Hubble Asteroid Hunter part 1: Using deep learning and crowdsourcing to survey asteroid trails in ESA's Hubble data archive

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Introduction: The Hubble Space Telescope (HST) archives hide many unexpected treasures, such as trails of asteroids, showing a characteristic curvature due to the parallax induced by the orbital motion of the spacecraft. We have explored two decades of HST data for serendipitously observed asteroid trails with a deep learning algorithm on Google Cloud, trained on volunteer classifications from the Hubble Asteroid Hunter (www.asteroidhunter.org) citizen science project. This project was set up as a collaboration between the ESAC Science Data Center (ESDC), Zooniverse and engineers at Google as a proof of concept to valorize the rich data in the ESA archives.

Crowdsourcing: We launched the Hubble Asteroid Hunter citizen science project on the Zooniverse platform on the International Asteroid Day, on 30th June 2019. For one year, 11482 volunteers provided nearly 2 million classifications for 150000 HST images, finding 1488 asteroid trails. The volunteers also tagged trails of artificial satellites and strong gravitational lenses on the forum of the project; we study these objects in upcoming publications.

Deep learning classifications: We used the classifications provided by the citizen scientists to train an automated object detection algorithm based on deep learning, AutoML, on Google Cloud. The multi-object classification algorithm achieved a precision of 78% and a recall of 61% for a confidence score of 0.5. Taking advantage of cloud computing, we trained the algorithm in 7 hours of wall-clock time and classified the entire archive of HST ACS and WFC3/UVIS images taken in the last 20 years in only 3 hours, a task that would have taken volunteers one year to complete. Using AutoML, we identified another 1000 asteroid trails in the HST images.

Results: We visually inspected the classifications and identified a final sample of 1701 high-confidence asteroid trails [1] (see Fig. 1). We matched only 670 trails with known Solar System objects from the Minor Planet Center Database, the remaining 1031 trails corresponding to unknown asteroids. The unidentified asteroids are 1.6 magnitudes fainter than the asteroids we succeeded to identify. They are statistically fainter than asteroids found from the ground (typically >22 mag), highlighting the advantages of space observations and HST for observing faint, small asteroids.

Conclusions: This work describes a method for finding new asteroids in astronomical archives that span decades; it could be effectively applied to other datasets, increasing the overall sample of well-characterised small bodies in the Solar System and refining their ephemerides. We showed that the collaboration between AI methods and crowdsourcing is an efficient way of exploring increasingly large datasets by taking full advantage of the intuition of the human brain and the processing power of machine learning, enhancing the scientific exploitation of data archives.

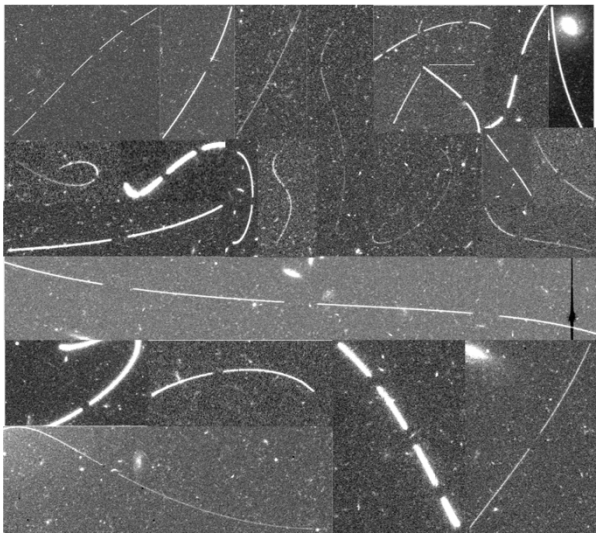

Figure 1: Diversity of asteroid trails identified in HST images.

References: [1] Kruk et al. (2022) *Hubble Asteroid Hunter I. Identifying asteroid trails in Hubble Space Telescope images*.