Strengthening Planetary Defense:
Detecting Unknown Asteroids using Open Data, Math, and Python

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Asteroid Collision Risks are Real and Unpredictable. Many asteroids remain undetected or their orbits are uncertain. Their paths can intersect with the orbit of Earth raising possibilities of collision. In 2013 the undetected Chelyabinsk asteroid collided with Earth showing risk of asteroid collision are real.

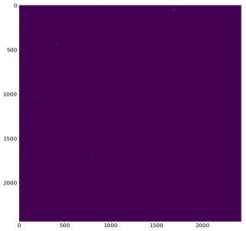
Imaging the Night Sky Using Robotic Telescopes:

Telescopes at different latitudes (Australia, United States, Canada and Spain) operated by Faulkes Telescope Project (UK), the Open University (UK) and Burke Gaffney Observatory (Canada) were used to get full sky coverage. I wrote research proposals as some robotic telescopes provide limited free observation time to students.

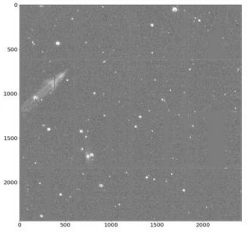
Pre-processing of Images:

Raw images from telescopes are mostly dark with a few bright pixels. As undetected asteroids are likely to be faint, I coded a scaling function to display the fainter pixels. The function queried the brightness of each pixel to calculate the mean value and reduced the range of pixel brightness of the image to between 1 and 2 standard deviations of the mean.

Raw Image (2400 x 2400 pixels)
Only few bright pixels show up



Scaled Image (2400 x 2400 pixels)
Celestial objects are revealed



Meta-data in the Flexible Image Transport System (FITS) image header (right ascension, declination, focal length, pixel size and pixel scale) was used to plate solve the images.

Querying Open Datasets to Find Known Objects:

To find unknown asteroids I had to find known objects in my images. GAIA EDR3 star catalogue of the European Space Agency (ESA) was used to find known stars. The Horizons database of the NASA Jet Propulsion Laboratory was used to find known asteroids. Field of view, right ascension and declination, date and time in UTC was used to query known asteroids.

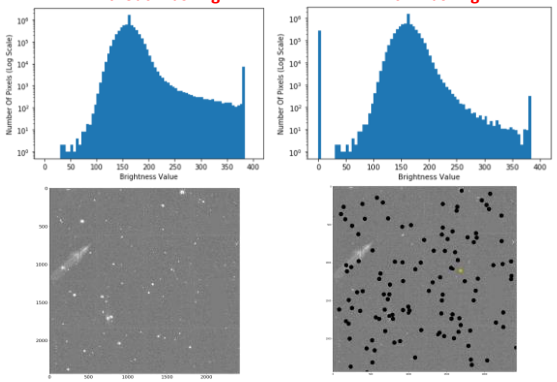
Network of Robotic Telescopes Used for the Project

Masking and Eliminating Known Objects:

I used a python library to project the celestial coordinates of known stars and asteroids found in the sky catalogues onto the pixel coordinates of my image. To improve the accuracy of these positions I wrote a centroiding algorithm. It assumed stars were circular, brightest in the center, and becoming dimmer as we moved towards the edge. This gave me their radius to generate custom-sized masks to cover them and eliminate them. The remaining objects in the images were possible unknown asteroid candidates or noise.

Image pixel brightness (log scale)

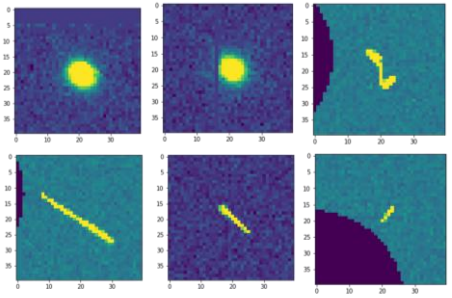
Without Masking **With Masking**



Filtering Noise to Find Unknown Asteroids:

Noise can appear because of dust, hot pixels, or drifting of telescopes during observation. While noise is normally a few scattered uniformly bright pixels, asteroids are pixels of varying brightness clumped together. I wrote a standard deviation algorithm to measure the spread in pixel brightness. I eliminated objects with smaller spreads that are more likely to be noise. The remaining objects were classified as possible asteroid candidates.

Possible Asteroid Candidates Detected



Reporting Asteroid Candidates to IAU and Outreach:

My algorithm detected 30 possible asteroid candidates. I created Minor Planet Centre (MPC) reports for all of them and submitted them through the International Asteroid Search Campaign (IASC). Three of my observations were classified as preliminary asteroids as they matched the criteria set by their expert team.

I made my project open-source on GitHub to crowdsource planetary defense and have given training and presentations at the Royal Astronomical Society of Canada (RASC) General Assembly 2022 and the NASA Youth SpaceApps 2022.

Databases Used:

GAIA EDR3 Database Release:
https://www.cosmos.esa.int/web/gaia/earlydr3
Horizons Database for Asteroids:
https://ssd.jpl.nasa.gov/horizons/
IASC Campaign: http://iasc.cosmosearch.org/