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# AI-enhanced Citizen Science Discovery of an Active Asteroid: (410590) 2008 GB140

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## Abstract

We report the discovery of cometary activity emanating from Main-belt asteroid 410590 (2008 GB<sub>140</sub>), a finding facilitated, for the first time, by an artificial intelligence (AI) assistant. The assistant, TailNet, is a prototype we designed to enhance volunteer efforts of our Citizen Science project *Active Asteroids*, a NASA Partner program hosted on the *Zooniverse* platform. Our follow-up investigation revealed eight Dark Energy Camera images showing 2008 GB<sub>140</sub> with a tail spanning UT 2023 April 23–UT 2023 July 3, when the object was inbound to perihelion. We classify 2008 GB<sub>140</sub> as an active asteroid and a candidate Main-belt comet (MBC)—a main-belt asteroid that undergoes volatile sublimation-driven activity. Notably, 2008 GB<sub>140</sub> is presently near perihelion, thus the object is a prime target for follow-up observations to further characterize its activity.

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## 1. Introduction

Citizen Science is a framework in which scientific goals and public engagement are achieved simultaneously. Typically, volunteers carry out tasks that would be overwhelming in number or complexity for scientists. Notably, tasks usually are not possible to be carried out by automated means (i.e., AI), though the classification data from Citizen Science programs may be employed in training such systems.

Our NASA Partner program *Active Asteroids*<sup>17</sup> is a Citizen Science project designed to locate rare asteroids that show cometary activity. These objects inform our understanding of the early solar system and how it evolved, and point to where volatiles may be found today (Jewitt & Hsieh 2022). With the help of some 9000 volunteers our project has yielded many results since it launched in 2021, but the volume of data is exceptionally challenging to analyze, even with automated analytic vetting applied (Chandler et al. 2024a, in press). Moreover, upcoming petascale surveys, like the Vera C. Rubin Observatory's Legacy Survey of Space and Time, will increase the volume of images available to scour by orders of magnitude (Ivezić et al. 2019; Vera C. Rubin Observatory LSST Solar System Science Collaboration et al. 2021; Schwamb et al. 2023).

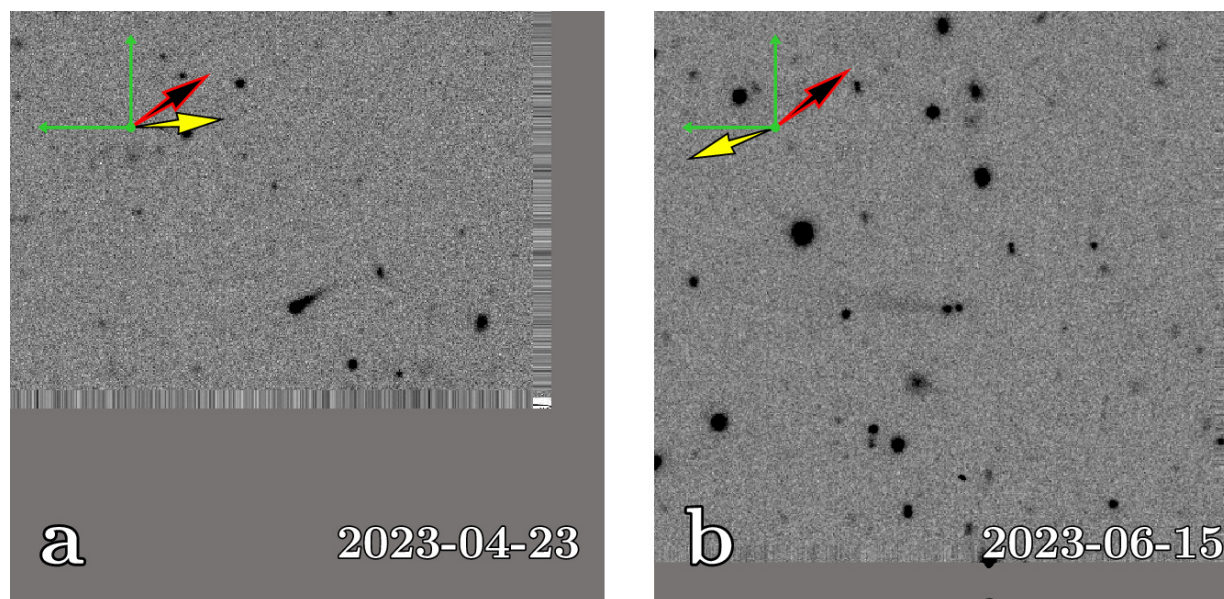
## 2. Methods

In essence, the *Active Asteroids* program shows images of known asteroids (and comets) to volunteers. These images have already been pre-screened to filter out, for example, images with exposure times insufficient to yield visible activity indicators. Volunteers classify images as either showing cometary activity (a tail or coma), or not. We analyze these classifications and assign likelihood scores to images based on weighted factors like participant experience, Chandler et al. 2024a, in press).

We set out to create an AI assistant to augment our image screening process. To this end, and informed by our past big data AI applications (e.g., Sedaghat & Mahabal 2018; Sedaghat et al. 2021, 2023), we created a binary classifier, "TailNet," that leverages Convolutional Neural Networks (CNNs; Krizhevsky et al. 2017). Notably, CNNs have proven successful with astronomical applications involving both our underlying Dark Energy Camera data source and *Zooniverse*-based Citizen Science (e.g., Walmsley et al. 2022). When training TailNet, the aforementioned likelihood scores served as the input labels.

## 3. Results

Despite TailNet still being a prototype, it identified images of 2008 GB<sub>140</sub> (as well as 2016UU<sub>121</sub>; Sedaghat et al. 2024) as highly unlikely to be inactive, which we interpreted as likely to show activity. Our subsequent archival investigation revealed eight images of 2008 GB<sub>140</sub> showing activity (Figure 1) spanning UT 2023 April 23 to UT 2023 July 3. Then, 2008 GB<sub>140</sub> was inbound at true anomaly angles  $259^\circ < f < 273^\circ$  and heliocentric distances  $2.956 > r_H > 2.852 \text{ au}$ .



**Figure 1.** 2008 GB<sub>140</sub> (center) in these *r*-band DECam images. The FOV is 126'' $\times$ 126'', with north up and east left. The anti-motion (yellow arrow) and anti-solar (red-bordered black arrow) directions are marked. (a) UT 2023 April 23, 90s (Prop. ID 2019A-0305, PI Drlica-Wagner, observers A.Drlica-Wagner). (b) UT 2023 June 15, co-added 1 $\times$ 70s and 1 $\times$ 64s exposures (Prop. ID 2014B-0404, PI Schlegel, observers D.Schlegel, S.Tolley).

2008 GB<sub>140</sub> (semimajor axis  $a=2.933$ au, eccentricity  $e=0.145$ , inclination  $i=14^\circ 2$ , perihelion distance  $q=2.507$ au, aphelion distance  $Q=3.360$ au) is a Main-belt asteroid with a Tisserand Parameter with respect to Jupiter  $T_J=3.214$ . Thus, along with the activity we uncovered, we classify 2008 GB<sub>140</sub> as an active asteroid. Moreover, 2008 GB<sub>140</sub> is a candidate Main-belt comet as its activity near perihelion is compatible with sublimation-driven activity. 2008 GB<sub>140</sub> is inbound to perihelion ( $f=317^\circ$  on UT 2023 January 14) and thus is likely still active; further observations would help characterize the nature of 2008 GB<sub>140</sub>'s activity and provide other insights into its physical properties.

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This project used data obtained with the Dark Energy Camera (DECam), which was constructed by the Dark Energy Survey (DES) 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 2014B-0404, PI: D. Schlegel; Prop. ID 2019A-0305, PI Drlica-Wagner).

*Facility:* CTIO:4m (DECam) - .

*Software:* astropy (Robitaille et al. 2013), astrometry.net (Lang et al. 2010), PyTorch (Paszke et al. 2019).

## Footnotes

17 <https://activeasteroids.net>

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