Asteroid hunting with PUNCH

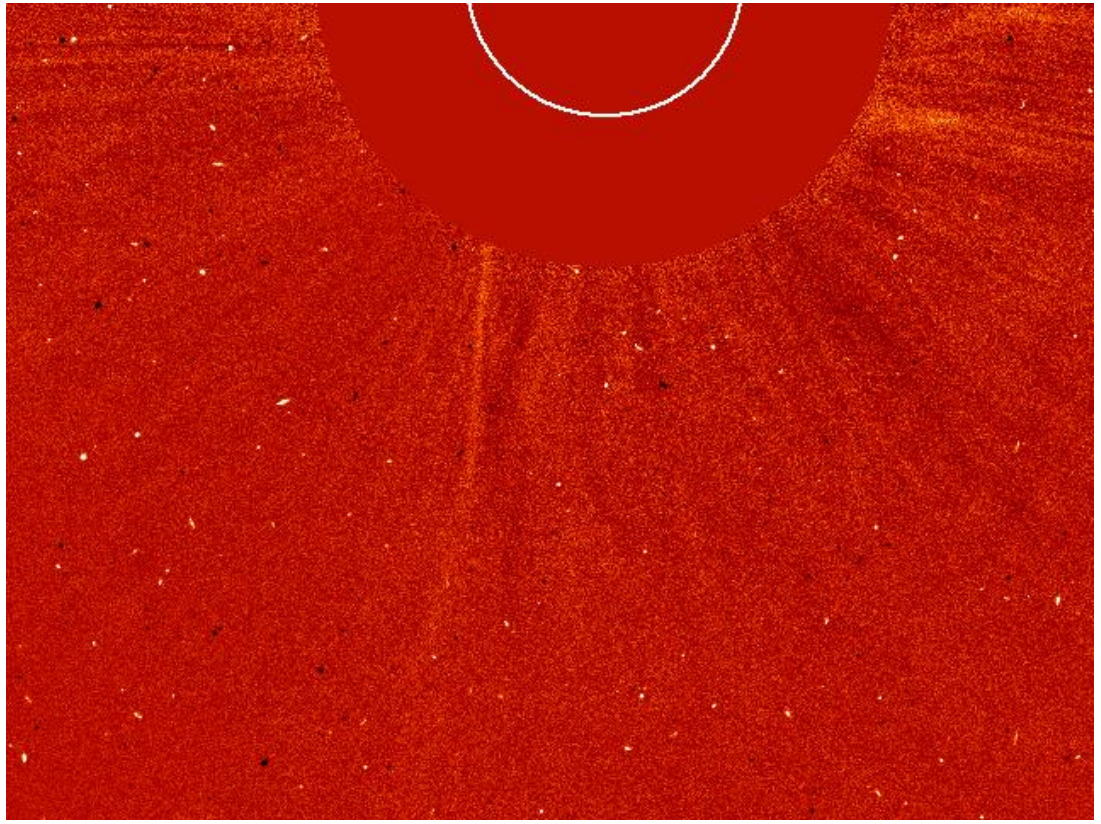
Kevin Walsh, Simon Porter, Rogerio Deienno, Craig DeForest, Marcus Hughes (SwRI)

Leveraging PUNCH for solar system objects

- **Low solar elongation**
- **Constant imaging cadence**
- **Polarimetry**

Leveraging PUNCH for solar system objects

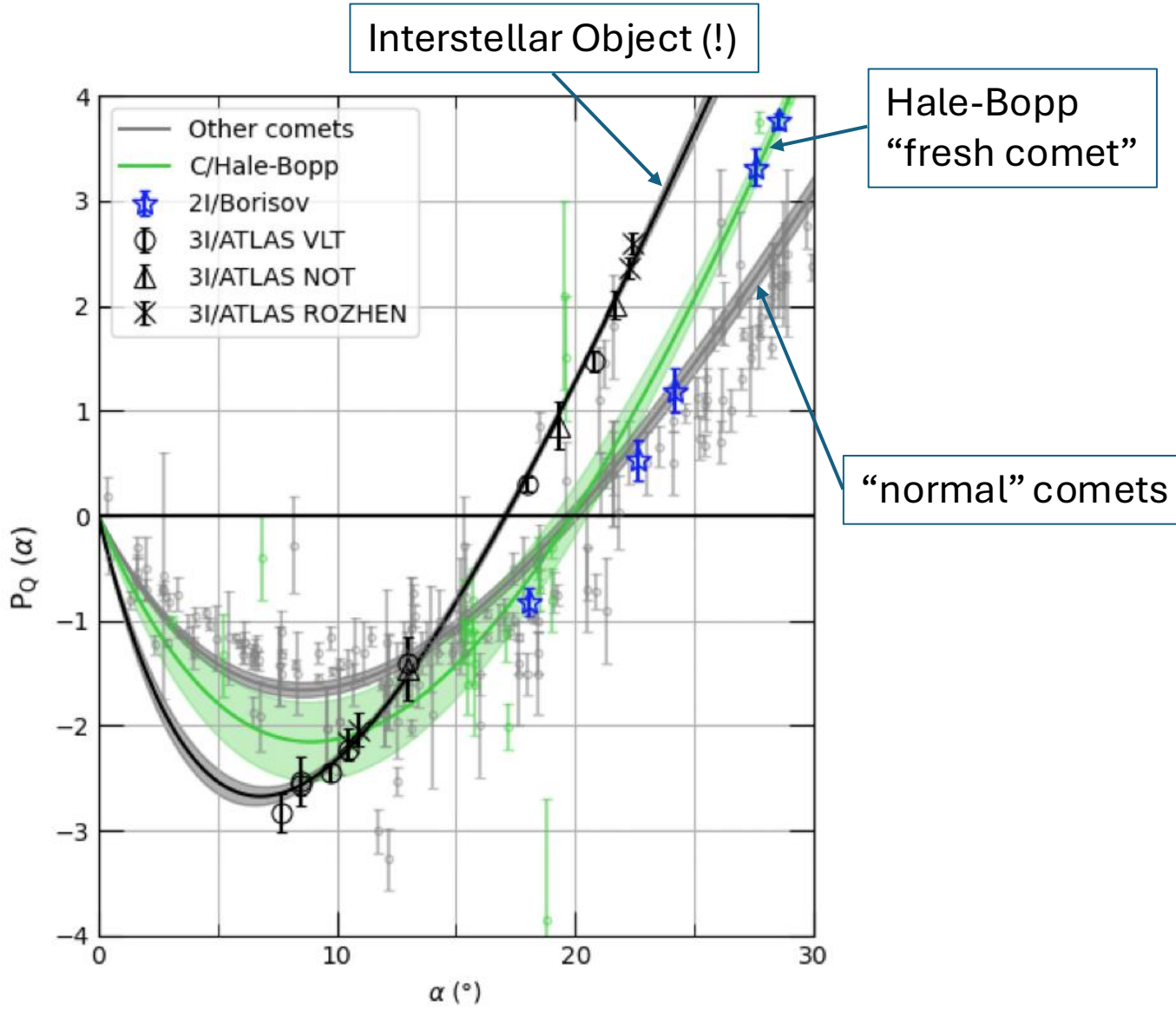
- **Low solar elongation**
  - Maximal heating for comets/asteroids
  - THIS IS WHEN SOME OBJECTS GO BOOM!
  - Exploring wide range of phase angles rapidly
    - Rare chance to see phase angle above 90 deg. (when objects pass between Earth-Sun)



This isn't entirely new – SOHO has been seeing comets for decades

Leveraging PUNCH for solar system objects

- **Constant imaging cadence**
  - Can't be matched by any ground-based observatory
  - Many all-sky ground based telescopes can go deeper, but are limited by solar elongation restrictions (and weather).
- **Polarimetry**
  - Reports on comet dust properties
  - Asteroid physical properties



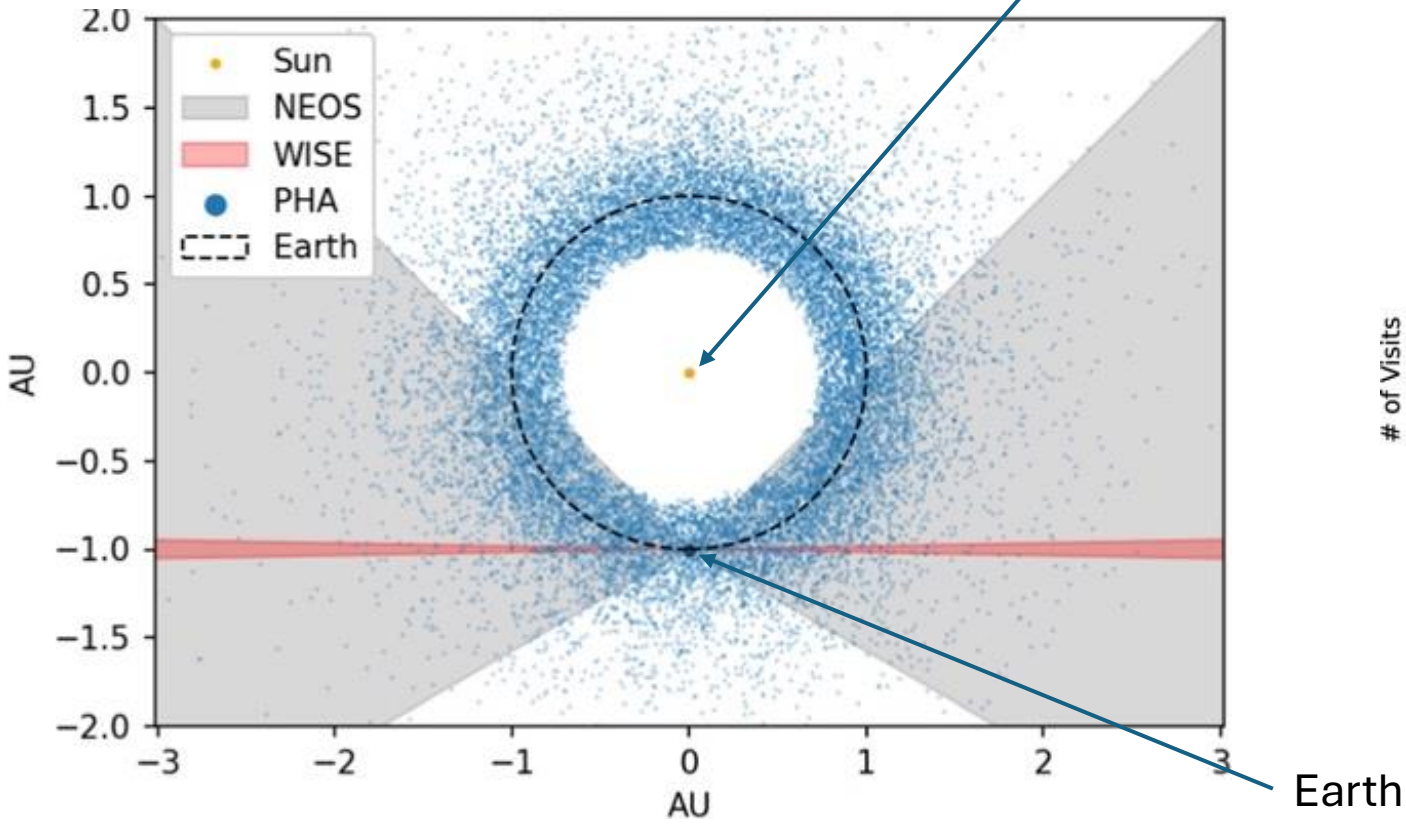
PUNCH solar system targets

- Asteroids – PUNCH looks where no one else does
  - Discovering near-Earth asteroids is big business – NASA is required to do this
  - Scientifically interesting for a bevy of reasons
  - Numerical models predict a sizeable number of Earth crossing asteroids that spend A LOT of time in the PUNCH field of view and no time in typical surveys.

- Comets – tracking and polarimetry (Simon talked about this)
  - Comets activity increases dramatically near Sun
  - Comets often brighten at phase angle > 90deg, offering a chance to study forward scattering off dust in the coma

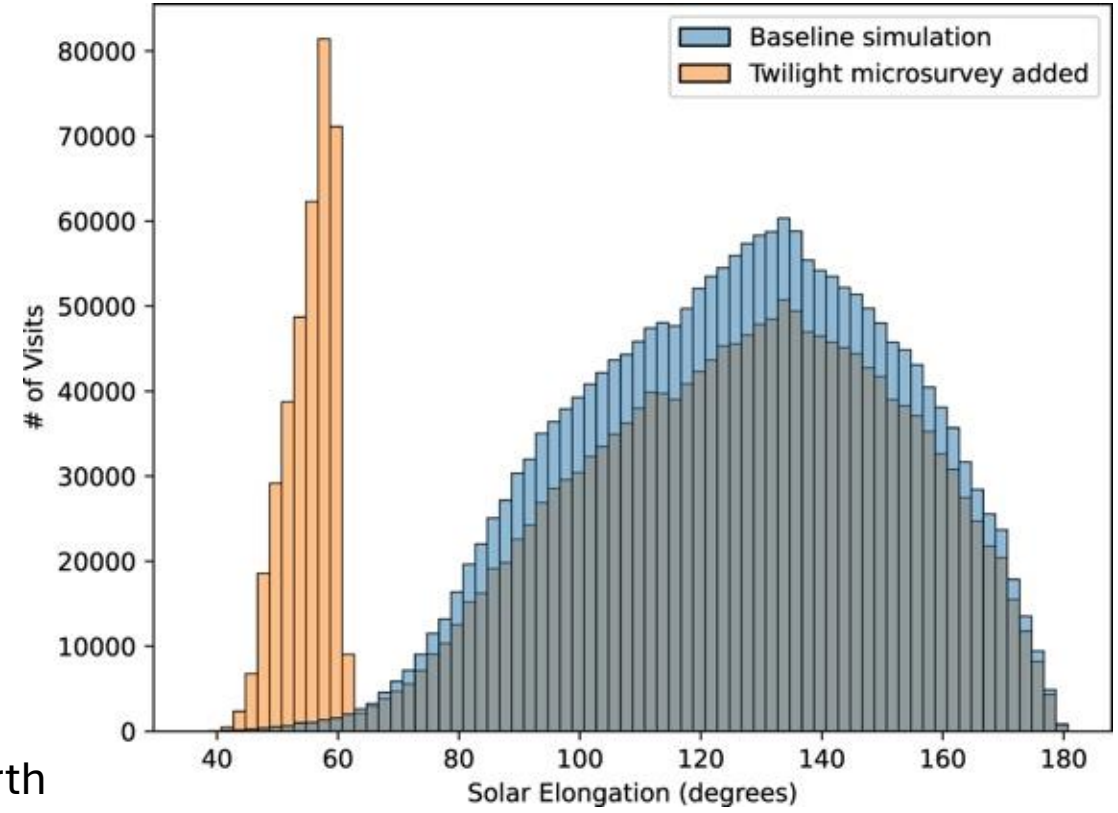
PUNCH is *always* looking where nearly everyone else can *never* look

NEO Surveyor



Mainzer et al. 2023

LSST



Schwamb et al. 2023

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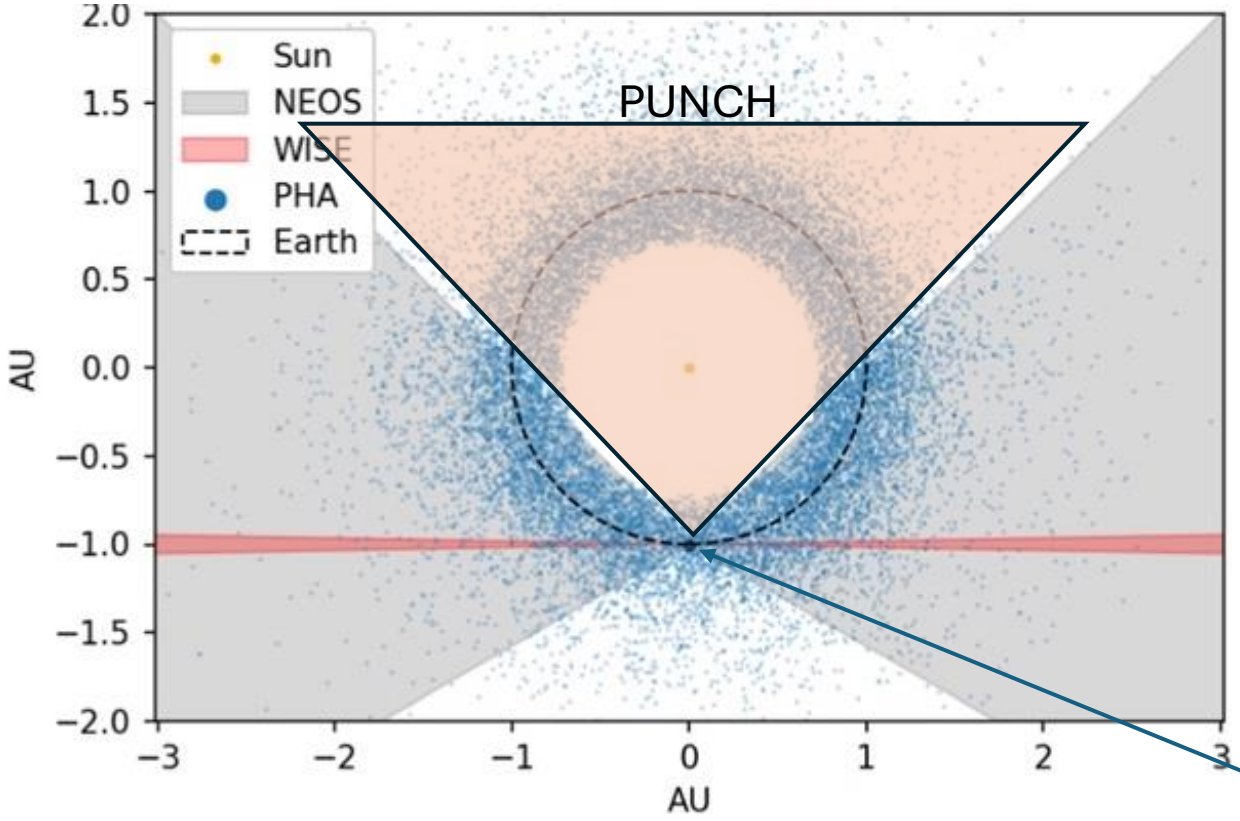

Mainzer et al. 2023

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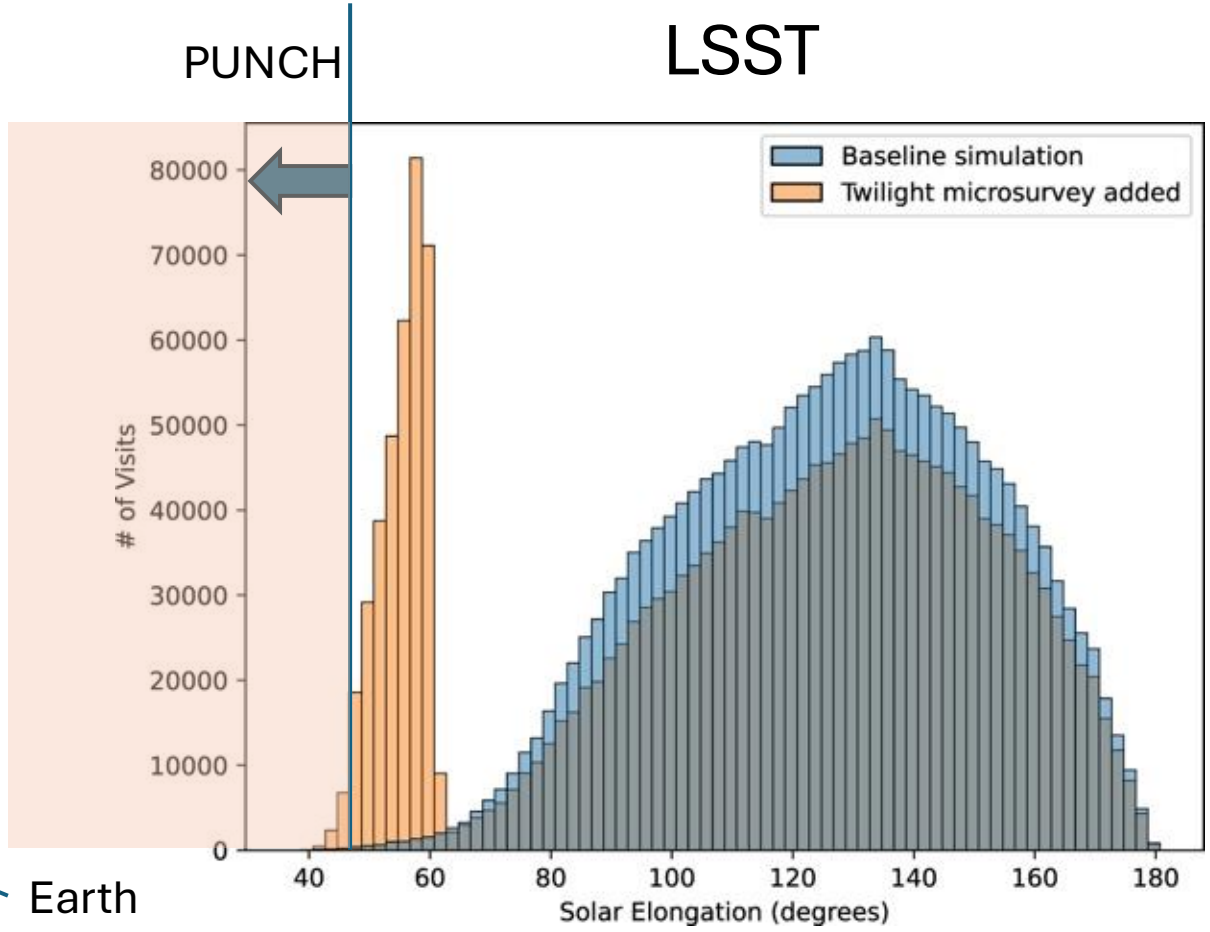


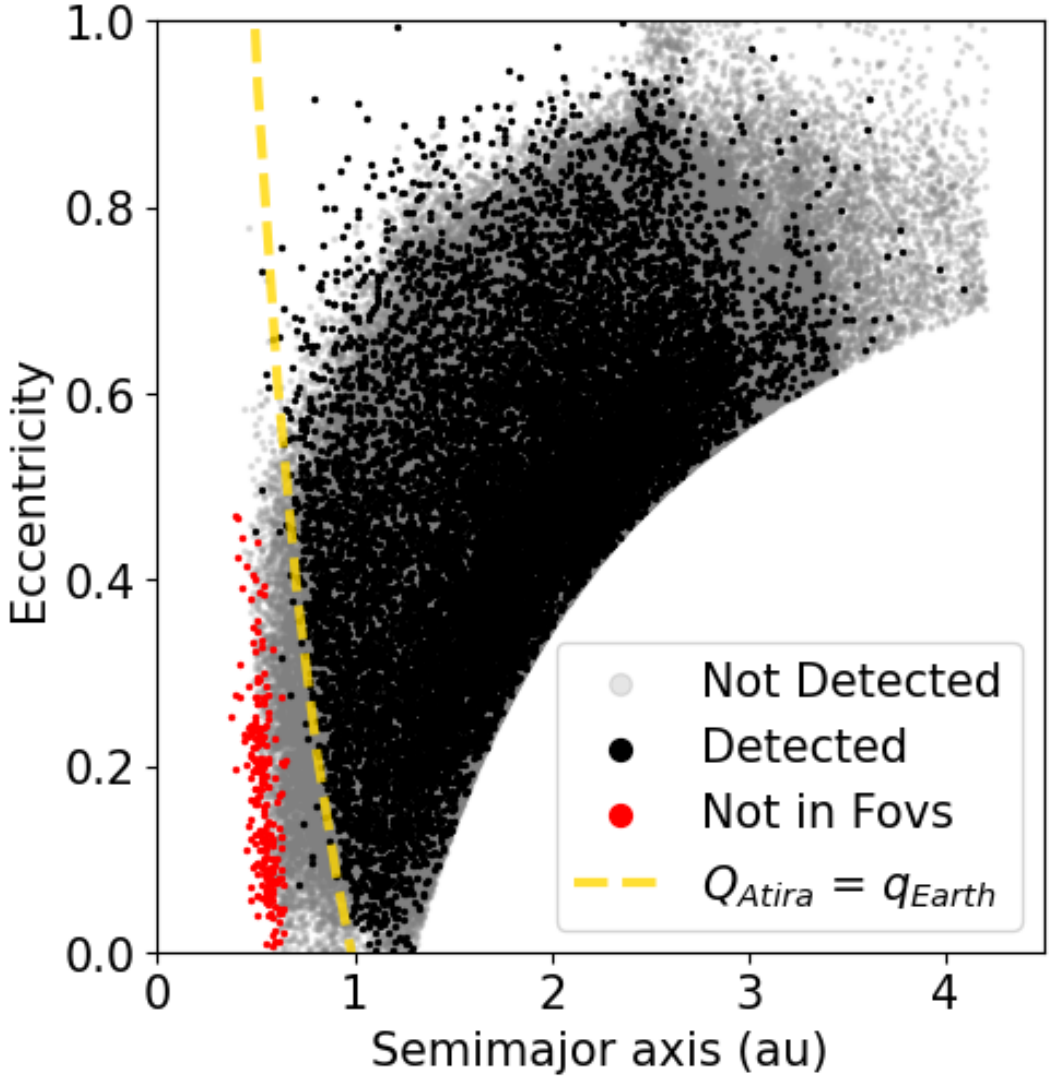
Earth

Schwamb et al. 2023

But is there anything there to find?

- At SwRI in Boulder, a population model for NEOs has been developed – “NEOMOD”

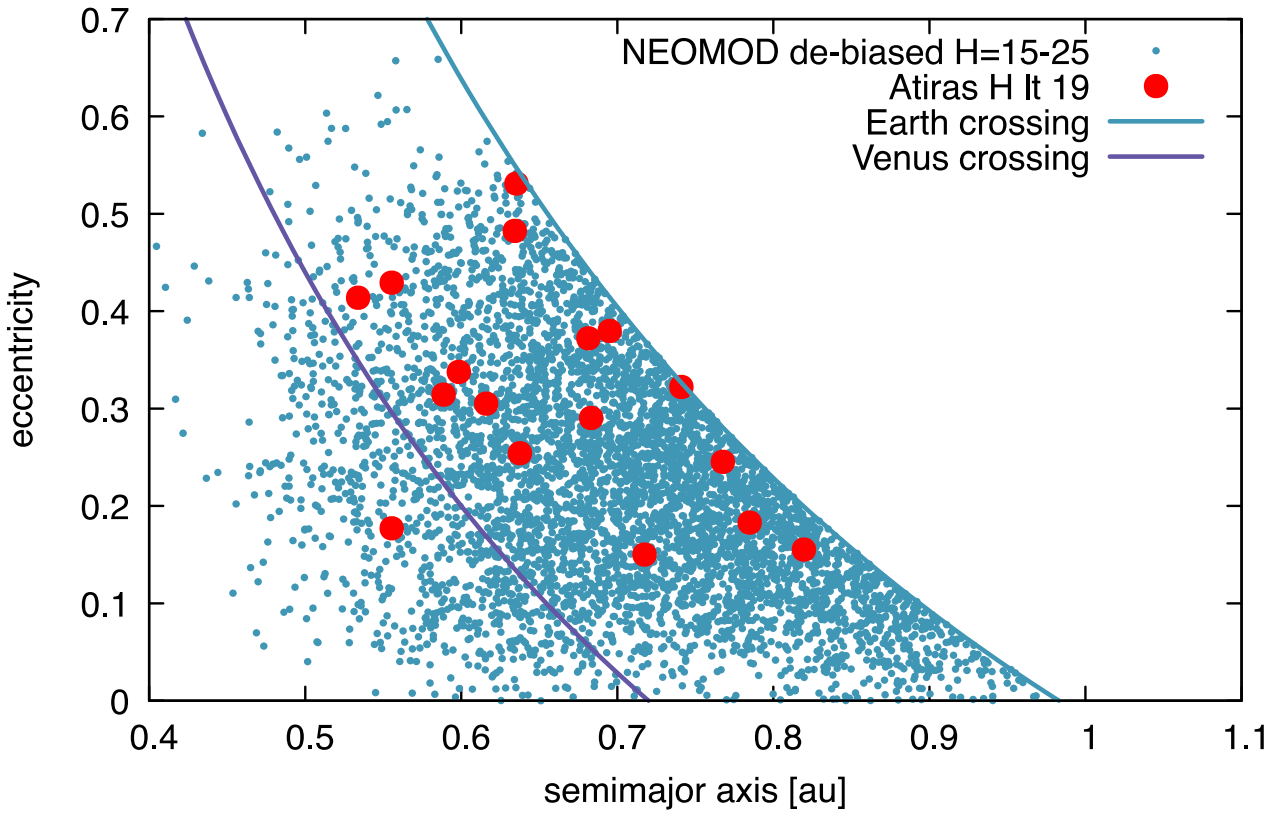
- It uses dynamical models, constrained by calibrated asteroid surveys (CSS, ATLAS) to predict the actual population based on the reported discoveries and reported observing strategies
  - Black dots are detections
  - Gray dots are predicted, but not detected
  - Red dots are predicted and never even crossed the FOV of a survey



Deienno et al. 2024

But is there anything there to find?

- There are ~30 asteroids known on orbits entirely inside that of the Earth (8 > 1km)
- There is one that orbits entirely inside the orbit of Venus



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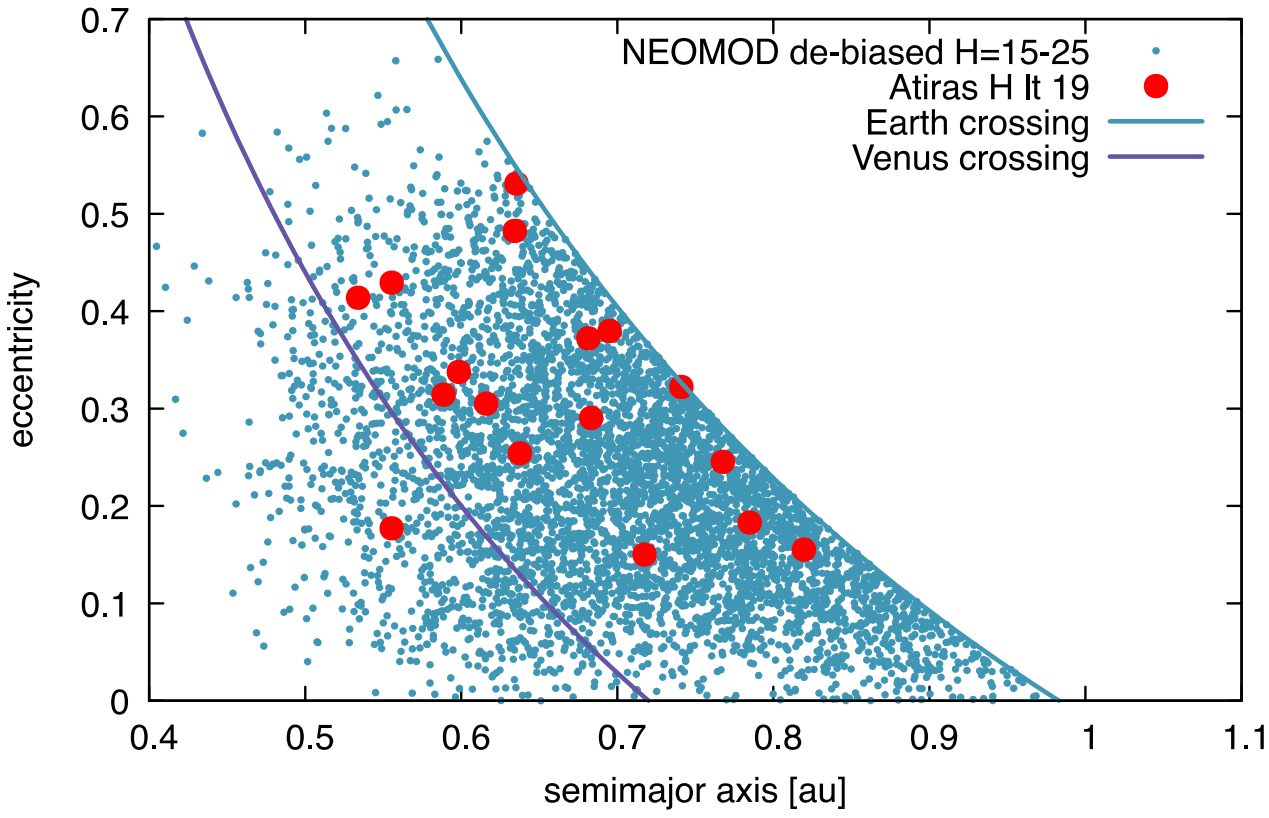
- Population model NEOMOD predicts 15 > 1km



There is value in finding these

- NASA mandated to do so
  - George E. Brown, Jr. NEO Survey Act objective of detecting, tracking, cataloging, and characterizing at least 90% of NEOs equal to or larger than 140 m in diameter

- NASA puts significant resources into this effort
  - NEO Surveyor is a nearly billion dollar space telescope built for this purpose
  - Funds Catalina Sky survey, ATLAS survey….

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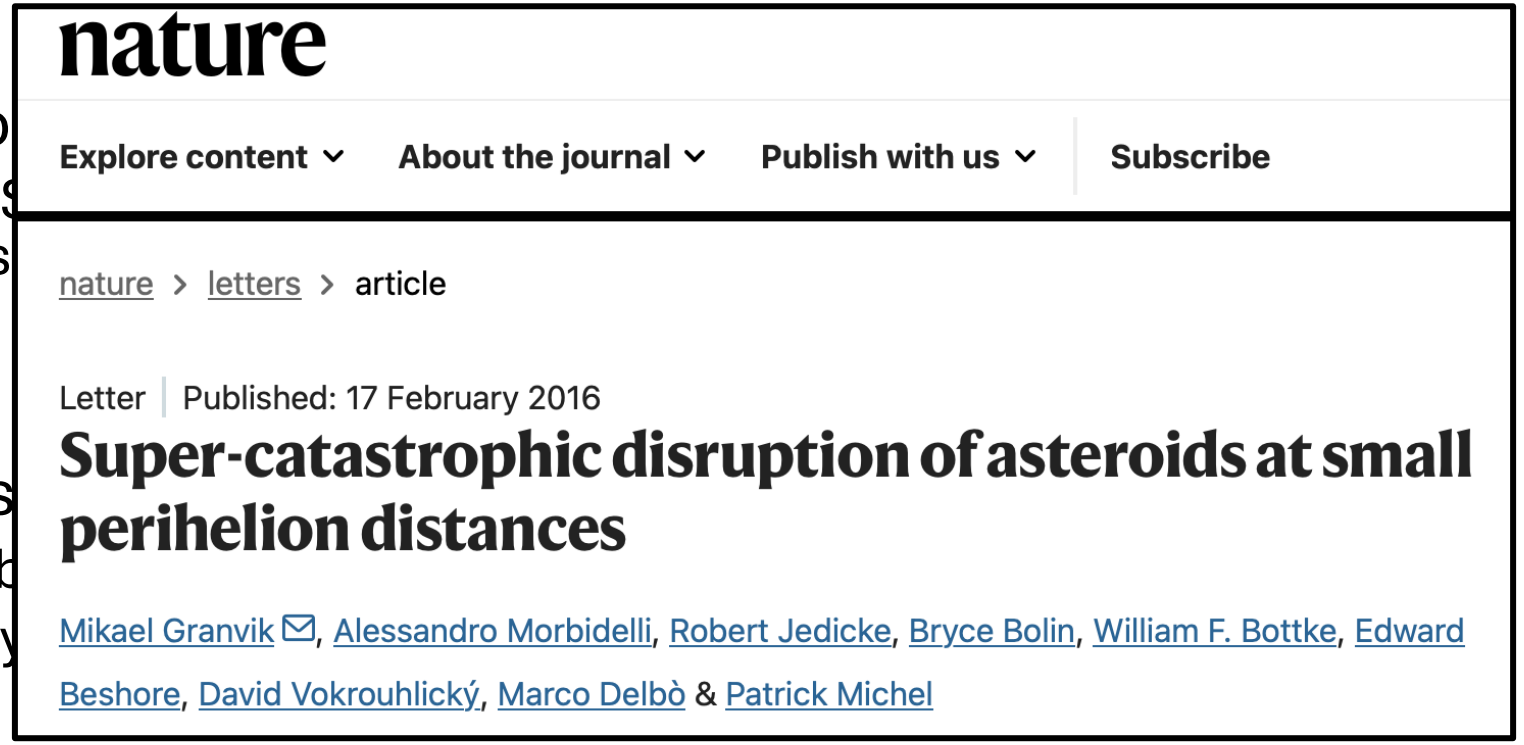
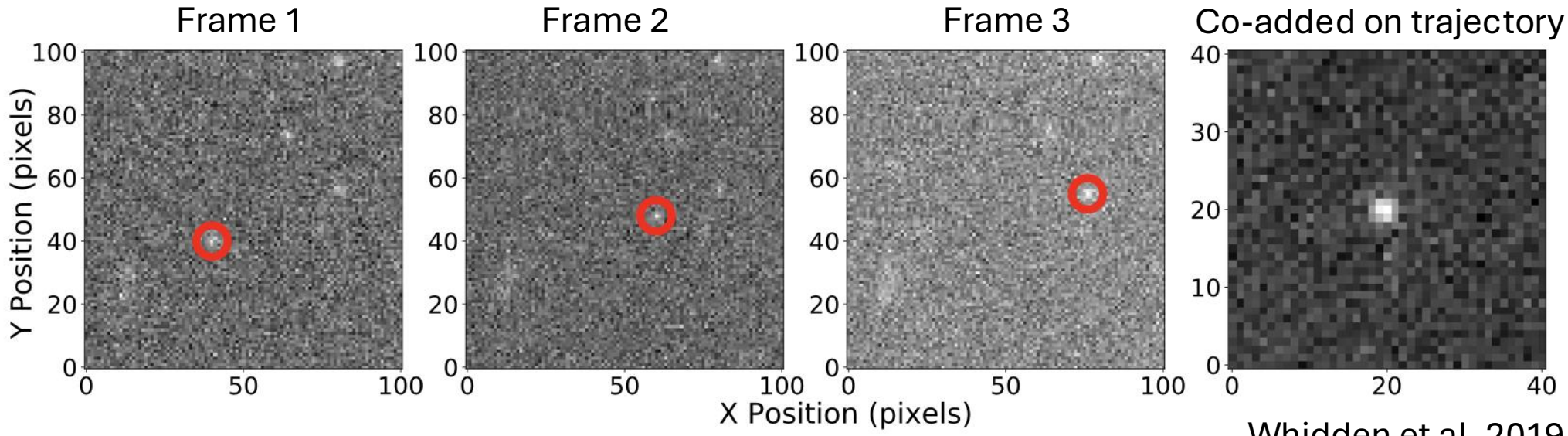
  - Funds Catalina Sky survey
- Interesting science in constraining the population models and understanding physical mechanisms of asteroid fragmentation/disruption



Shift+stack tracking of moving objects

- For a pixel in an image – shift and then stack all subsequent images along all possible trajectories
  - Repeat at all pixels
- Ideal GPU problem.
- We have good knowledge of possible trajectories (NEOMOD)



Whidden et al. 2019

We can get to ~14.5th magnitude

- 15hr of Clear images we can find ~13.5mag asteroid
- 15hr of clear images (barely) finds ~14.5 mag asteroid
- 15.5 mag… not so much (in 24+hr of exposure)

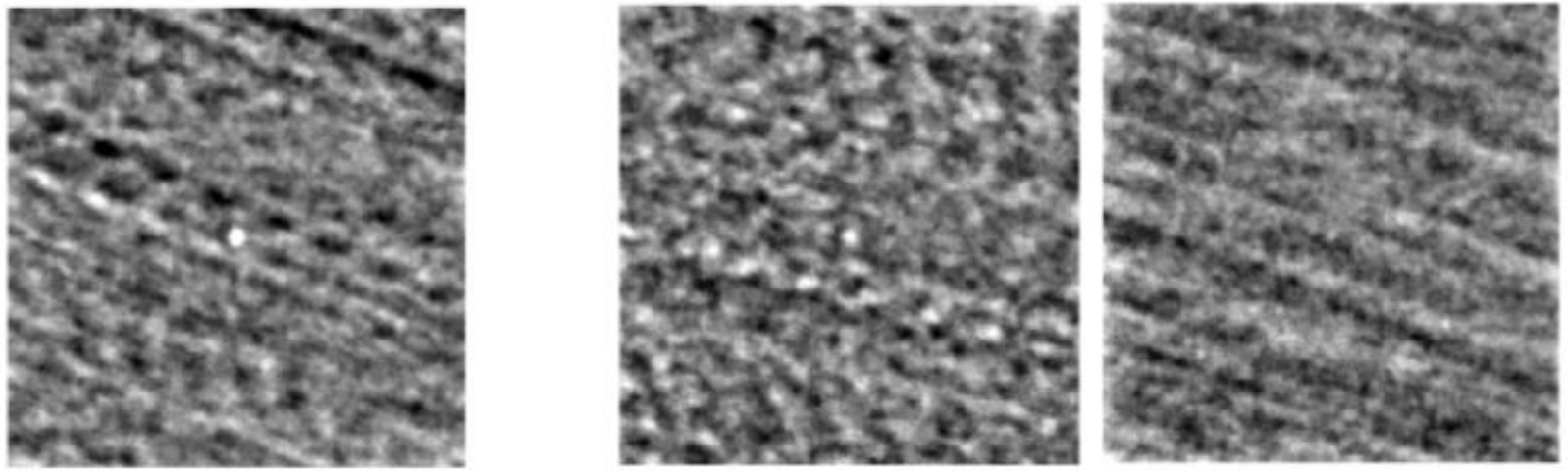
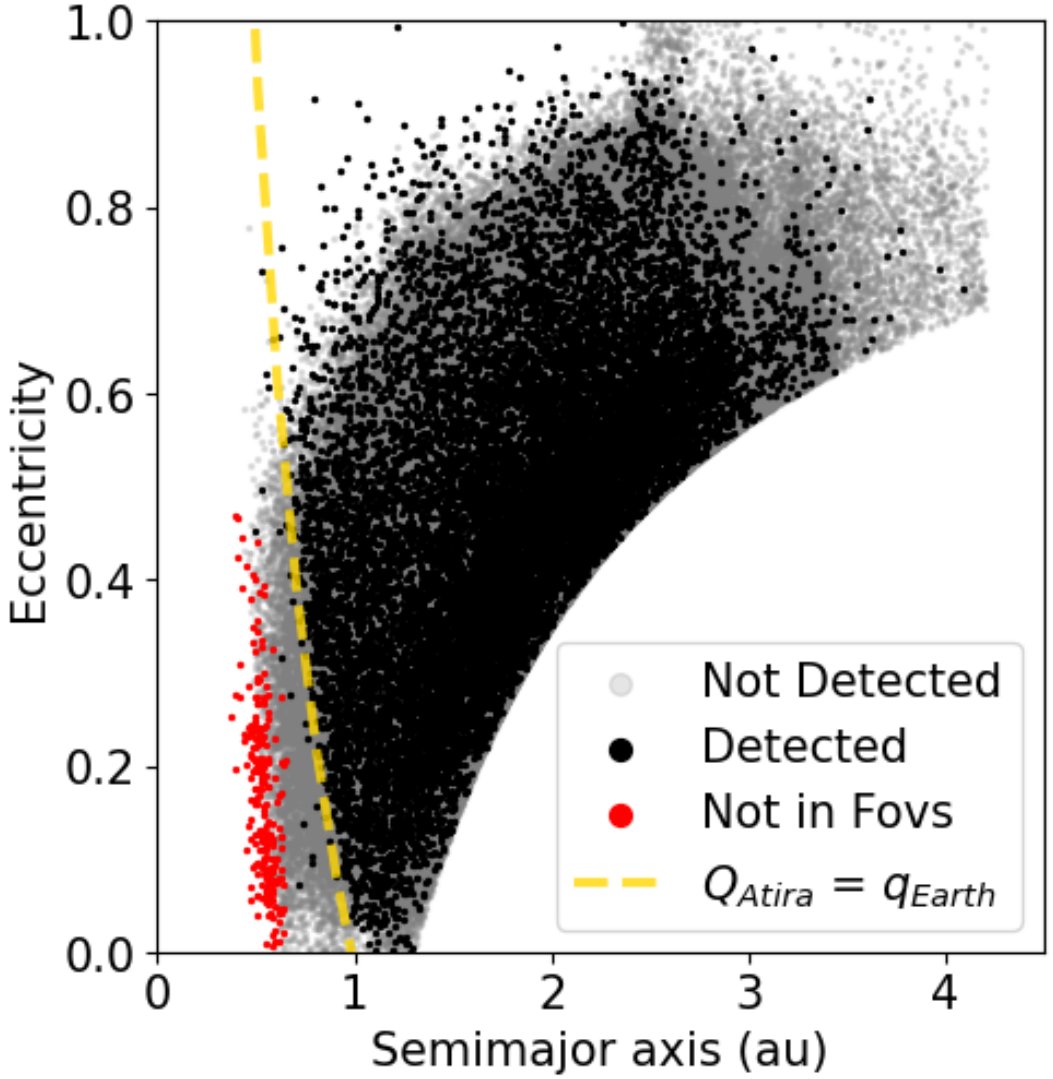


Fig. 5: (left) Asteroid (88) Thisbe, detected with high signal-to-noise in 15hr of clear filter exposure time at visual magnitude of ∼13.5. (center) Asteroid (47) Ajlava recovered in 15hr of clear filter exposure time at visual magnitude of ∼14.5. (right) Near-Earth Asteroid (66146) recovered in 24hr of exposure time with clear filters only, at a visual magnitude of ∼15.5.

How bright will they be?

- I took the undetected objects (gray dots)
  - Integrated their orbits (2 years)
  - Calculated predicted brightness due to relevant geometry, sizes and phase functions
  - Undiscovered objects can reach 17th magnitude
    - They would be ~1.5km



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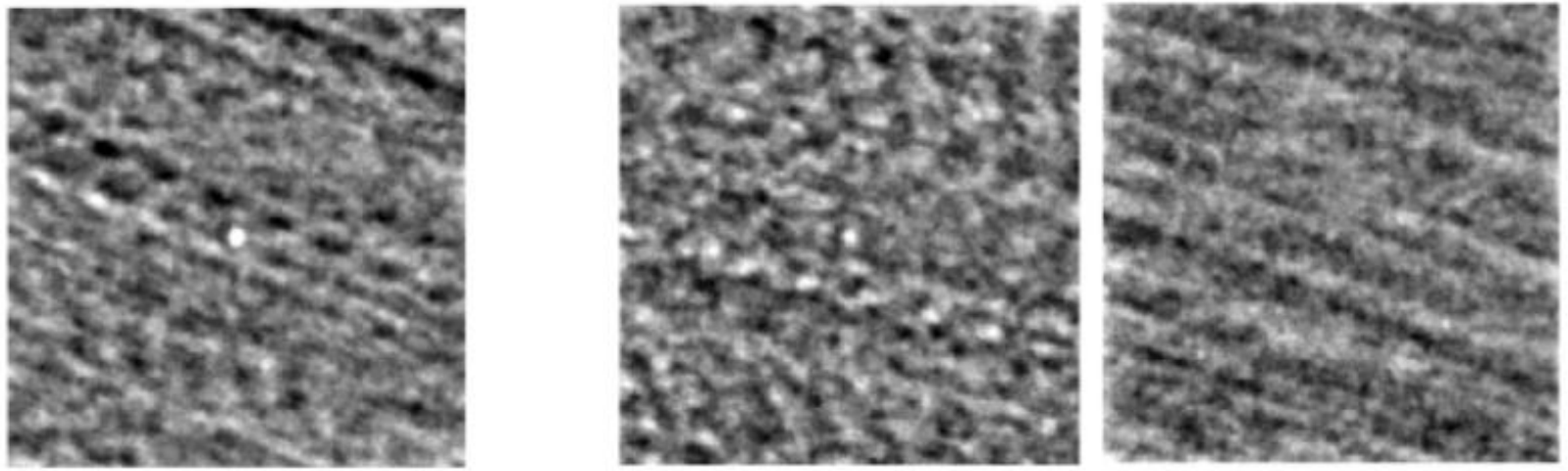

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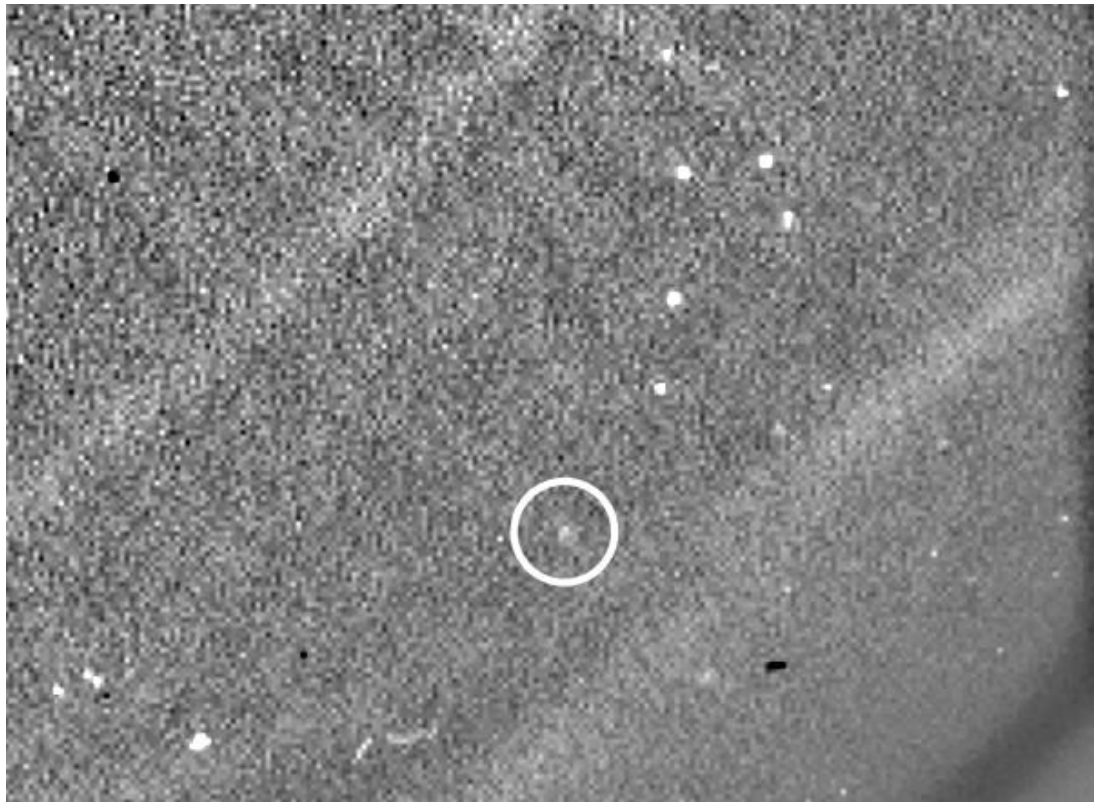
Limiting magnitude at 25° elongation	Number of discoveries	Largest H	Smallest D ($pV = 0.15$)
17	1-4	17.0	1.4 km
17.5	5-8	17.4	1.1 km
18	10-12	17.9	0.9 km

Predicted != reality

- The predictions from NEOMOD suggest that we need ~2 more magnitudes of depth to start discovering new objects.
  - We can run a survey to 14th magnitude, we can rule out the existence of other objects and confirm the modeling prediction.
  - We will likely discover comets
  - We might be surprised.
    - Asteroids breakup – predicted in numerical models, seen at asteroid Bennu, and at 3200 Phaeton
      - Phaeton is a ~5km “rock comet” that is a mission target for JAXA Destiny+ mission

Additional asteroid studies

- Asteroid activity
  - We are hunting some candidates that pass between Earth and Sun (phase angle > 90deg) to search for potential dust clouds/coma
  - Asteroid 3200 Phaeton is famously active at low perihelia “rock comet”
    - Parent of the Geminid meteor shower
- Asteroid polarimetry
  - Probes regolith material properties – sparse literature due to observing challenges



Phaeton in SOHO – PUNCH WILL DO MUCH BETTER In Fall 2026

Conclusions

- We are still hunting for deeper imaging with image stacking
- There is a ton of really exciting asteroid science we can still do
    - Phaeton in Fall of 2026 will be exciting.