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Small Solar System Bodies Science with Ariel

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with thanks to the Ariel Complementary Science Working Group

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Background

Small Solar System Bodies (SSSBs) preserve the formation history of the Solar System.

Their Near-infrared (NIR) spectra provide crucial information [1,2,3] on:

- Water-related materials
- The origin of life

Key diagnostic features:

- 2.7 μm \rightarrow hydrated minerals
- 3.1 μm \rightarrow water ice
- 3.4 μm \rightarrow organics & carbonate

These wavelengths suffer from strong atmospheric absorption (Fig.1).

- Limited observations possible for bright asteroids
- Space telescopes provide significantly higher-quality data

After the survey using the AKARI satellite (2008–2010), high-quality NIR (incl. 3 μm) observations remain limited. We evaluate the observability of SSSBs with Ariel.

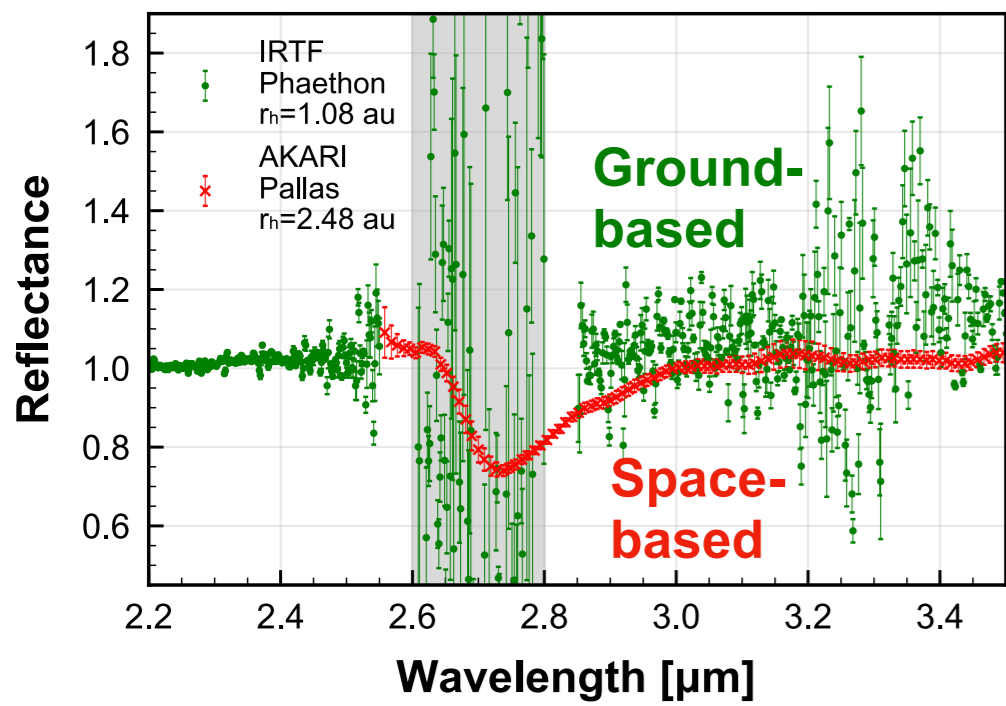


Fig.1. Reflectance spectra of near-Earth asteroid Phaethon [4] and main-belt asteroid Pallas [2].

Methods

- Sample selection (Fig.2):
 - 1,458,430 known SSSBs (The MPC Orbit Database)
- Screening using:
 - absolute magnitude (H)
 - orbital elements (q and Q)
- Query via JPL Horizons (@gaia)
 - V-band magnitude
 - Solar elongation
 - Coordinates
 - Sky motion
- Survey Period :
 - Jan 2032 – December 2035

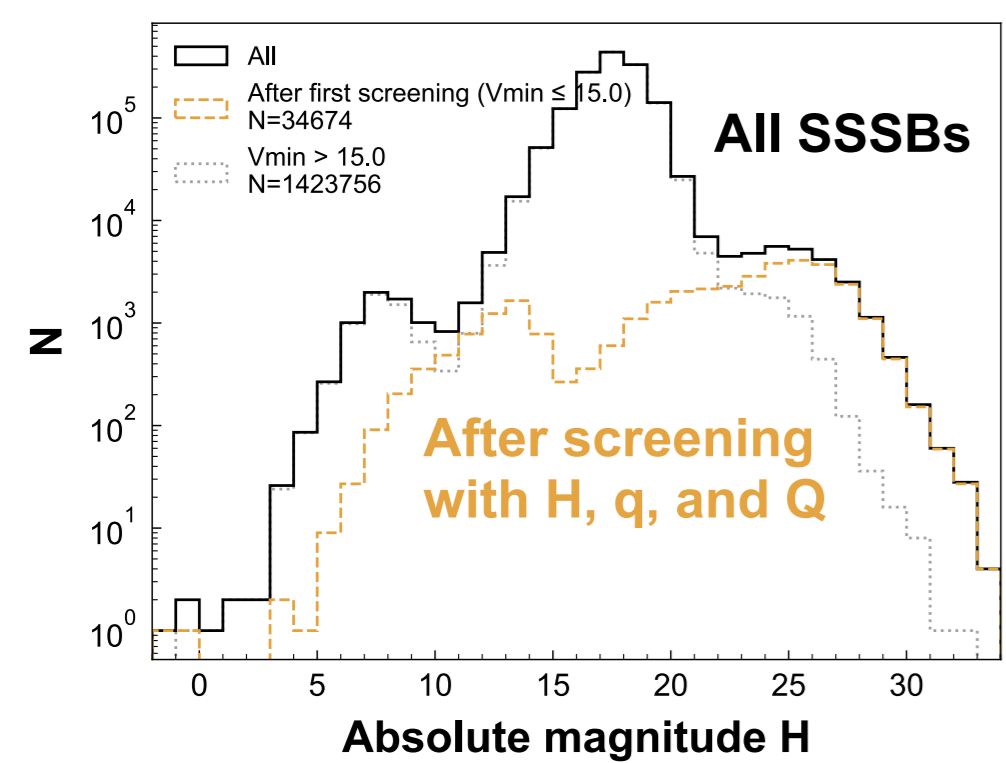


Fig.2. Absolute magnitude distribution of SSSBs.

Take-home message

Surveying **~800 small Solar System bodies** with Ariel (tentative visibility limit of $V < 15$ & solar elongation between 70° and 110°) will map hydrated minerals, including the 3 μm band, to probe the origin of Earth's water and life. Targets span from main-belt asteroids to near-Earth asteroids relevant for planetary defense. The combination of target brightness and apparent sky motion (~ 10 milliarcseconds/s) ensures high-quality observations, enabling robust science and making this a **flexible and competitive complementary science (CS) program**.

Results

Potential Candidates

With a tentative visibility limit ($V < 15$, solar elongation 70° – 110°): **808** unique candidates (Fig.3)

- NEA $N=24$ ($\sim 3.0\%$)
- MBA $N=774$ ($\sim 95.8\%$)
- Others $N=10$ ($\sim 1.2\%$)

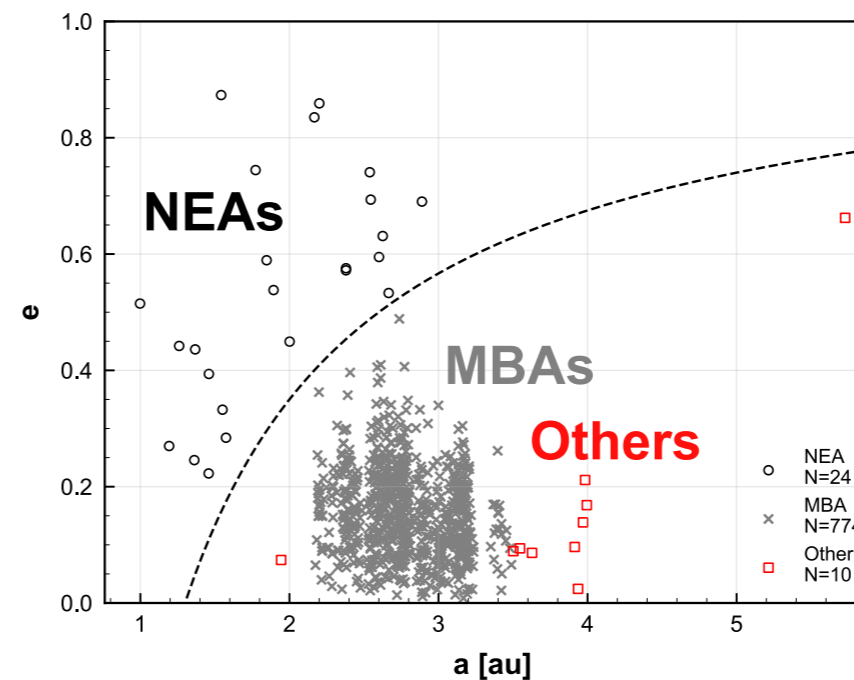
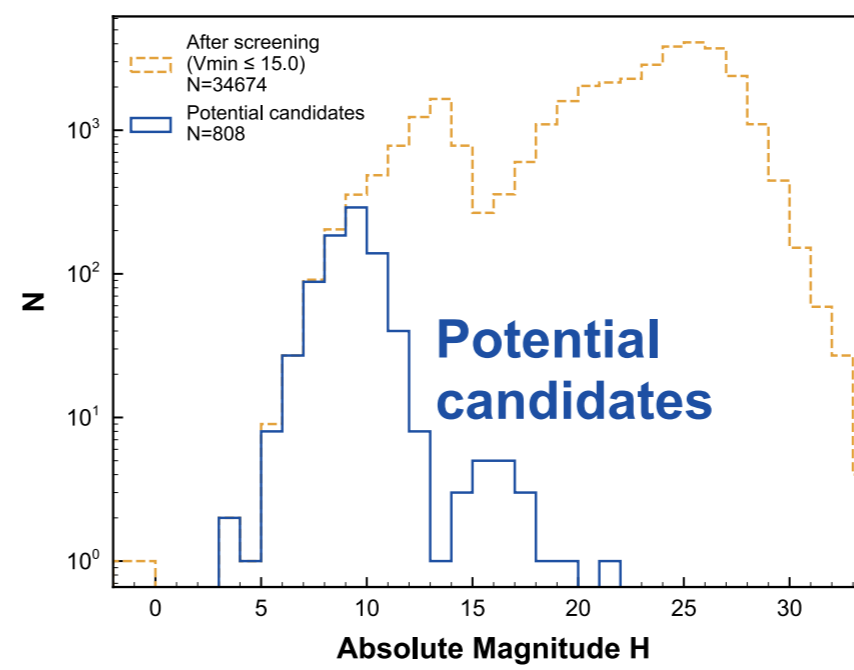


Fig.3. (top) Absolute magnitude distribution of candidate SSSBs. (bottom) Semi-major axis vs. eccentricity of candidate SSSBs.

Observable Targets Over Time

At any time, Ariel can observe

- $V < 15$: $N \sim 109$
- $V < 14$: $N \sim 53$
- $V < 13$: $N \sim 21$
- $V < 12$: $N \sim 8$

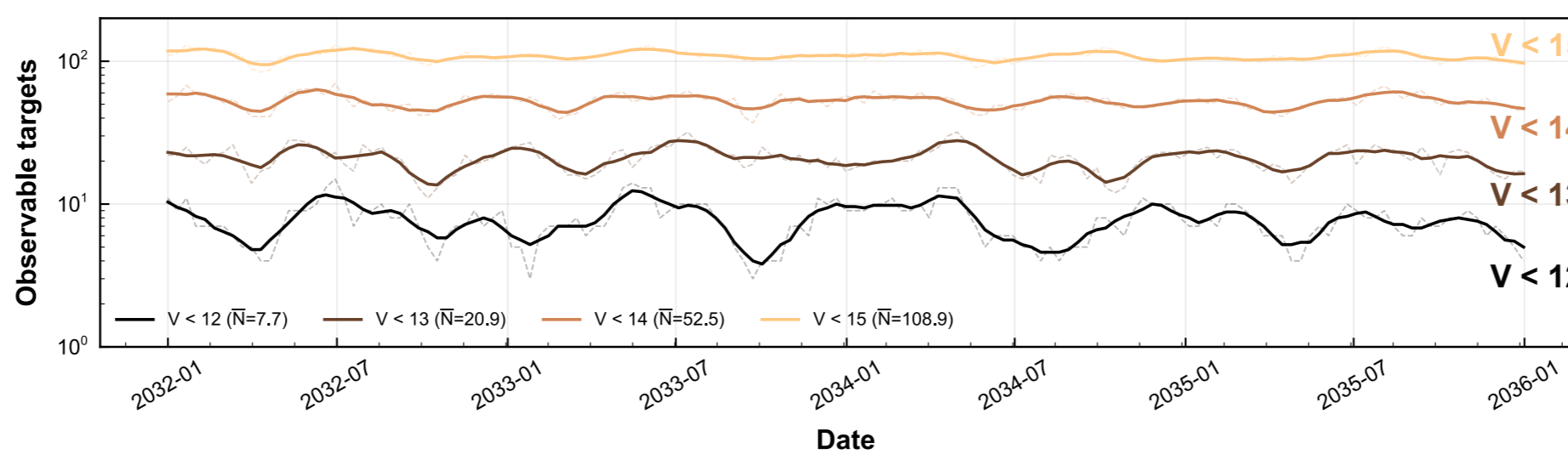


Fig.4. Number of observable targets over time.

Assuming brightest SSSBs observed first and **no overlaps**: (3-day, 7-day, 30-day cadence) \rightarrow ($N=487$, $N=209$, $N=48$)

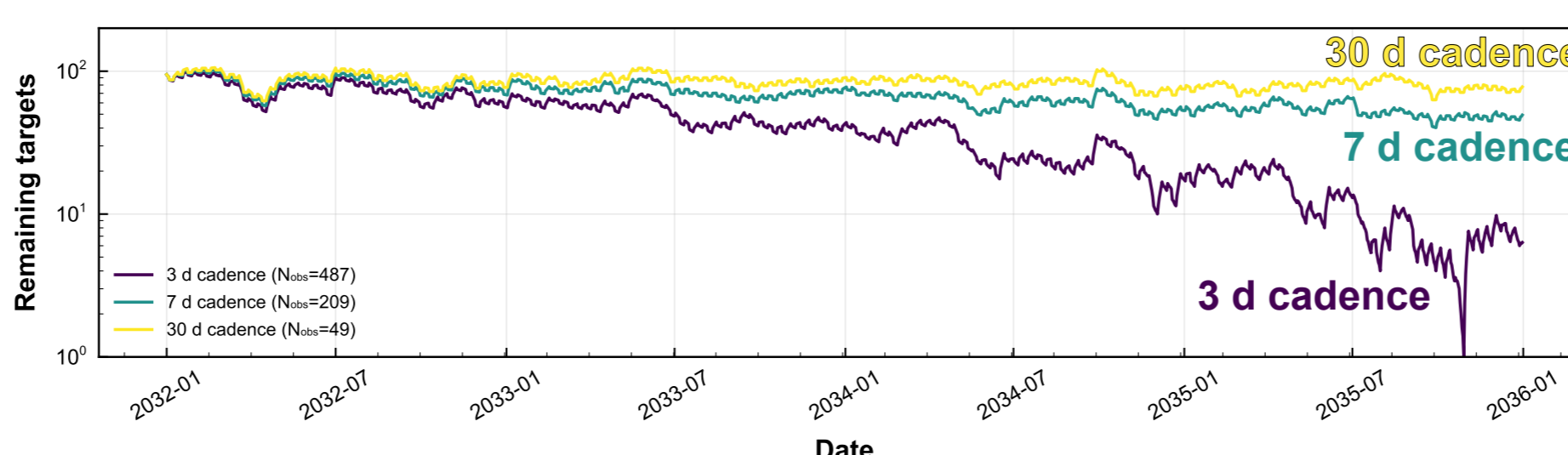


Fig.5. Number of remaining observable targets over time.

Discussion

Comparison with AKARI

Ariel candidates includes all 66 SSSBs observed with AKARI/Infrared camera (IRC) [2].

\rightarrow Provides a **more diverse sample** and allows **validation of results**

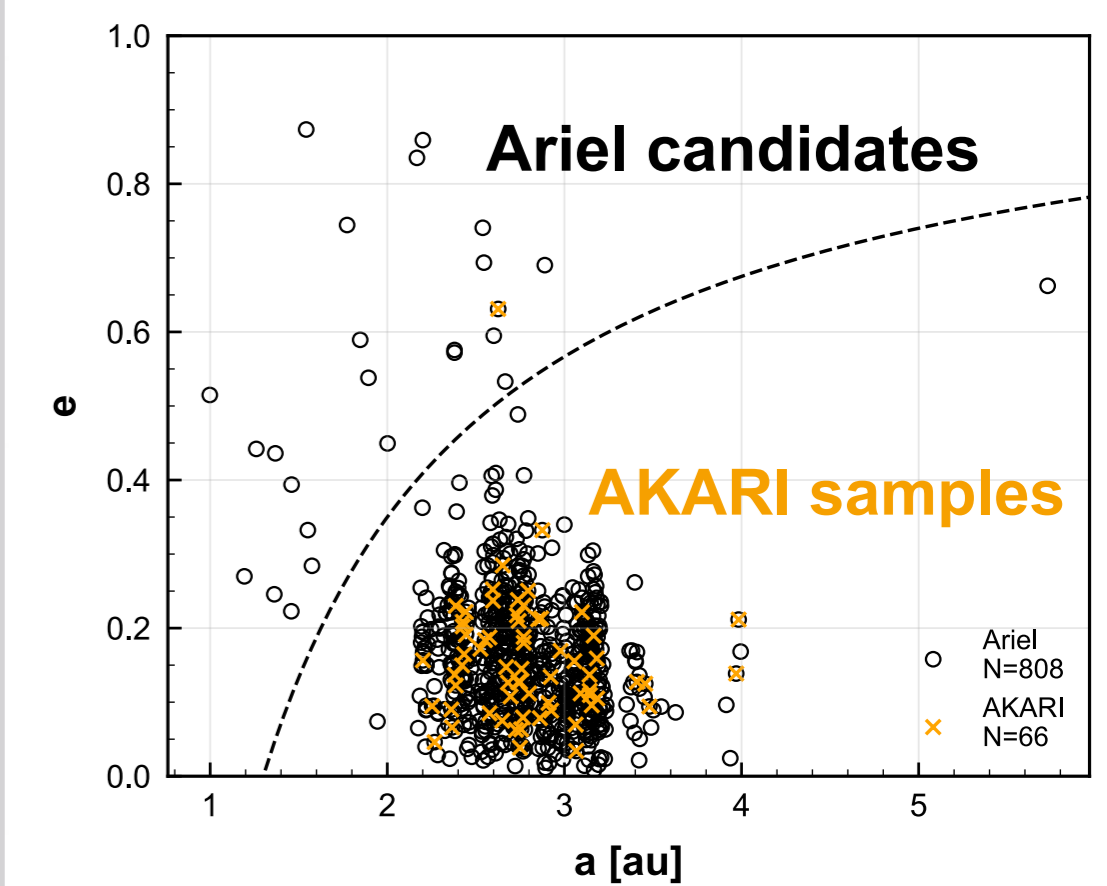


Fig.6. Semi-major axis vs. eccentricity of Ariel candidate and AKARI/IRC Observed SSSBs.

Sky motion

Ariel candidates exhibit very slow sky motion (~ 10 milliarcseconds/s), comparable to that of planets (Fig. 7).

\rightarrow **Flexible and competitive targets** for complementary science (CS)

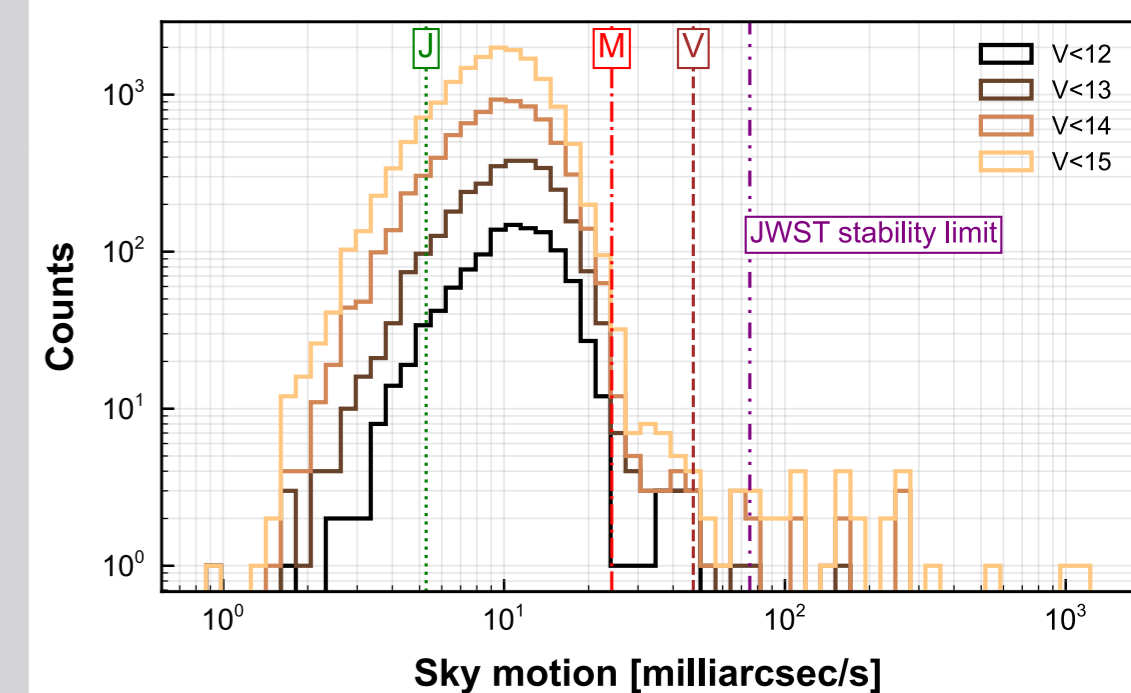


Fig.7. Apparent sky motion of Ariel candidates. Vertical lines indicate the typical sky motion of Jupiter, Mars, and Venus, as well as the JWST stability limit.

Future works

- Assess S/N of key absorption bands (e.g., hydrated minerals at 2.7 μm , water ice at 3.1 μm)
- Simulate spectra accounting for apparent sky motion
- Remove and/or assess thermal tail at longer wavelengths
- Evaluate surface heterogeneity via multiple observations at different rotation phases

References

[1] Takir, D. & Emery, J. P. (2012) "Outer Main Belt asteroids: Identification and distribution of four 3- μm spectral groups", Icarus, 219, 641. [2] Usui, F. et al. (2019) "AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec", PASJ, 71, 1. [3] Rivkin A. S. et al. (2025) "Observations and Quantitative Compositional Analysis of Ceres, Pallas, and Hygiea Using JWST/NIRSpec", PSJ, 6, 9. [4] Takir, D. et al. (2020) "Near-infrared observations of active asteroid (3200) Phaethon reveal no evidence for hydration", Nat. Comm., 11, 2050.