Binocular Vision: Measuring Asteroids Parallax Using Ground and Space Based Telescopes

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Near-Earth Objects (NEOs) pose potential threats due to their proximity to Earth. This project enhances asteroid classification by computing color index data from a ground-based 1-meter telescope and the space-based GEOstare telescope. Using these dual viewpoints, we calculate parallax to improve both classification accuracy and trajectory determination, advancing NEO detection and risk assessment.

INTRODUCTION

Problem:
Near-Earth Objects (NEOs) can pose risks to our planet, but accurately detecting and classifying them remains challenging.

Method:
We use simultaneous observations from a ground-based 1-meter telescope and the GEOStare space telescope, analyzing color indices to classify asteroids and parallax measurements to determine their distance.

Results:
Asteroid classification without the need for large, expensive telescopes, and a novel method for approximating asteroid distances.

Introduction A

- Classify the asteroid type which provides insight into its composition and density.
- Identifying the asteroid type also improves our understanding of its orbital trajectory, atmospheric interactions, potential mitigation strategies, and the optimal telescope for observation.

Introduction B

Parallax: Is the shift in an objects apparent position (relative to the background stars) when perceived when from two different locations (two different telescopes)

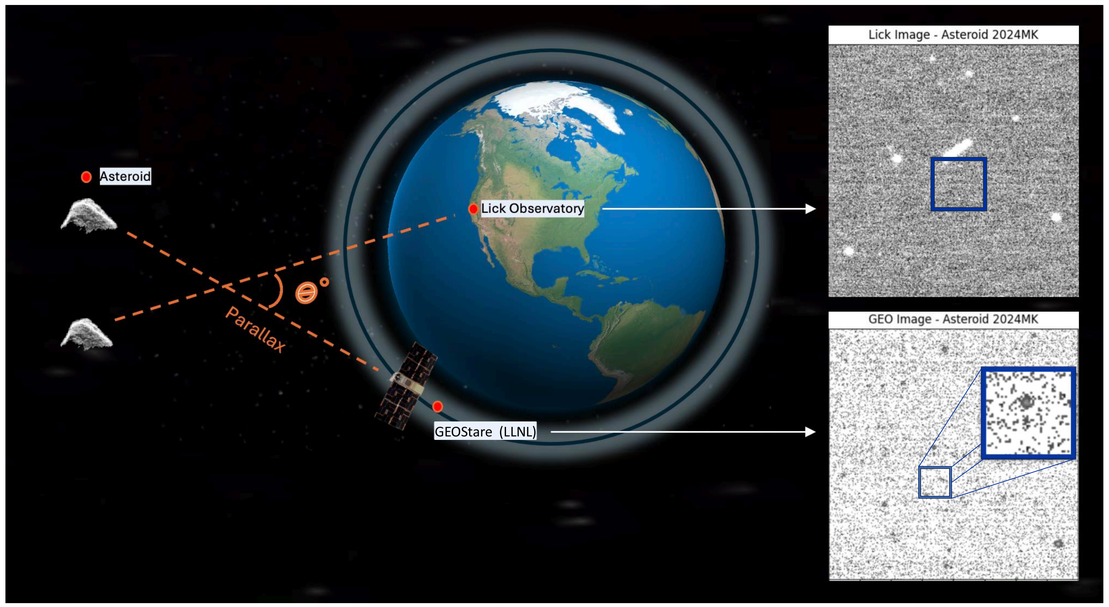
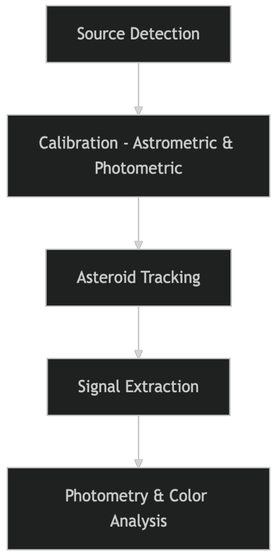


Figure #1: Visualization of parallax, showing the location of the asteroid on the left, the Lick Observatory and GEOStare telescope (marked with red dots) in the center, and the corresponding images (framed around the asteroid 2024MK) from each telescope on the right. The diagram illustrates how the positions of the asteroid appear different when viewed from each observatory.

METHODS



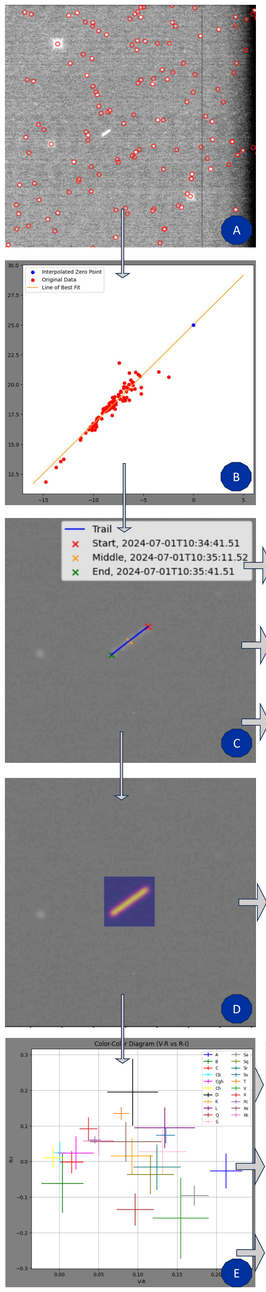


Figure #2
Output images corresponding to each step in the methods flow chart (left):
A: Stellar source detection using Gaia catalog overlay.
B: Zero-point calibration: Gaia source magnitudes vs. instrumental source magnitudes.
C: Asteroid trail prediction: Trial length (equation #2) and orientation (equation #3) determined from total proper motion (equation #1)
D: Trail model: Convolution of the 2D Gaussian PSF with the rectangular asteroid trail (equation #4)
E: Photometry and color analysis using filter-specific averaged apparent magnitudes (equations #5-7), plotted in color space.

$$\mu_{\text{total}} = \sqrt{(\mu_{\text{lon}})^2 + (\mu_{\text{lat}})^2} \quad (1)$$

$$L = \mu_{\text{total}} \times \text{Exposure (days)} \quad (2)$$

$$\theta = \arctan 2(\mu_{\text{lat}}, \mu_{\text{lon}}) \quad (3)$$

$$\text{Trail Model} = \text{PSF} \otimes \text{Rect}(x, y) \quad (4)$$

$$F = \frac{\sum(M \cdot I)}{\sum M^2} \quad (5)$$

$$m = ZP - 2.5 \log_{10}(F) \quad (6)$$

$$\sigma_m = 2.5 \log_{10}(e) \times \frac{\text{RMS}}{F} \quad (7)$$

CONCLUSIONS

Asteroid Type:

2024MK is classified as an "-type" asteroid based on color analysis and photometric measurements.

Next Steps:

By analyzing data from both Lick Observatory (ground-based) and GeoStare (space-based), we can determine the parallax angle of the asteroid.

Parallax Angle Calculation:
The parallax angle (θ) is calculated by measuring the apparent positional shift of the asteroid between the two observations

$$\theta = \arccos\left(\frac{\vec{r}_1 \cdot \vec{r}_2}{|\vec{r}_1||\vec{r}_2|}\right)$$

where $\vec{r}_1$ and $\vec{r}_2$ are the position vectors from each telescope to the asteroid.

Distance Calculation:

$$d = \frac{B}{\tan(\theta)}$$

where B is the baseline distance between the two telescopes.

Significance:

Classifying asteroids with small telescopes enables rapid, cost-effective identification of composition and potential risk. Determining distance via parallax improves predictions of closest approach and helps assess impact threat and observation priorities.

REFERENCES

[1] Alpha Coders, "Earth from Space," [Online]. Available: https://pics.alphacoders.com/pictures/view/463496. [Accessed: 25-Aug-2025].

[2] Terran Orbital, "GeoStare SV2 Mission," [Online]. Available: https://terranorbital.com/missions/geostaresv2/. [Accessed: 25-Aug-2025].

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