End-to-End Asteroid Precovery Pipeline

Apurva Balaji [1], Amelia Skeers [1], Justin Atchison [2], Rylie Bull [2], Tam Nguyen [1]
[1] University of Maryland, [2] Johns Hopkins Applied Physics Laboratory

Overview

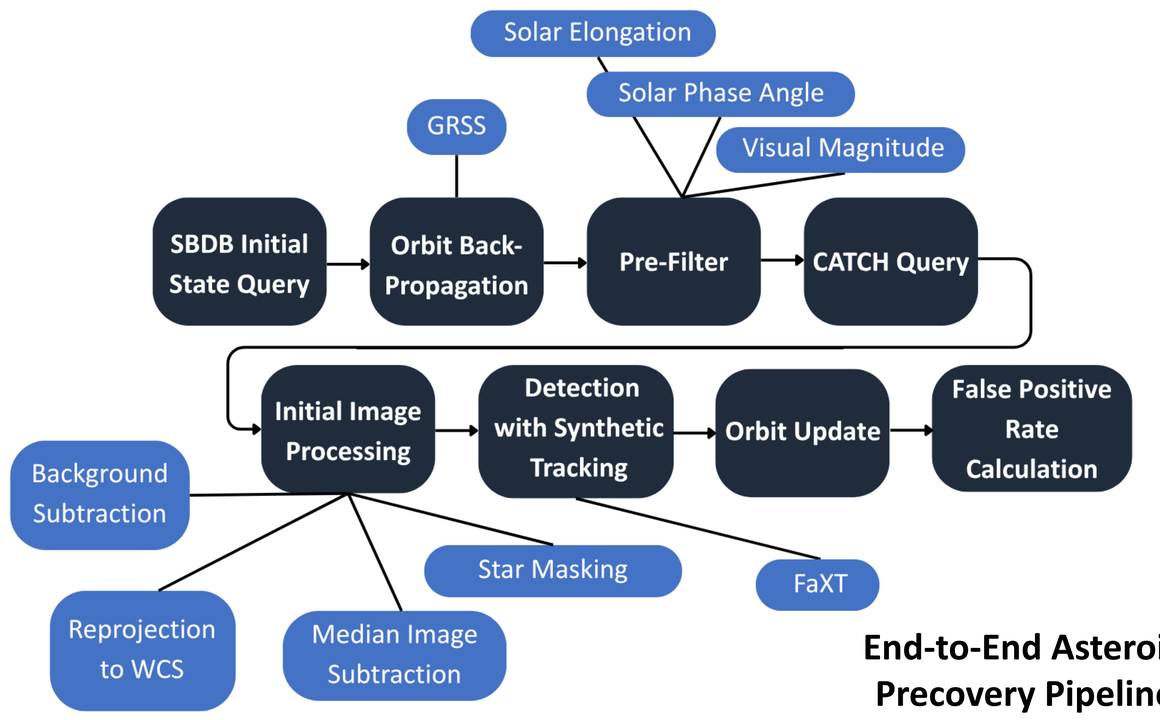
- New surveys, such as Vera C. Rubin Observatory and NEO Surveyor, will produce an unprecedented number of new asteroid discoveries that need to be validated and refined.
- **Asteroid Precovery** is the search for observations of discovered asteroids in archival images.
- Precovery can provide valuable observations with low resource requirements but may suffer from limited sensitivity.
- **Synthetic tracking** can close sensitivity gaps to achieve successful asteroid precovery.

Methods to Obtain Additional Observations to Refine Orbits

Asteroid Follow-Up	Asteroid Precovery
Potentially long wait time to collect sufficient data	Low wait time; potential to achieve longer arcs
Requires follow-up telescope time and resources	No additional resources other than computing
Observations can be planned to meet sensitivity requirements	Relies on existence of coincidental observations, with potentially low sensitivity.

Technical Approach

1. Query initial state from the Small-Body Database (SBDB) [1].
2. Back-Propagate object with the Gauss-Radau Small-Body Simulator (GRSS) [2] and filter out infeasible observing periods.
3. Query archival image data from the Comet Asteroid Telescopic Catalog Hunter (CATCH) [3] by the University of Maryland.
4. Perform image processing (background subtraction, reprojection, median image subtraction, star masking).
5. Utilize FaXT [4], an efficient divide-and-conquer synthetic tracking method and optimize detection.
6. Compute updated orbit solution with new precovery detection.



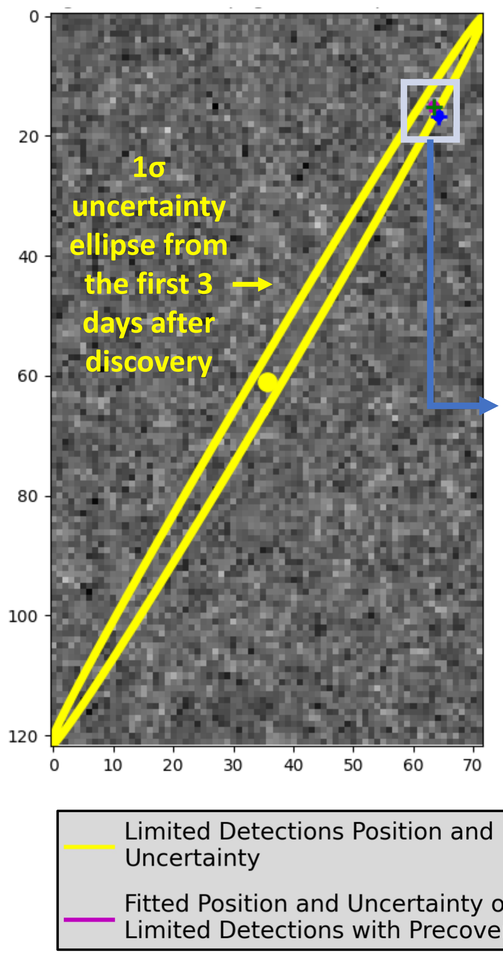
End-to-End Asteroid Precovery Pipeline

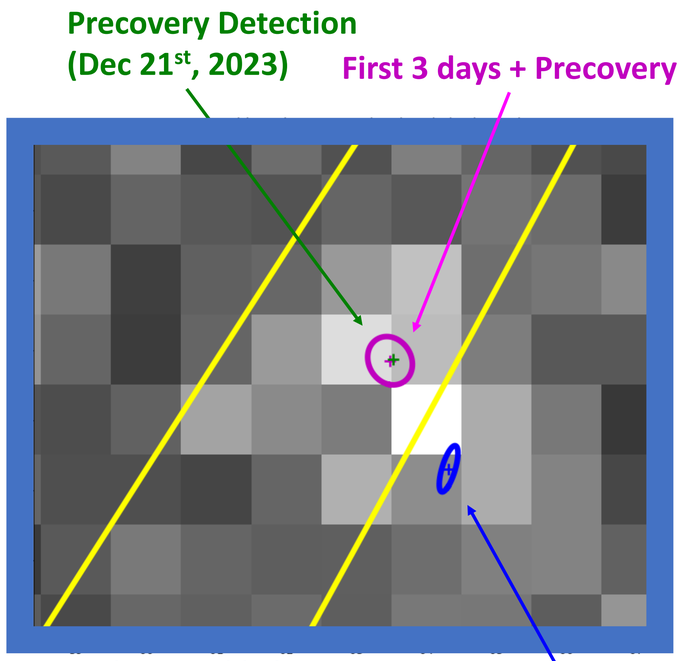
Selected Results

2024 AA2

- Initial Discovery: January 7th, 2024
- Precovery with ATLAS Sutherland: December 21st, 2023

Co-Added FaXT Image along Optimal Velocity with the Back-Propagated and Optimized Locations

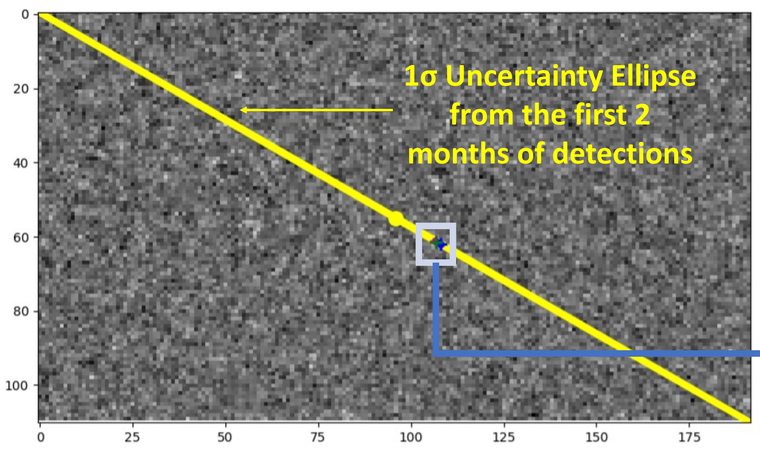




Zoomed in co-added image with 1σ uncertainty ellipses

2025 AK2

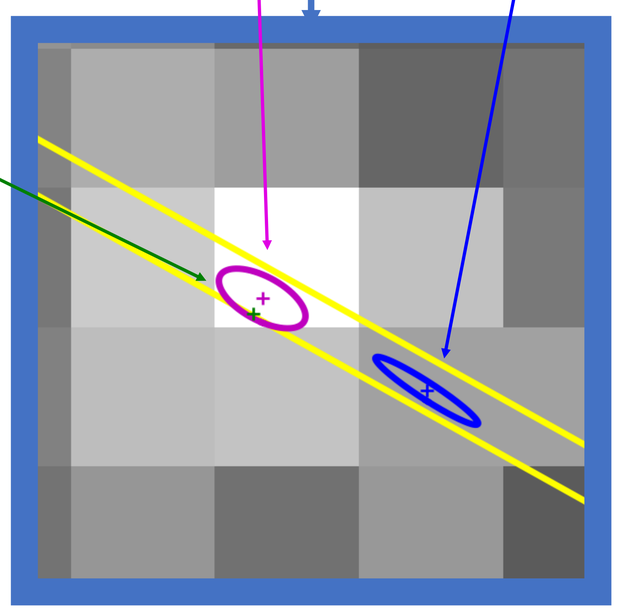
- Initial Discovery: January 5th, 2025
- Precovery with Catalina Mt. Lemmon: January 15th, 2024



Co-Added FaXT Image along Optimal Velocity with the Back-Propagated and Optimized Locations

Position Accuracy Improvement with Precovery

	2024 AA2	2025 AK2
Limited Detections	97.8”	21.3”
Limited Detections + Precovery	3.25”	2.01”



Zoomed in co-added image with 1σ uncertainty ellipses

Conclusions

We demonstrated efficient asteroid precovery with synthetic tracking that rapidly improves orbit solutions of newly discovered objects.

Next steps include error quantification and false positive analysis

References:
[1] Solar System Dynamics, “JPL Solar System Dynamics,” NASA Jet Propulsion Laboratory. [Online]. Available: https://ssd.jpl.nasa.gov/.
[2] R. Makadia, D. Farnocchia, S. R. Chesley, and S. Eggl, “Gauss-Radau Small-body Simulator (GRSS): An Open-source Library for Planetary Defense,” *Planetary Science Journal*, vol. 6, no. 4, Art. no. 85, Apr. 2025, doi: 10.3847/PSJ/adbc88.
[3] Comet Asteroid Telescopic Catalog Hunter (CATCH), “CATCH: Comet Asteroid Telescopic Catalog Hunter,” Univ. of Maryland, 2025. [Online]. Available: https://catch.astro.umd.edu/.
[4] T. Nguyen, D. F. Woods, J. Ruprecht, and J. Birge, “Efficient Search and Detection of Faint Moving Objects in Image Data,” *Astronomical Journal*, vol. 167, no. 3, p. 113, Feb. 2024, doi: 10.3847/1538-3881/ad20e0.

UNIVERSITY OF MARYLAND

Contact Information: Apurva Balaji (apurvab@umd.edu)

This work was funded by the UMD/APL ASTRA Seed Grant

STRATEGIC SPACE SENSING