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2016 UU121: An Active Asteroid Discovery via AI-enhanced Citizen Science

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What are corridors?

Abstract

We report the discovery of an active asteroid, 2016 UU_{121}, for the first time via artificial intelligence-enhanced classification, informed by our NASA Partner program *Active Asteroids*, a Citizen Science project hosted on the *Zooniverse* platform. The early version of our deep neural network, TailNet, identified potential activity associated with 2016 UU_{121} in 40 Dark Energy Camera (DECam) images from UT 2021 September 10 to 11. The discovery was vetted and confirmed by our *Active Asteroids* core science team. In total, 66 DECam images of this object showed clear activity in the form of a tail. 2016 UU_{121} has a Tisserand parameter with respect to Jupiter of 3.161, thus we classify the object as an active asteroid. Moreover, the activity occurred near perihelion, so 2016 UU_{121} is also a candidate Main-belt comet.

1. Introduction

Active asteroids are minor planets that display comet-like tails and/or comae, despite being on orbits usually associated with asteroids, such as Main-belt asteroids. Some active asteroids, such as Main-belt comets (MBCs; Hsieh et al. 2015), are active because of volatile sublimation. These objects help us trace the location of volatiles in the solar system, and teach us about the primordial solar system. However, active asteroids and MBCs are rare, with roughly 60 and 20 identified to date, respectively. The paucity is due to, in large part, difficulty in locating these objects as they are rare (roughly 1 in 10,000 objects; Hsieh et al. 2015; Jewitt et al. 2015; Chandler et al. 2018; Chandler et al. 2024a, in press).

2. Methods

We set out to find more active minor planets with the help of the public by creating a Citizen Science project, *Active Asteroids*, [17] a NASA Partner program hosted on *Zooniverse* (Chandler 2022). We show images of known minor planets that we extract from the Dark Energy Camera public archive (Chandler et al. 2018) and ask project participants if they see evidence of comet-like activity in the form of a tail or coma. As of 2023 December 12, over 8800 volunteers have carried out 7.3 million classifications spanning some 482,000 unique images, resulting in over 20 discoveries thus far (Chandler et al. 2024a, in press).

To enhance the *Active Asteroids* user experience, we filter out images unlikely to show activity, such as those displaying an object too faint to reasonably be seen (Chandler 2022). Nonetheless, the number of images needing classification is still overwhelming, so we set out to further improve our screening with the help of artificial intelligence (AI). Our past work has shown that Convolutional Neural Networks (CNNs) (Krizhevsky et al. 2017) can not only surpass the performance of our classic methods of detection and characterization of transient objects (Sedaghat & Mahabal 2018), but also can reveal scientific insights into large astronomical data (Sedaghat et al. 2021, 2023). For the current work, we chose to use a simple CNN-based binary image classifier as an AI assistant, hereafter TailNet, with the intent of bootstrapping it on *Active Asteroids* labels, and iteratively improving the system step by step.

3. Results

Unexpectedly, 2016 UU_{121} (Figure 1) was flagged as highly unlikely to be inactive by a very preliminary version of our classifier, TailNet, which had only been trained on a limited number of project classifications. Further investigation by our team identified a total of 66 images of 2016 UU_{121} showing activity in the form of a tail oriented in the anti-motion direction (Figure 1). The images spanned two dates, UT 2021 September 9 and 10, when 2016 UU_{121} was at a heliocentric distance of r_H =1.938au and outbound from perihelion (true anomaly angle f=16°).

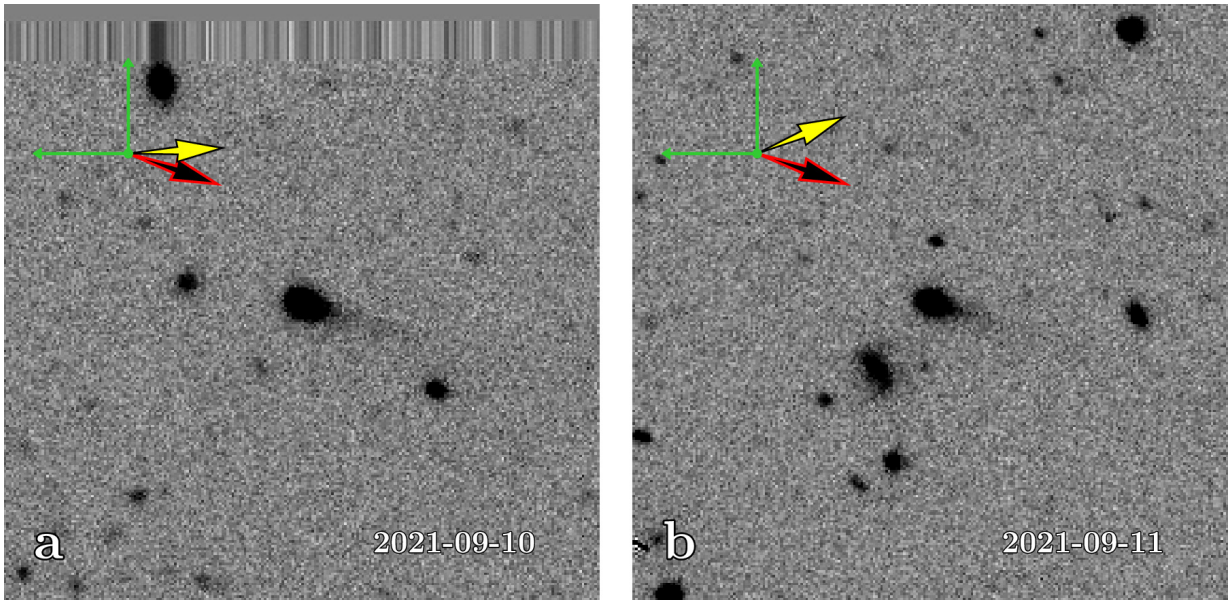

Figure 1. 2016 UU_{121} (at center) of the 63''×63'' (north up, east left) FOV with a tail oriented in the anti-motion (red-bordered black arrow) directions as projected on sky. Also indicated is the anti-solar direction (yellow arrow). All images were 120s *VR*-band exposures acquired with the Dark Energy Camera (DECam) on the Blanco 4m telescope at Cerro-Tololo Inter-American Observatory, Chile (Prop. ID 2019A-0337, PI Trilling). (a) UT 2021 September 10 (observer Edward Lin). (b) UT 2021 September 11 (observer David Gerdes).

We classify 2016 UU_{121} (semimajor axis a=2.971au, eccentricity e=0.354, inclination i=4.344, perihelion distance q=1.920au, aphelion distance Q=4.023au, Tisserand parameter with respect to Jupiter T_J=3.161;retrieved UT 2023 December 13 from JPL Horizons; Giorgini et al. 1996) as an active asteroid as it orbits entirely with the main asteroid belt. Furthermore, as the activity we identified occurred near perihelion, 2016 UU_{121} is also a Main-belt comet candidate. The simultaneous discovery of two active asteroids with AI and Citizen Science, 2016 UU_{121} and 2008 GB_{140} (Chandler et al. 2024), is unprecedented.

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This project used data obtained with the Dark Energy Camera, which was constructed by the Dark Energy Survey collaboration. This research uses services or data provided by the Astro Data Archive at NSF's NOIRLab. Based on observations at Cerro Tololo Inter-American Observatory, NSF's NOIRLab (NOIRLab Prop. ID 2019A-0337, PI Trilling), and the CADC Solar System Object Information Search (Gwyn et al. 2012).

Facility: CTIO:4m (DECam) - .

Software: astrometry.net (Lang et al. 2010), PyTorch (Paszke et al. 2019).

Footnotes

17 http://activeasteroids.net