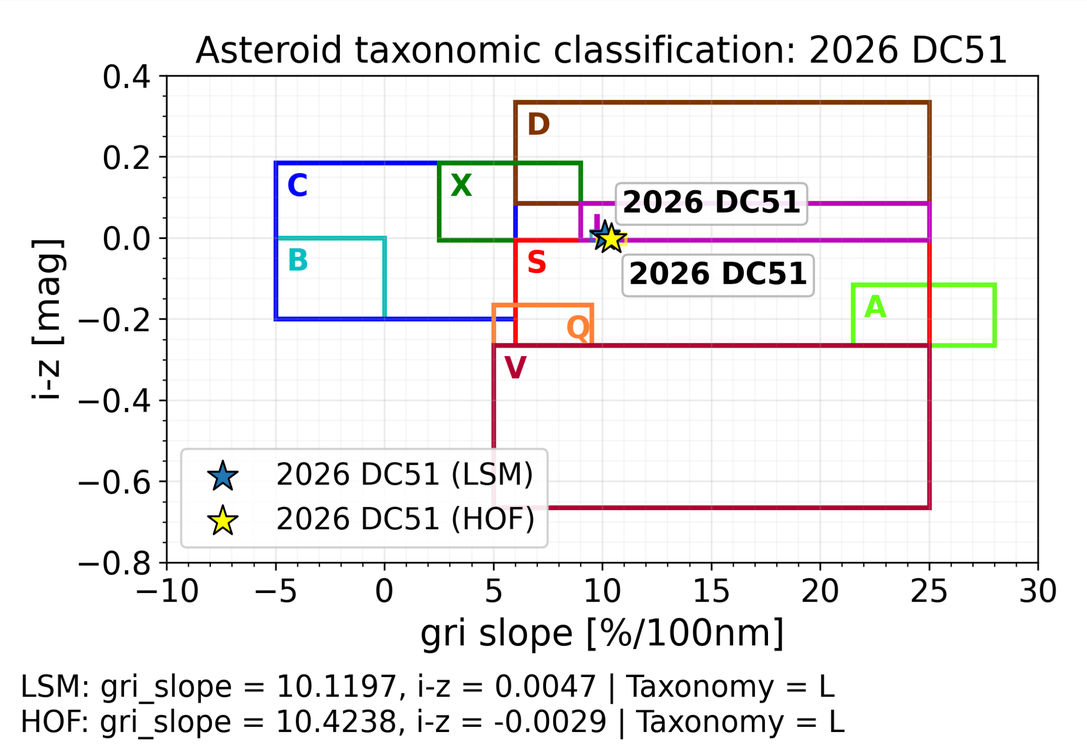


Rotation period
~ 1.51 hours

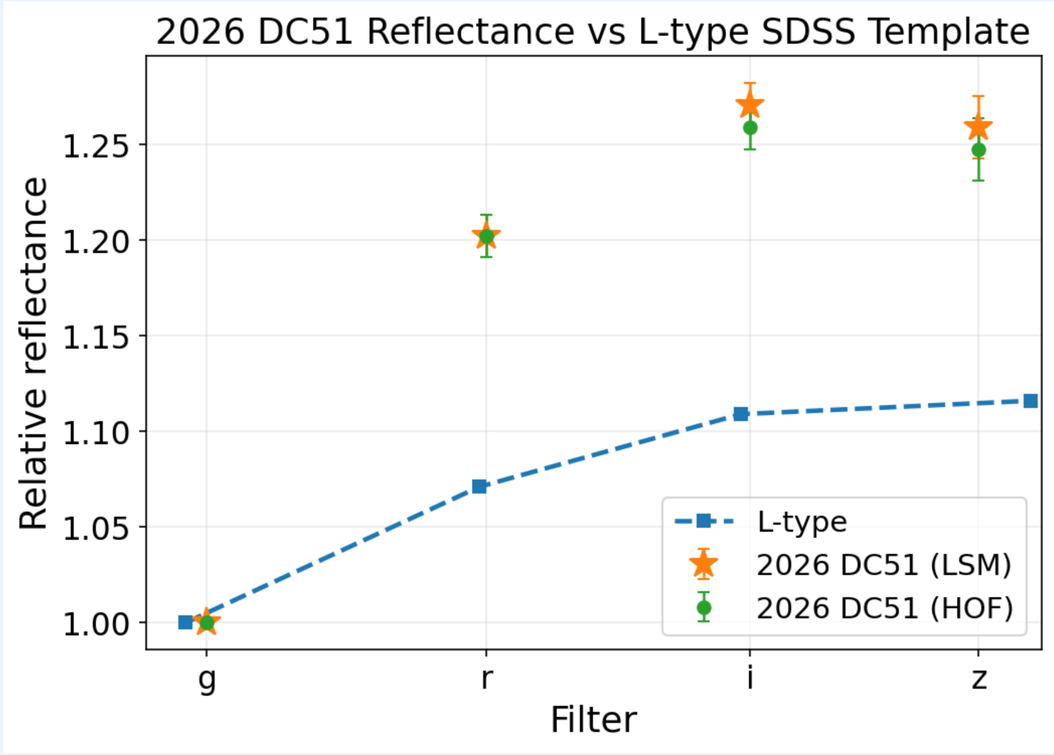




Example: 2026 DC51 Taxonomic Result



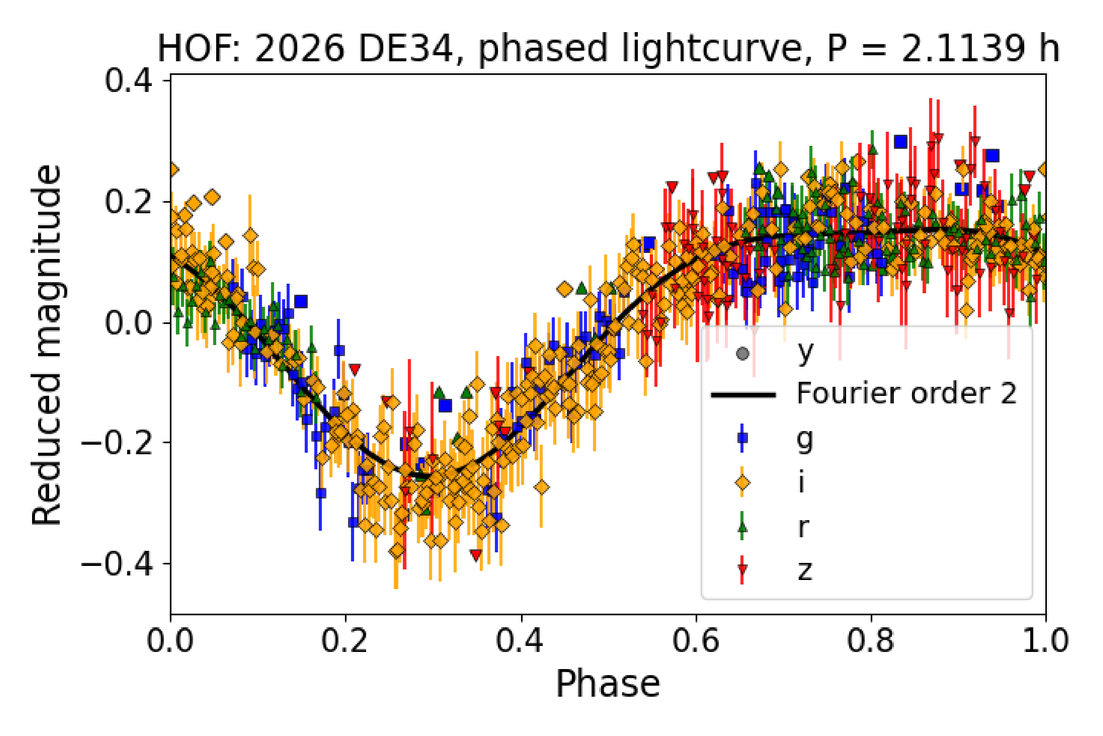
LSM: gri_slope = 10.1197, i-z = 0.0047 | Taxonomy = L
HOF: gri_slope = 10.4238, i-z = -0.0029 | Taxonomy = L

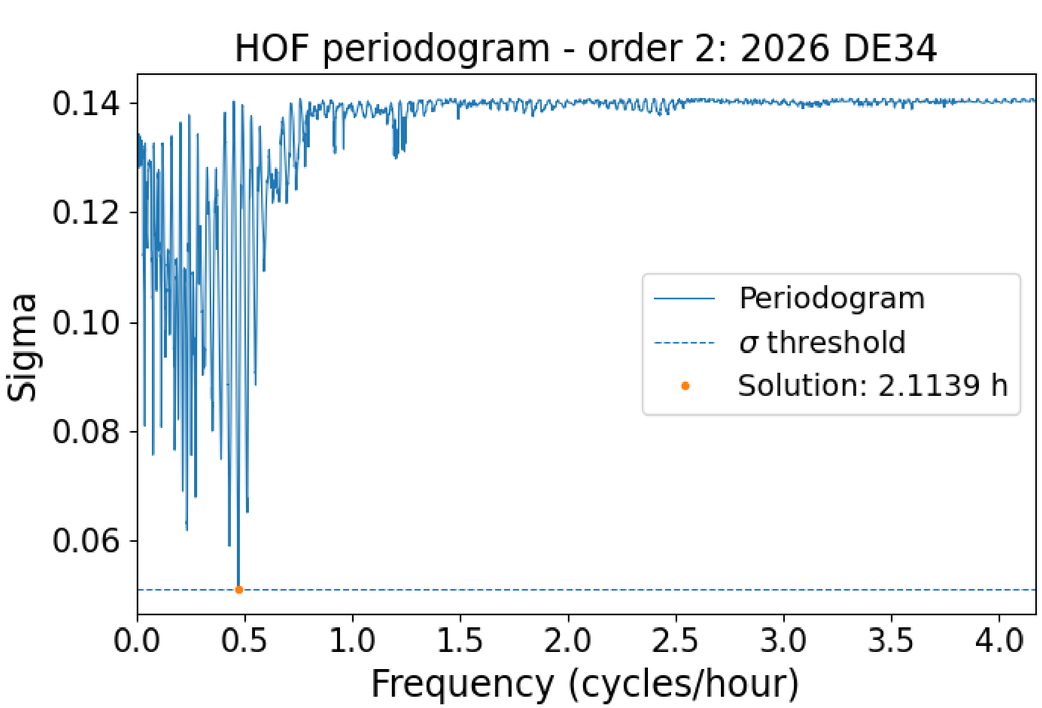


Classification: **L-type**

Example: 2026 DE34 Period Determination

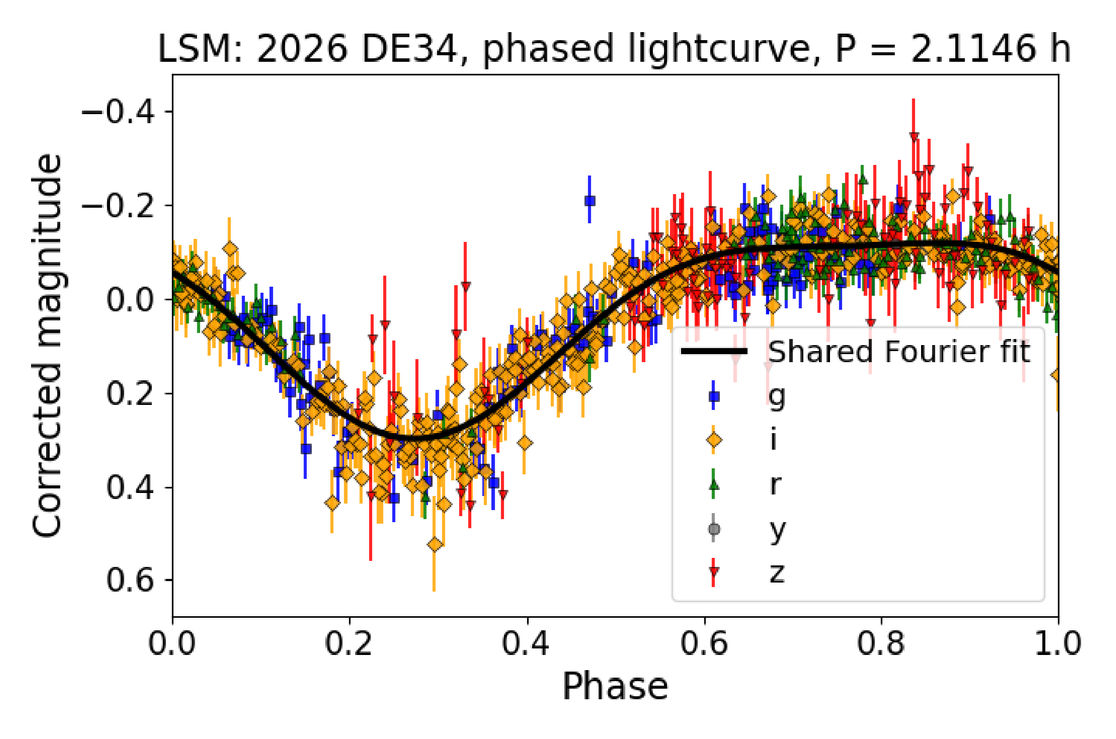
HOF method:

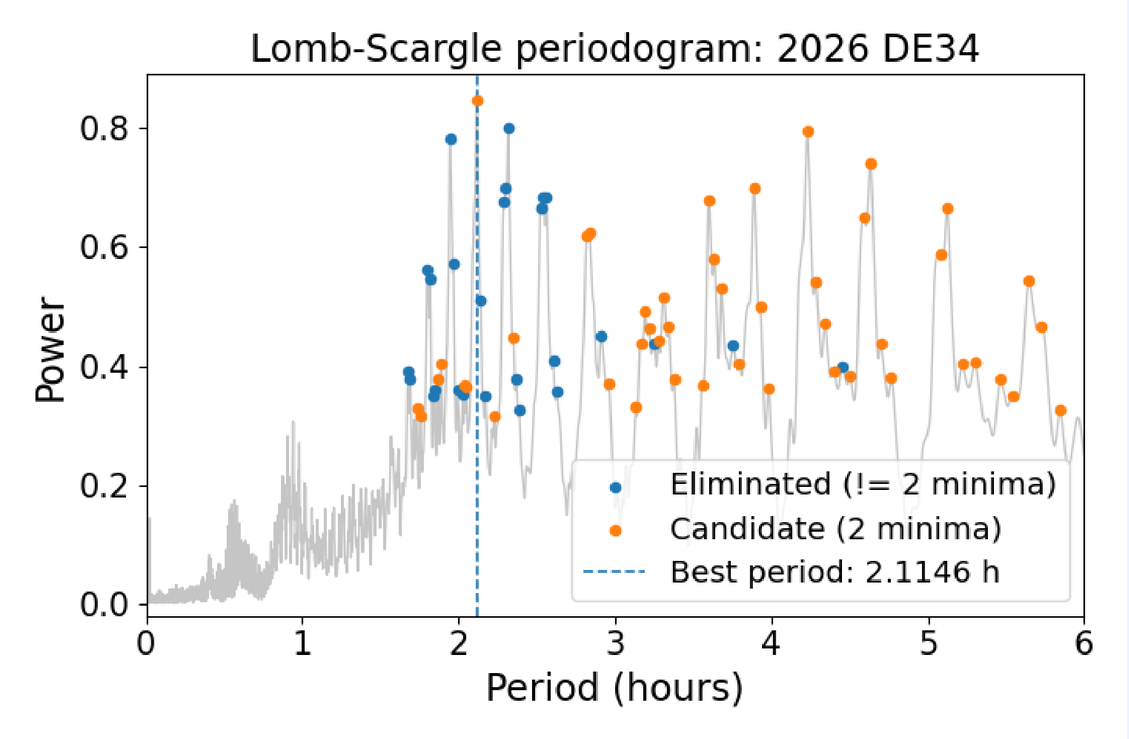




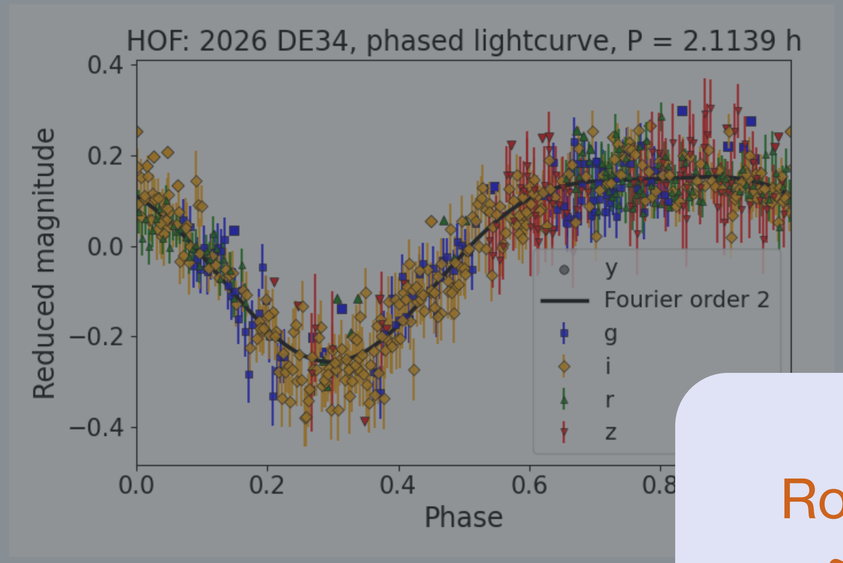
Example: 2026 DE34 Period Determination

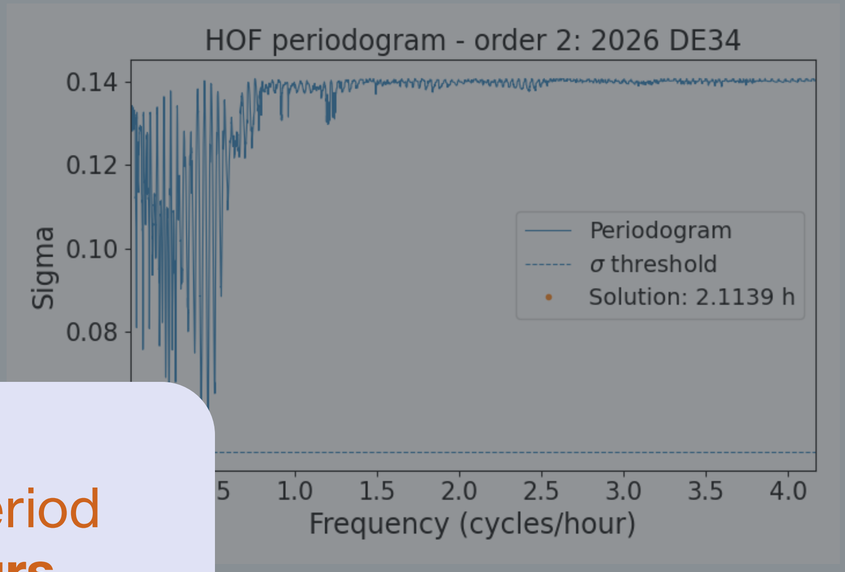
LSM method:



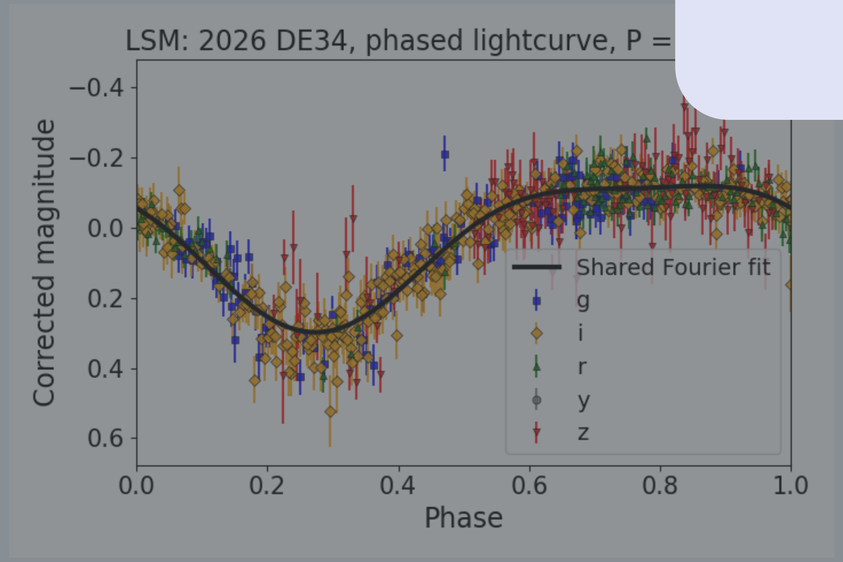


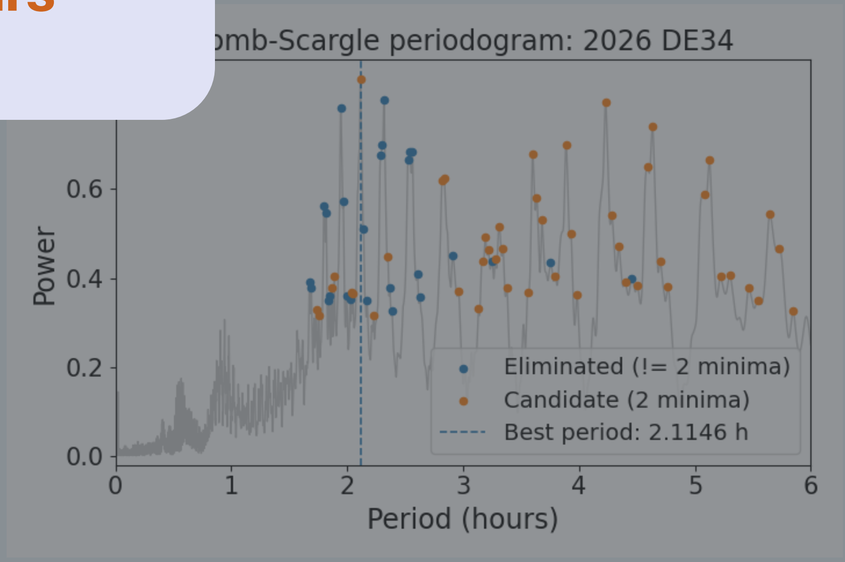
Example: 2026 DE34 Period Determination



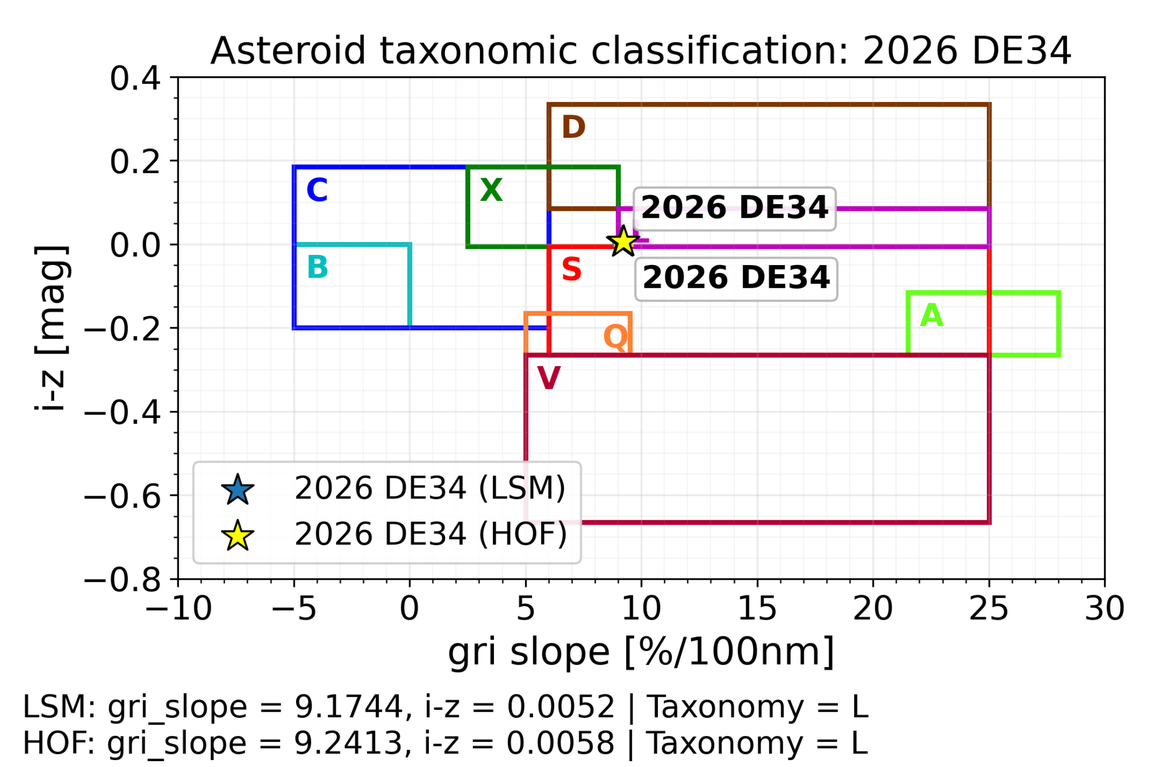


Rotation period
~ 2.11 hours

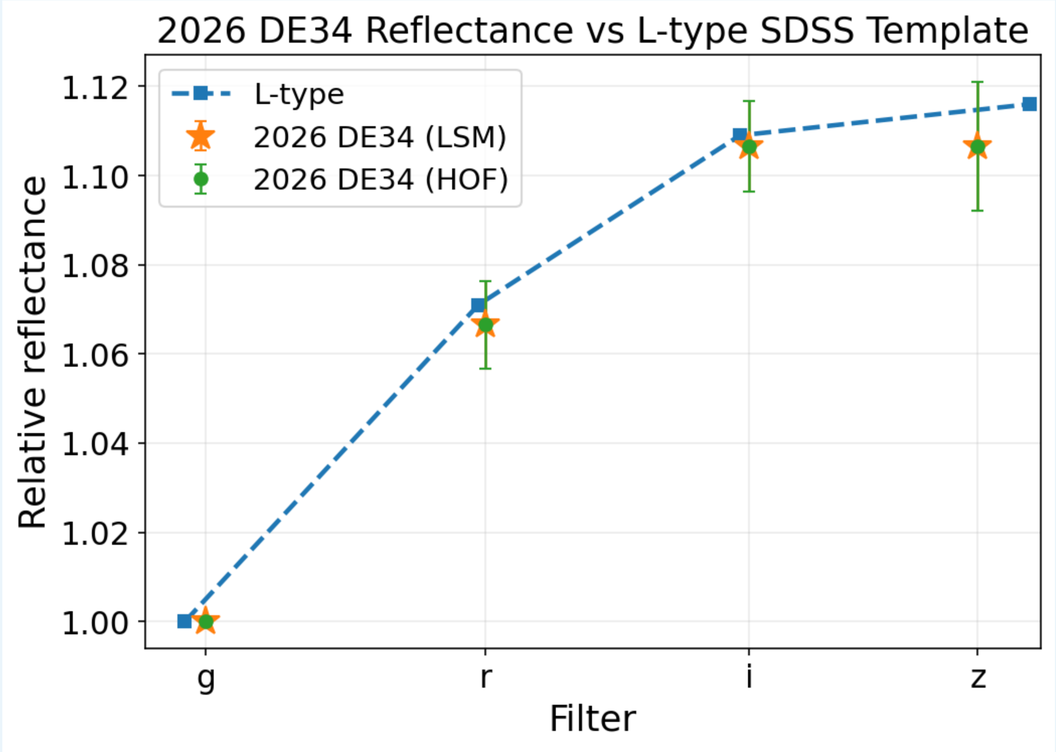




Example: 2026 DE34 Taxonomic Result

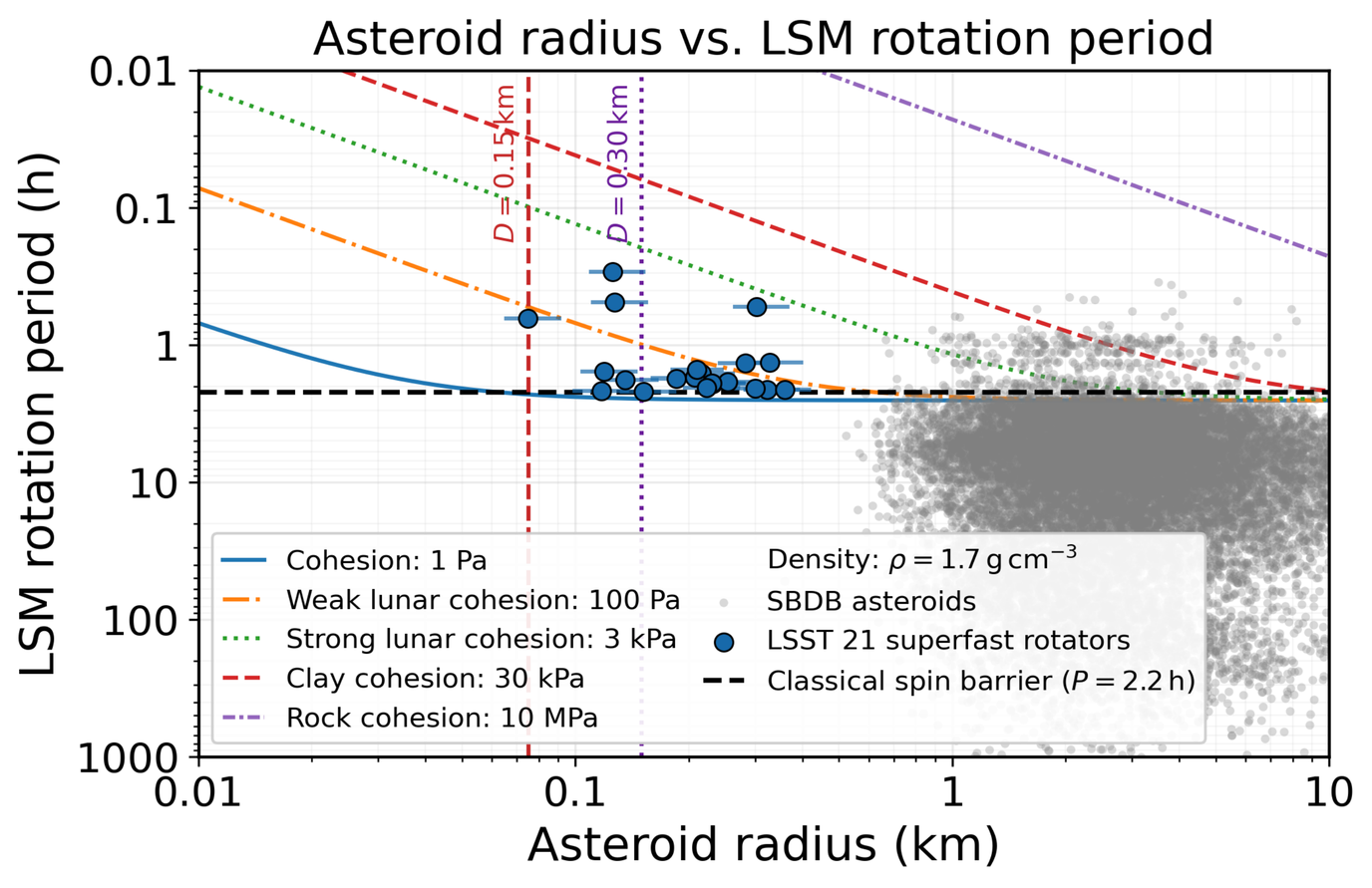


LSM: gri_slope = 9.1744, i-z = 0.0052 | Taxonomy = L
HOF: gri_slope = 9.2413, i-z = 0.0058 | Taxonomy = L



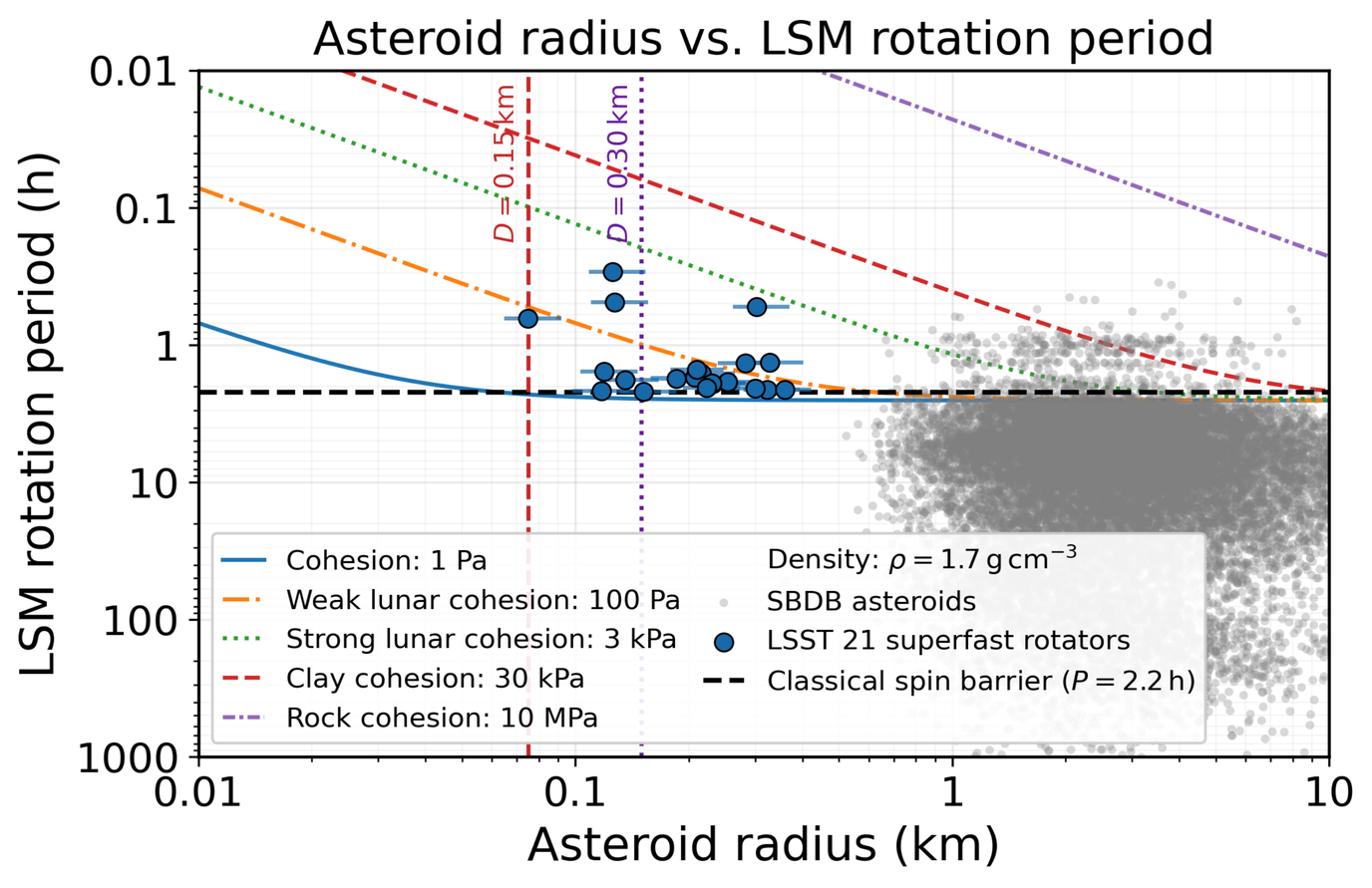
Classification: **L-type**

Results: 21 Superfast Rotators



Analysis by Mastropietro et al. (2026), following Greenstreet et al. (2026)

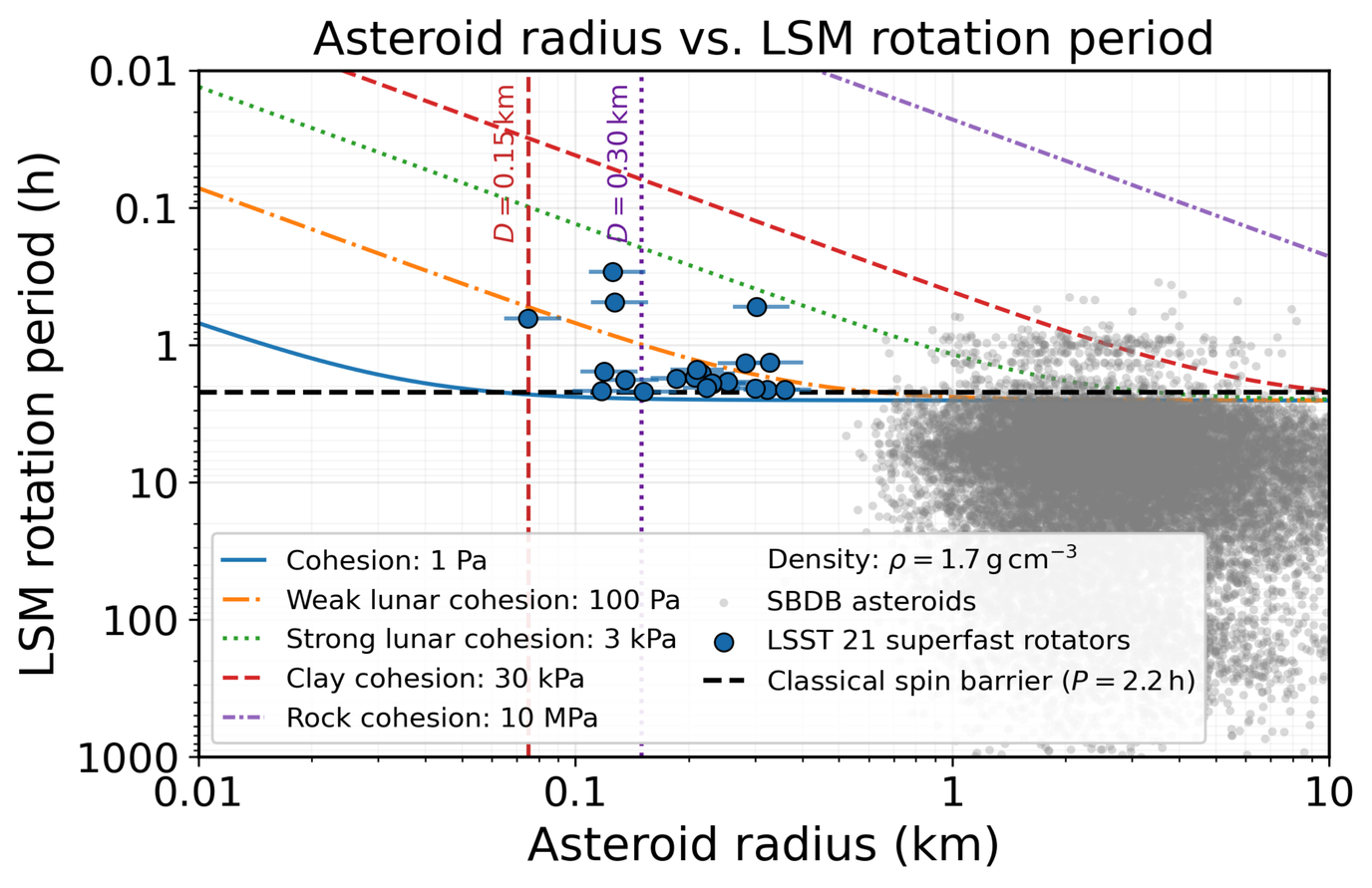
Results: 21 Superfast Rotators



- Cohesion curves: **1 Pa–10 MPa**

Analysis by Mastropietro et al. (2026), following Greenstreet et al. (2026)

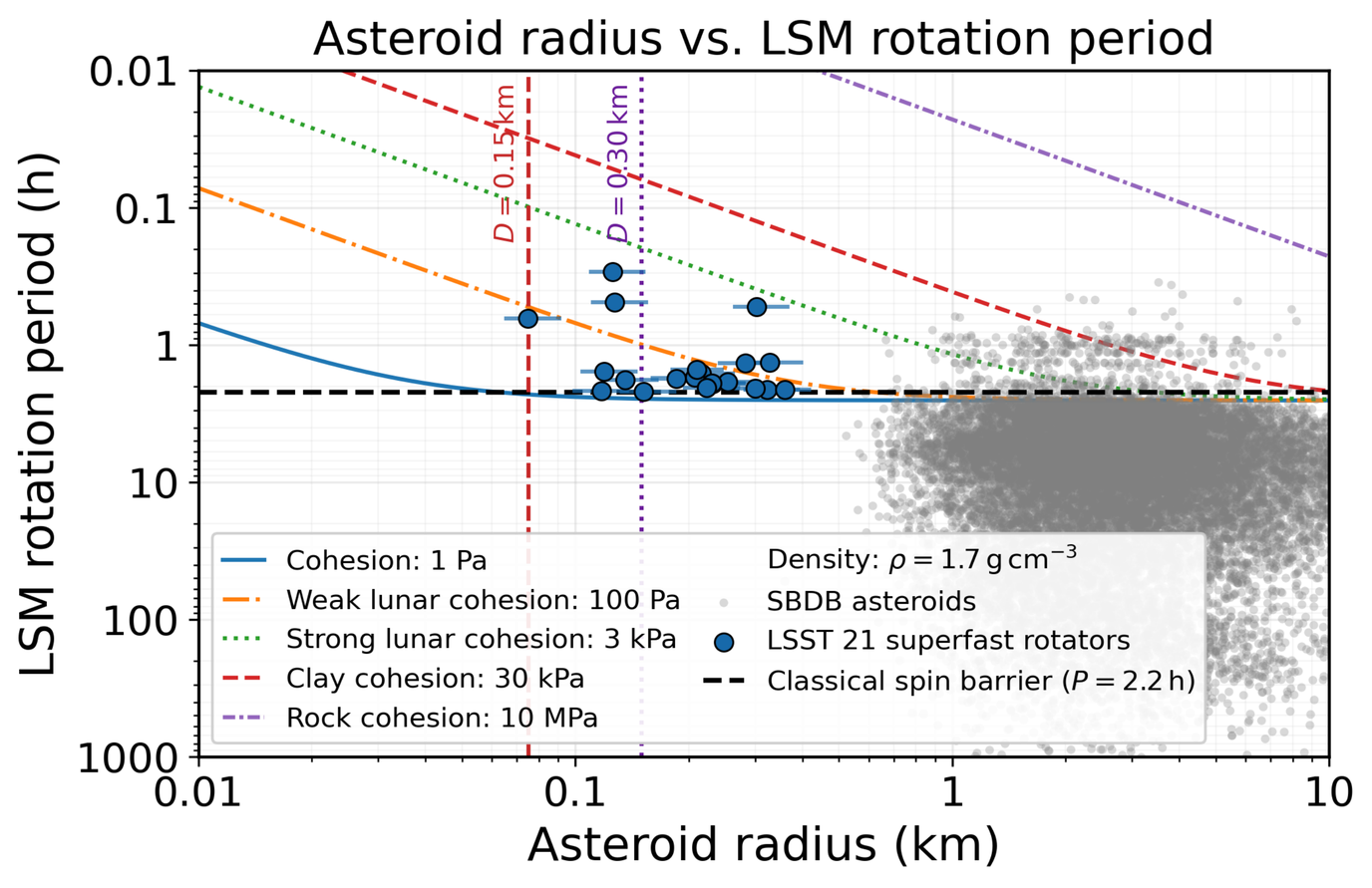
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- Cohesion curves: **1 Pa–10 MPa**
- **Most objects**: Low cohesion

Analysis by Mastropietro et al. (2026), following Greenstreet et al. (2026)

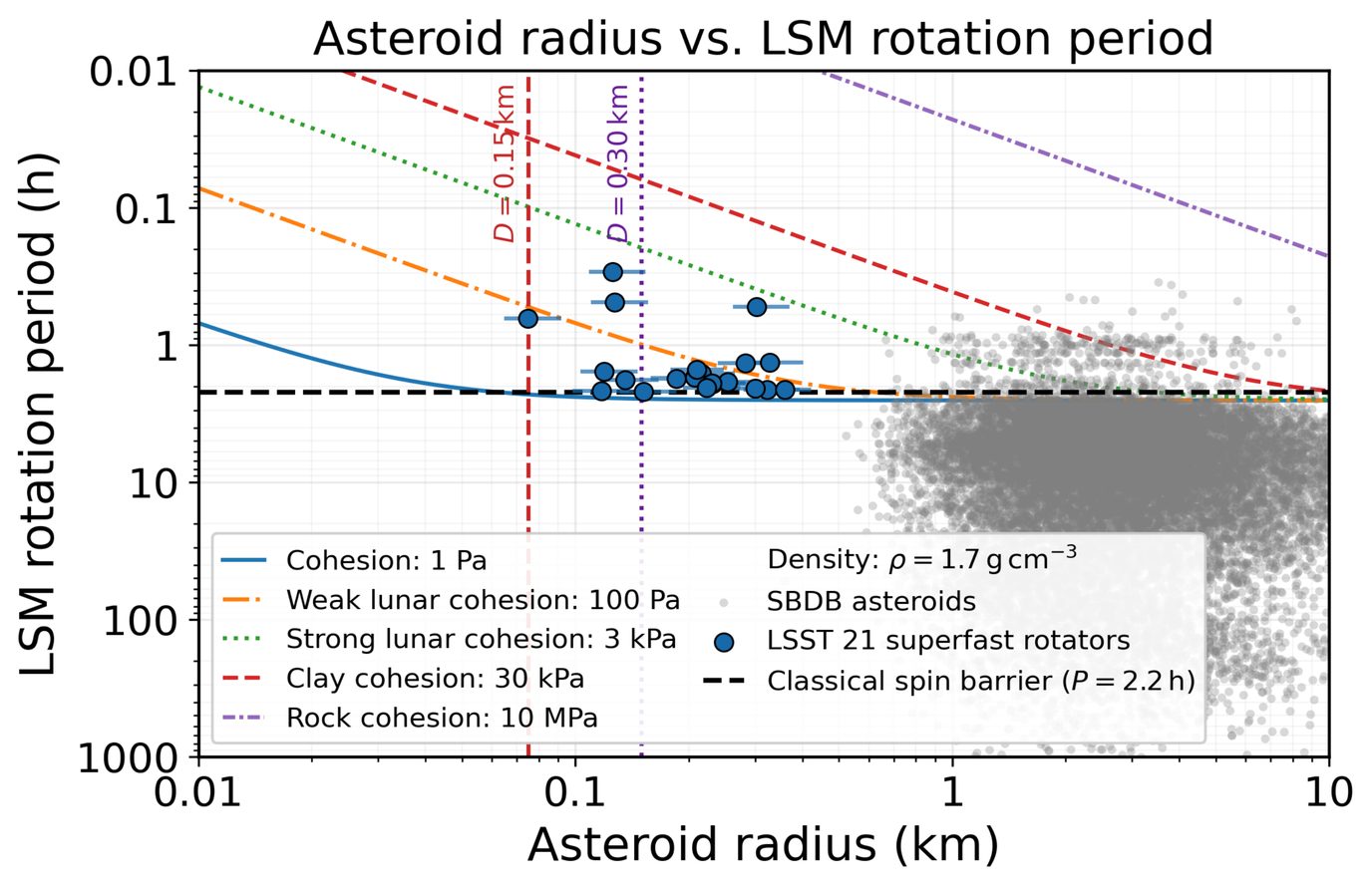
Results: 21 Superfast Rotators



- Cohesion curves: **1 Pa–10 MPa**
- **Most objects**: Low cohesion
- **Five objects**: Intermediate cohesion

Analysis by Mastropietro et al. (2026), following Greenstreet et al. (2026)

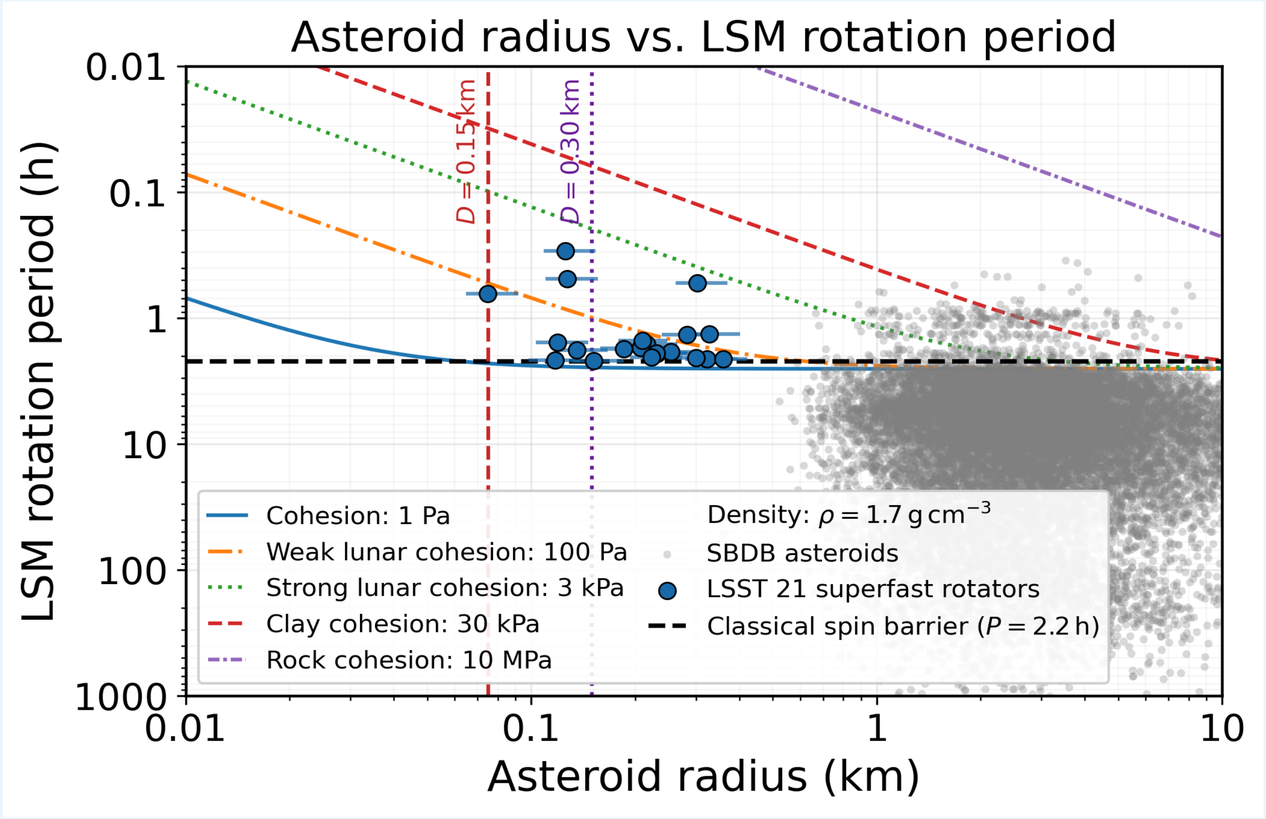
Results: 21 Superfast Rotators



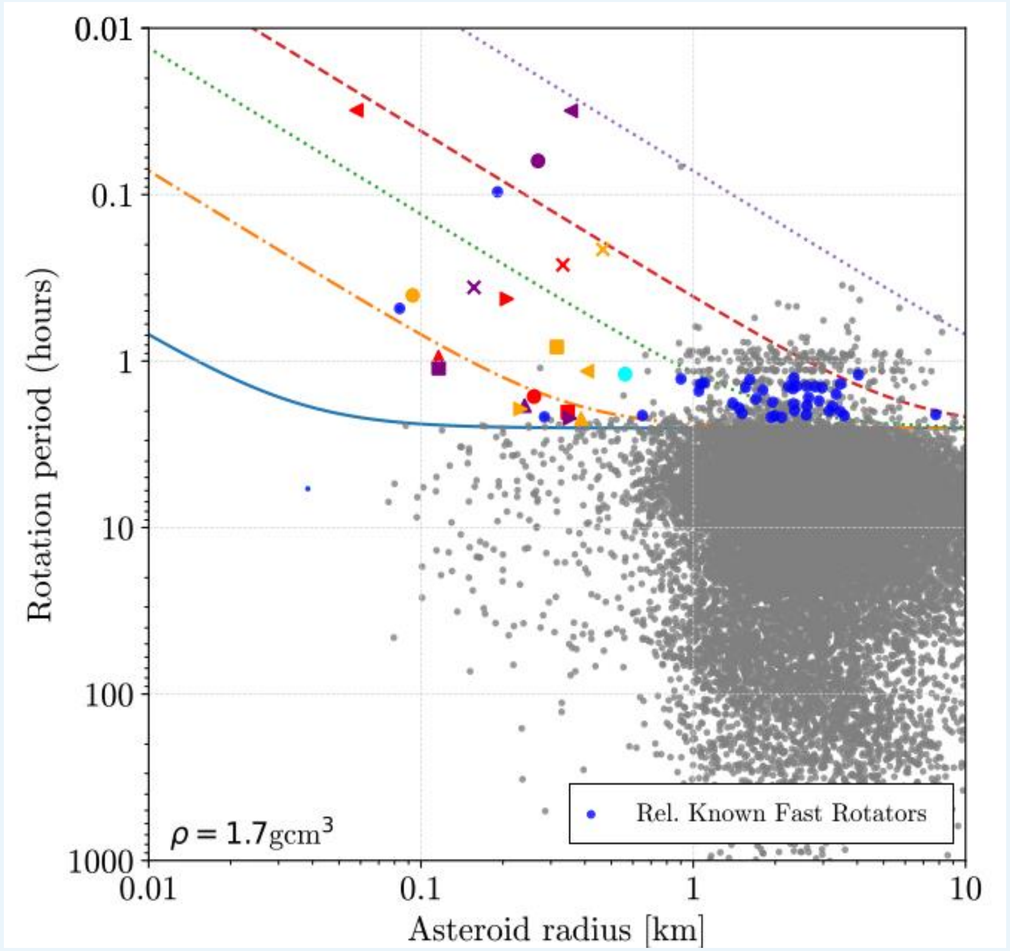
- Cohesion curves: **1 Pa–10 MPa**
- **Most objects**: Low cohesion
- **Five objects**: Intermediate cohesion
- **None**: Cohesion > 3 kPa

Analysis by Mastropietro et al. (2026), following Greenstreet et al. (2026)

Comparison with Greenstreet et al. (2026)

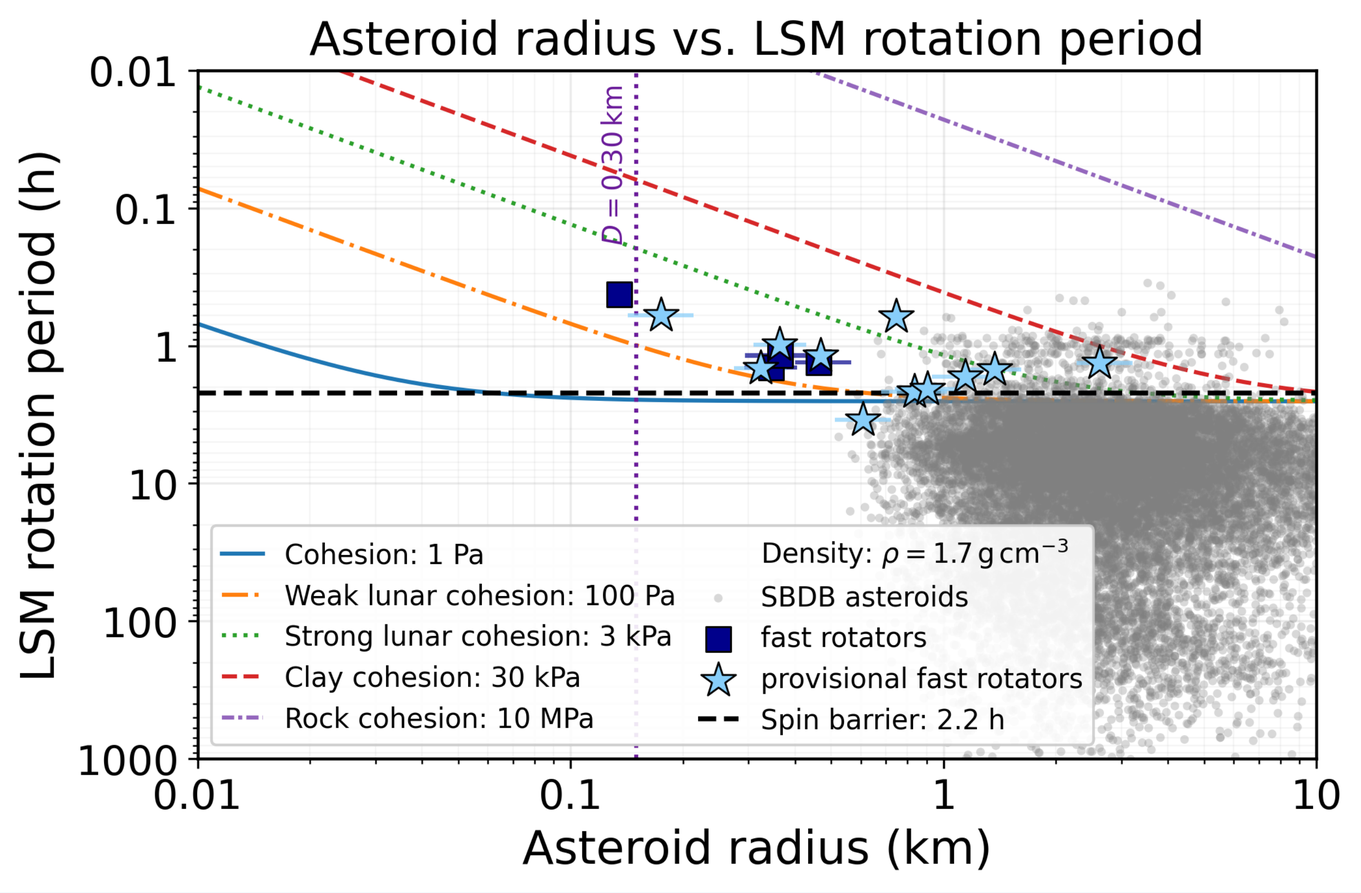


Analysis by Mastropietro et al. (2026)



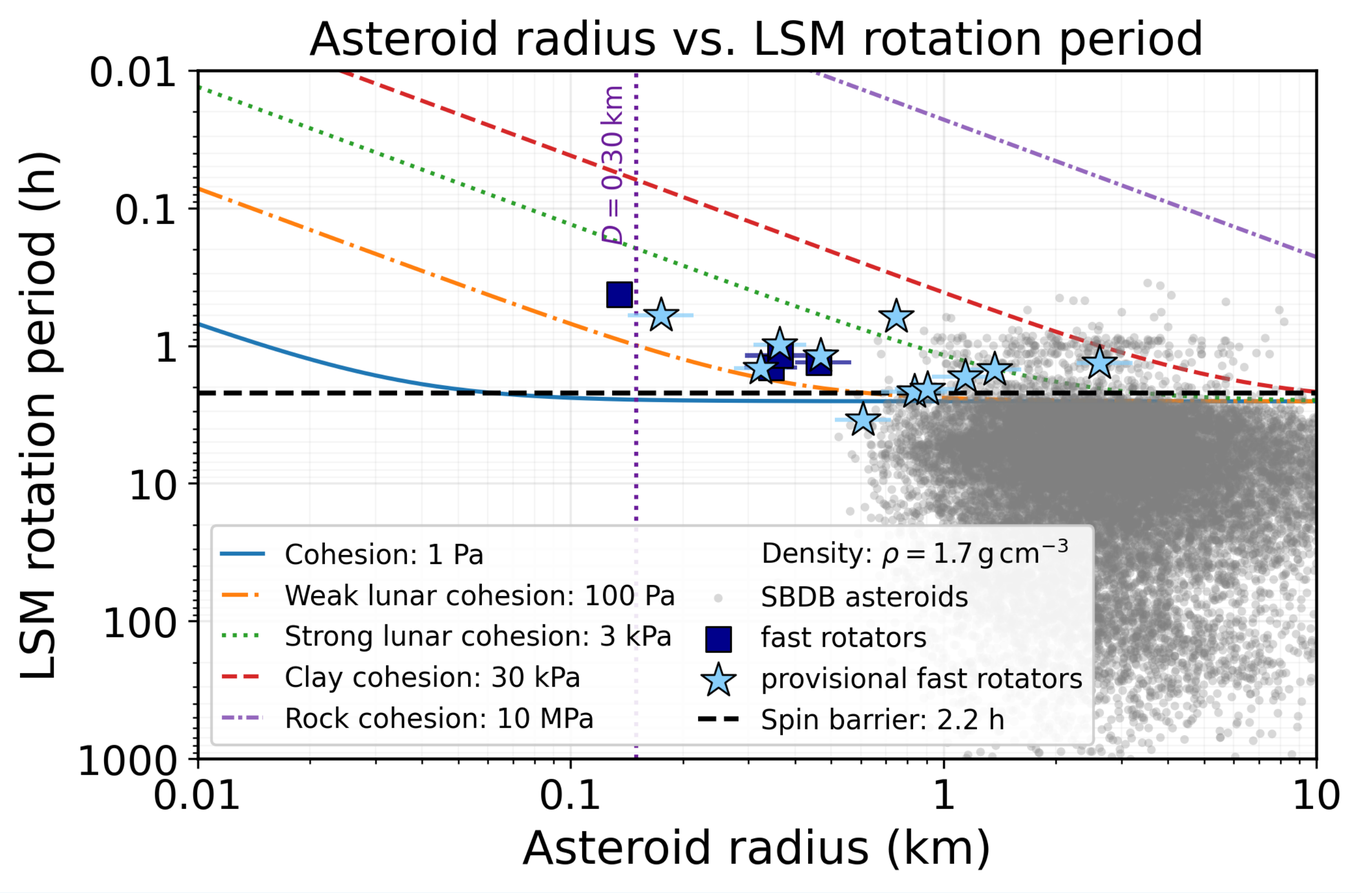
Greenstreet et al. (2026)

Work in Progress: EDP2 Fast Rotators



Mastropietro et al. (2026, in preparation)

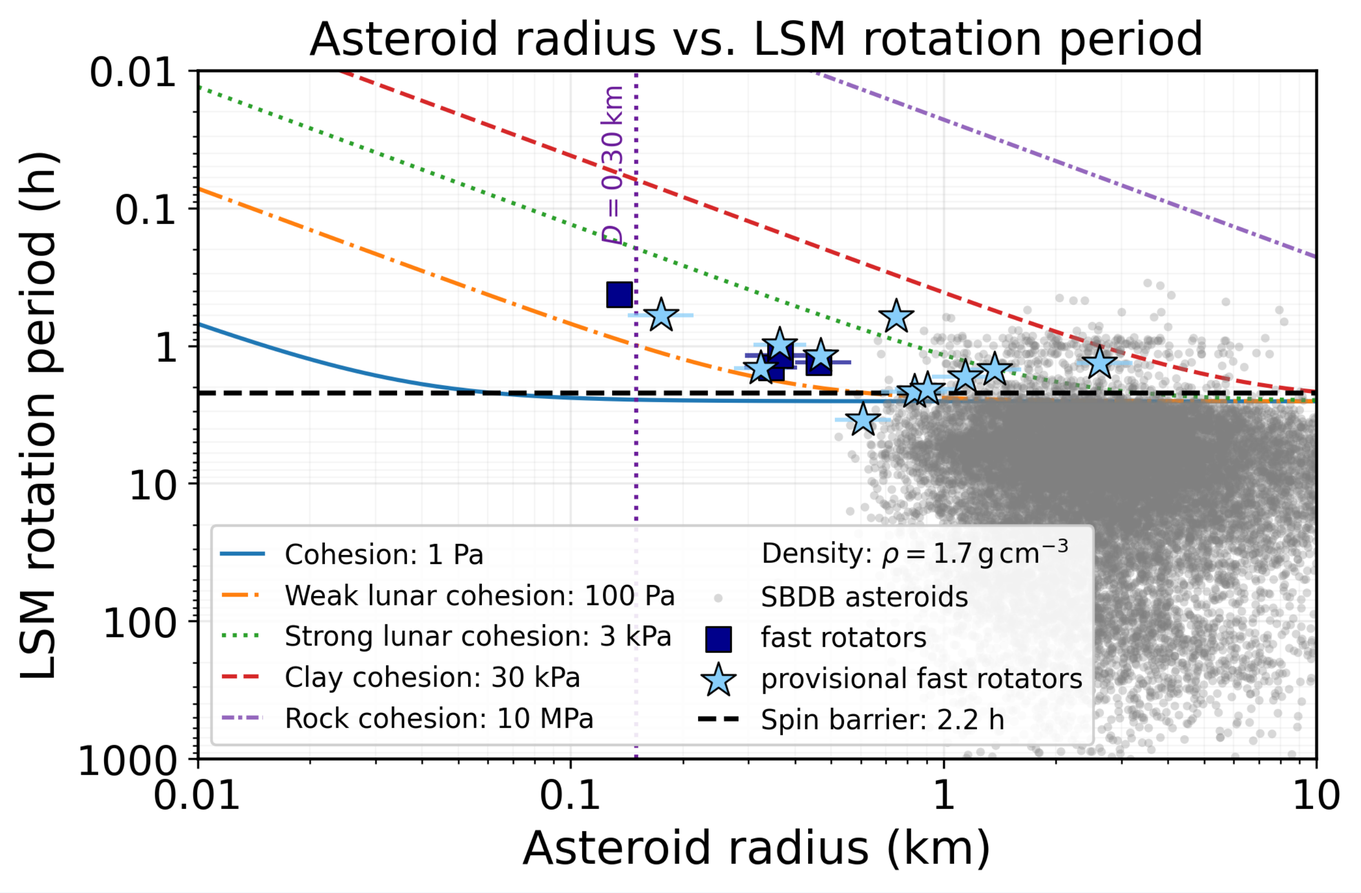
Work in Progress: EDP2 Fast Rotators



- Squares: **Consistent** HOF–LSM periods
- Stars: **Provisional** period solutions

Mastropietro et al. (2026, in preparation)

Work in Progress: EDP2 Fast Rotators

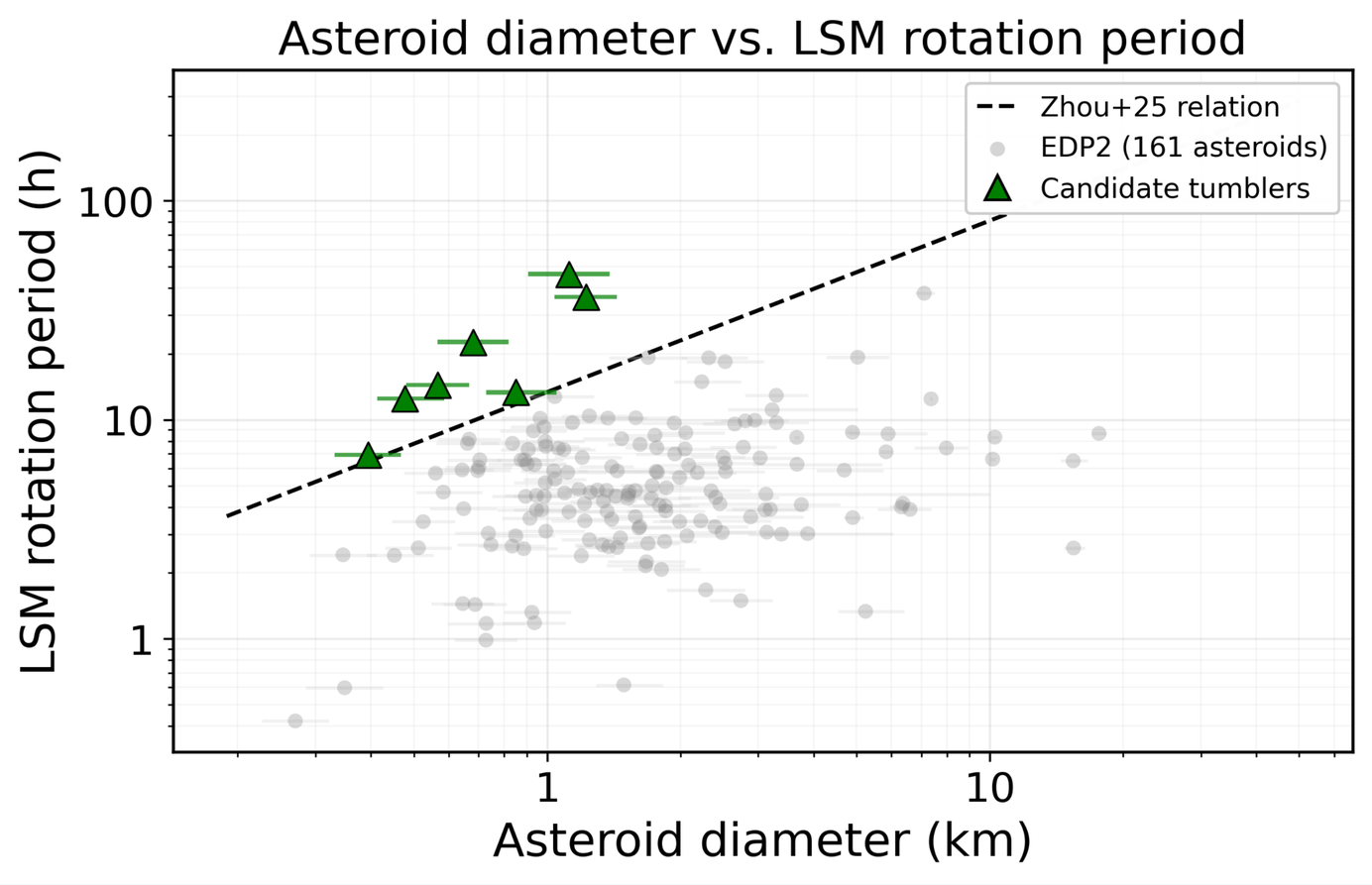


- Squares: **Consistent** HOF–LSM periods
- Stars: **Provisional** period solutions

- **Density test**: the four fast rotators remain between 100 Pa–3kPa cohesion curves

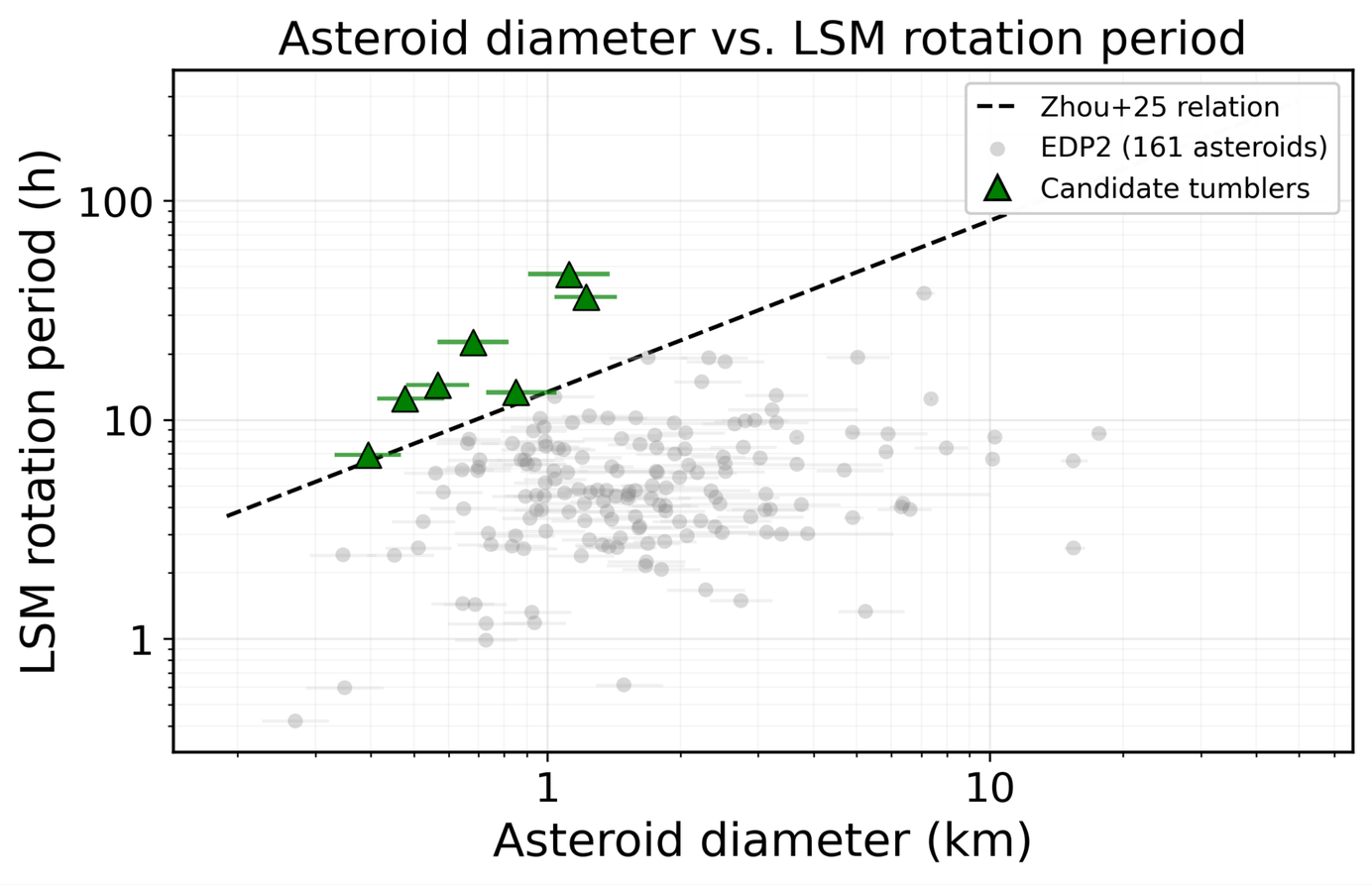
Mastropietro et al. (2026, in preparation)

Work in Progress: EDP2 Candidate Tumblers



Mastropietro et al. (2026, in preparation)

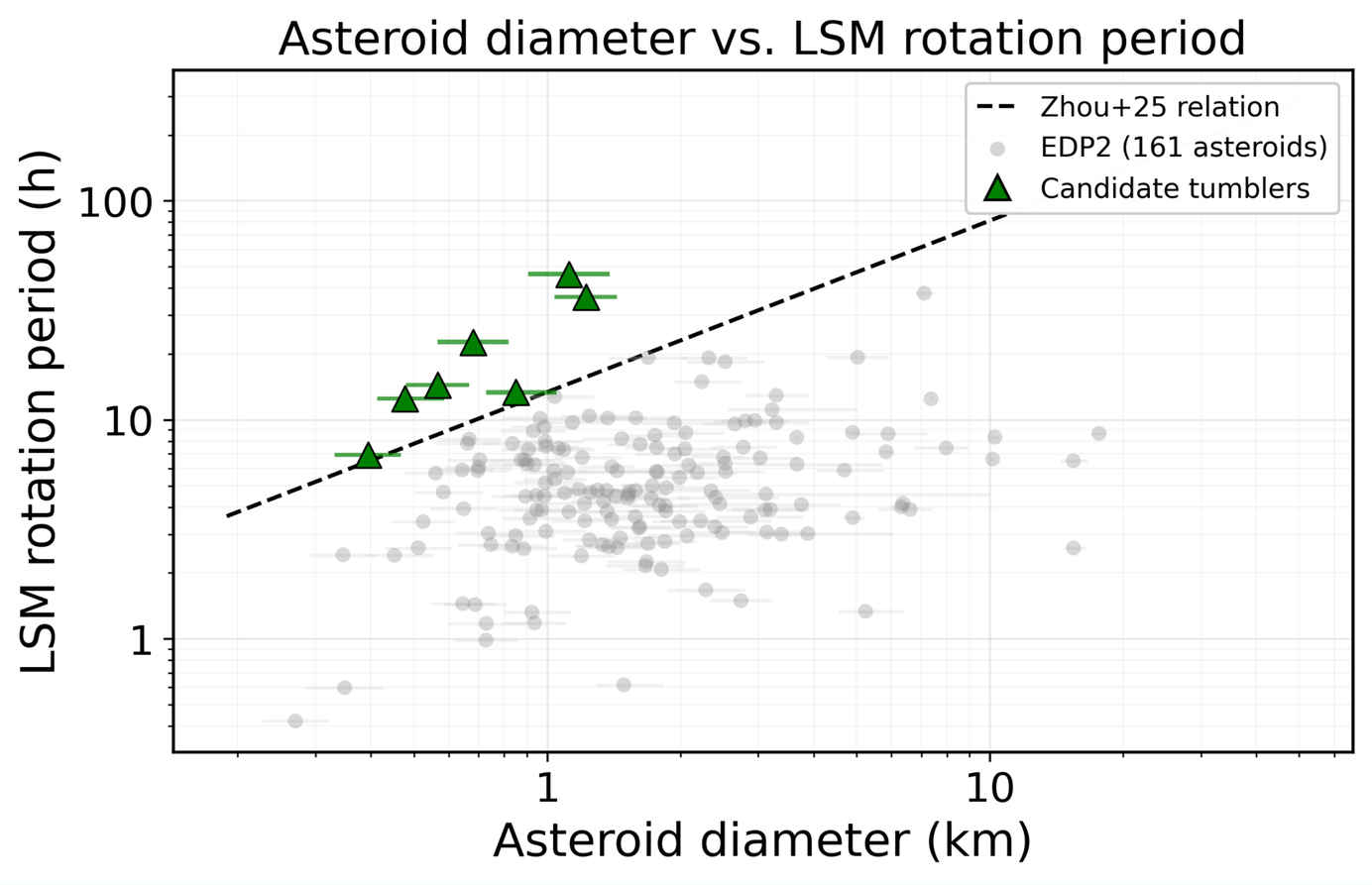
Work in Progress: EDP2 Candidate Tumblers



- **Tumblers**: Non-principal-axis rotation

Mastropietro et al. (2026, in preparation)

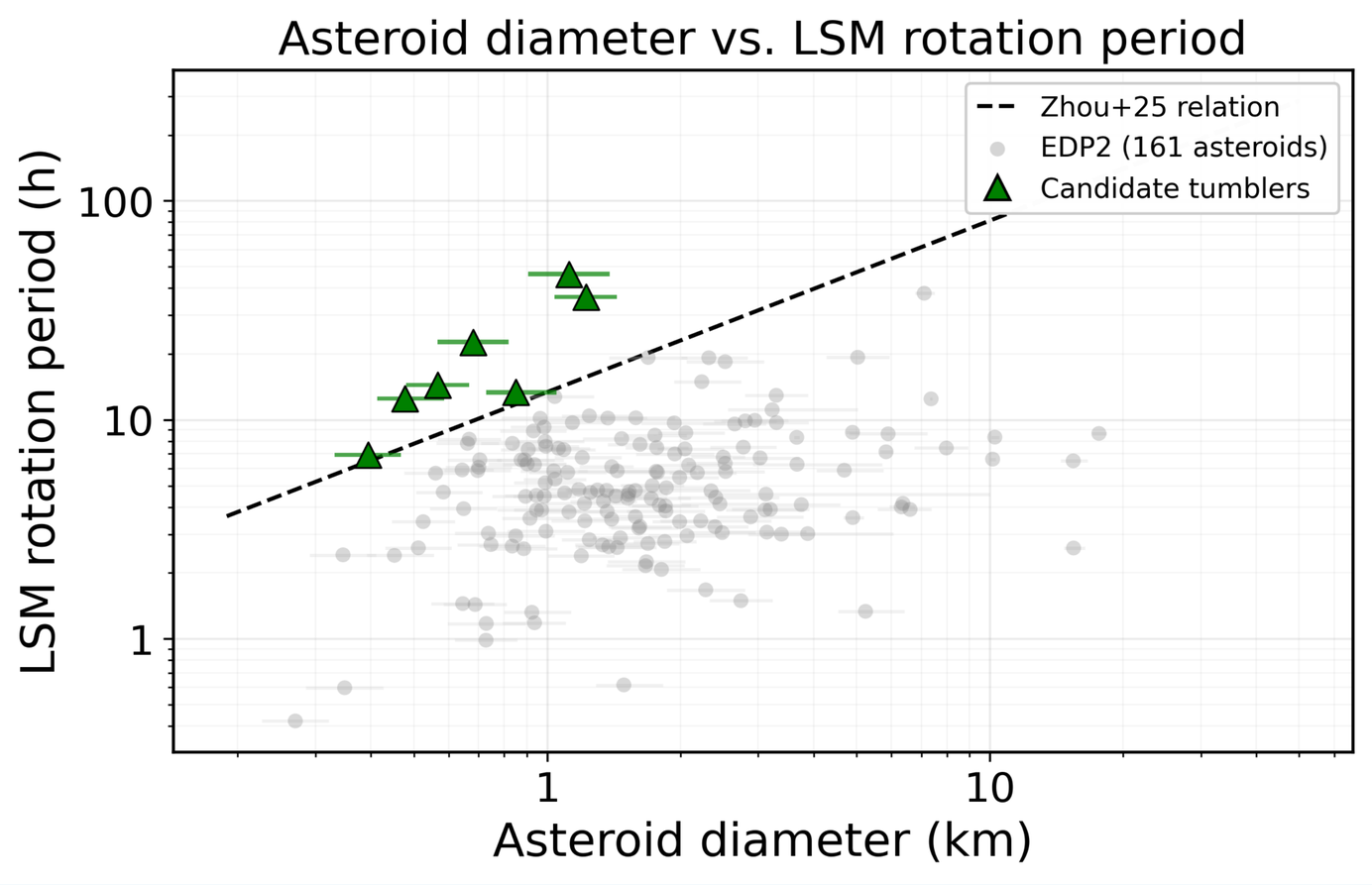
Work in Progress: EDP2 Candidate Tumblers



- **Tumblers**: Non-principal-axis rotation
- **Seven candidates**: Five above and two near the Zhou et al. (2025) relation

Mastropietro et al. (2026, in preparation)

Work in Progress: EDP2 Candidate Tumblers



- **Tumblers**: Non-principal-axis rotation
- **Seven candidates**: Five above and two near the Zhou et al. (2025) relation
- **Further lightcurve analysis required**

Mastropietro et al. (2026, in preparation)

Summary and Outlook

PUBLISHED RESULTS

- **21 previously unrecognized superfast rotators**

Summary and Outlook

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- **21 previously unrecognized superfast rotators**

- No previously published periods or colors

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ONGOING WORK

Extending the analysis to **Rubin EDP2**

- Fast rotators and candidate tumblers

Mastropietro et al. (2026, in preparation)

Publication & Dataset

Publication: Mastropietro, M., Carruba, V., and Bala, M. M., 2026, *Identification of 21 Superfast Rotators in Rubin LSST Data*, RNAAS, 10, 238

Dataset: Mastropietro, M., Carruba, V., and Bala, M. M., 2026, *Rotation Periods, Colors, and Taxonomic Classifications of 21 Superfast Rotators in Rubin LSST Data*, Zenodo

Paper

Dataset

REFERENCES

- Carruba et al. (2026): PSS, 283, 106350
- Greenstreet et al. (2026): ApJ, 996(2), L33
- DeMeo and Carry (2013): Icarus, 226(1), 723-741
- Zhou et al. (2025): Nature Astronomy, 9, 493-500

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