RNAAS RESEARCH NOTES OF THE AAS

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To cite this article: Colin Orion Chandler *et al* 2025 *Res. Notes AAS* **9** 3

Manuscript version: AAS-Provided PDF

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Draft version January 2, 2025
Typeset using LaTeX default style in AASTeX631

AI-Enhanced Citizen Science Discovers Cometary Activity on Near-Earth Object (523822) 2012 DG61

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ABSTRACT

We report the discovery of cometary activity in the form of a pronounced tail emanating from Near-Earth Object (523822) 2012 DG_{61}, identified in UT 2024 April 18 Dark Energy Camera (DECam) images by our AI assistant TailNet. TailNet is an AI designed to filter out images unlikely to show activity for volunteers of our NASA Partner "Active Asteroids" Citizen Science campaign, from which our AI is trained. Subsequently, our archival investigation revealed 2012 DG61 is recurrently active after we found it displaying a pronounced tail in a UT 2018 April 16 Steward Observatory Bart Bok 2.3 m telescope image and UT 2018 May 14 observations by G. Borisov with the 0.3 m telescope at MARGO Observatory. Our dynamical integrations reveal that 2012 DG61, an Apollo dynamical class member, is likely in 2:1 mean-motion resonance with Jupiter. We encourage additional observations to help characterize the activity morphology of this near-Earth comet.

Keywords: Asteroids (72), Comae (271), Comet tails (274), Near-Earth objects(1092), Convolutional neural networks (1938)

1. INTRODUCTION

Near-Earth objects (NEOs) are small solar system bodies with perihelion distances $q < 1.3$ au. The Near-Earth Comet (NEC) subset, comprising ∼0.5% of the NEOs (based on our own UT 2024 December 7 of the JPL Small-body

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Database; Giorgini et al. 1996), is further defined as displaying cometary activity (i.e., tails, comae) and having orbital periods < 200 yr. Most NEOs are Near-Earth Asteroids, which are further divided into dynamical groups, like Apollo asteroids (semi-major axes $a > 1$ au, $q < 1.017$ au). NEOs are scientifically valuable for myriad reasons, including informing our planetary defense strategies, e.g., the Double-Asteroid Redirection Test (DART) mission (Daly et al. 2023). The Chelyabinsk impactor was traced to the Apollos (Zuluaga & Ferrin 2013), emphasizing the importance of understanding these objects. NECs have broader significance, informing us about, e.g., the solar system's volatile distribution, delivery of water to terrestrial planets, small solar system body migration, and potential resources for future space exploration. However, active objects have proven challenging to discover, due to their rarity and difficulty in detecting faint activity. Consequently, they comprise < 1% of the 1.4 million known small solar system bodies.

2. METHODS

To find more active minor planets we set out to search millions of images of known small bodies with the help of our Citizen Science program *Active Asteroids*[1]. Launched in 2021, *Active Asteroids* has engaged with ∼12,000 volunteers who have conducted over 10 million classifications, i.e., stating whether or not they see activity (i.e., a tail), in images of minor planets we provide. We have made dozens of discoveries (e.g., Chandler et al. 2024a), but with millions of additional images needing classification we set out to optimize volunteer efforts by creating an AI assistant. Building upon Sedaghat & Mahabal (2018); Sedaghat et al. (2021, 2023)), including label noise handling (Sedaghat et al. 2024a), we designed a simple classifier, `TailNet`, to filter out images unlikely to show cometary activity. Conversely, `TailNet` can identify images unlikely to *not* show activity (i.e., images likely showing activity). `TailNet` has successfully identified active asteroids (Chandler et al. 2024b; Sedaghat et al. 2024b) and a Jupiter-family comet (DeSpain et al. 2024).

3. RESULTS

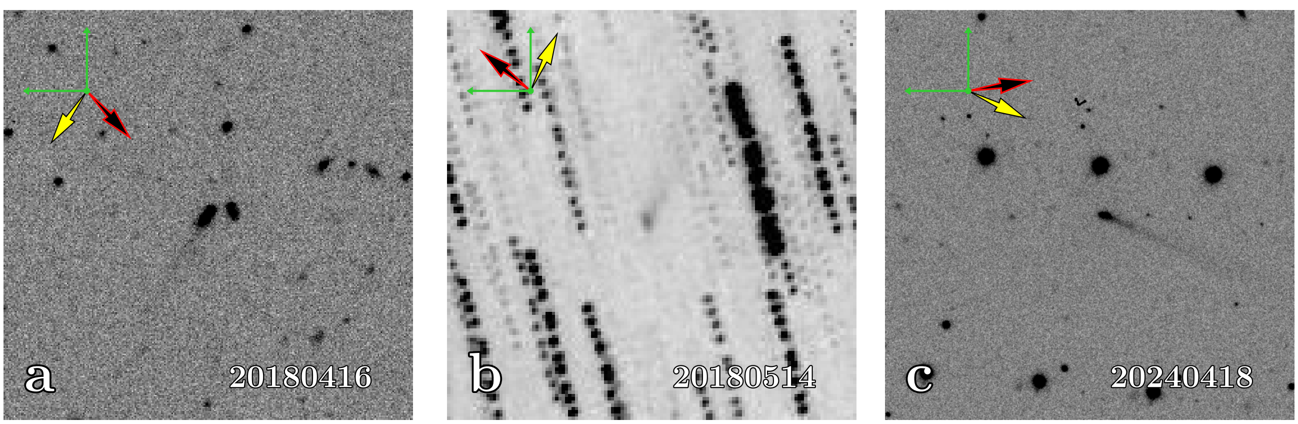

Figure 1. (523822) 2012 DG_{61} is centered in each image. The field of view is $126'' \times 126''$ (a, c) or $420'' \times 420''$ (b), with North up, East left. On-sky projected anti-motion (red arrow) and anti-solar (yellow arrow) directions are marked; in all images, an anti-solar oriented tail is evident. **(a)** UT 2018 April 16, 118.14 s g-band exposure via the 90prime camera on the Steward Observatory 2.3 m Bart Bok telescope (Kitt Peak National Observatory, Arizona). Prop. ID 2015A-0801, PI Xiaohui Fan; observers X. Peng, T. Zhang, Y. Ning. **(b)** UT 2015 May 14, 14-image co-addition, acquired with a 0.3 m telescope at MARGO Observatory (Crimea-Nauchnij); observer G. Borisov. **(c)** UT 2024 April 18, co-addition of 4×50 s r-band DECam (4 m Blanco telescope, Cerro Tololo Inter-American Observatory, Chile). Prop. ID 2023B-809270, PI Kleyna; observer Wilson Liu.

`TailNet` identified activity in UT 2024 April 18 DECam images (Figure 1c), when 2012 DG_{61} ($a = 3.257$ au, eccentricity $e = 0.737$, inclination $i = 15.306°$, $q = 0.857$ au, aphelion distance $Q = 5.656$ au, Tisserand parameter w.r.t. Jupiter $T_J = 2.629$; retrieved UT 2024 December 6 from JPL; Giorgini et al. 1996) was outbound from perihelion at true anomaly angle $\nu = 13°$, at a heliocentric distance of $r_H = 0.868$ au and a geocentric distance of $\Delta = 0.949$ au. Subsequently, our archival image search yielded an additional detection of activity (Figure 1a) from UT 2018 April

[1] https://activeasteroids.net

16, when 2012 DG_{61} was inbound ($\nu = 301°$), at a $r_H = 1.07$ au and $\Delta = 0.275$ au. We also located an article[2] by Andrey Ostapenko that led us to G. Borisov's observations, also from 2018 (Figure 1b). In all cases, a clear tail was oriented in the anti-solar direction.

We find Apollo-class NEO 2012 DG_{61} is likely undergoing sublimation-driven activity, given the outbursts occurring near multiple perihelion passages. The activity, along with the object's 5.877 yr period, leads us to further classify 2012 DG_{61} as a near-Earth comet. Our dynamical simulations with the `REBOUND` integrator (Rein & Liu 2012; Lu et al. 2024) indicate 2012 DG_{61} is likely in 2:1 mean-motion resonance with Jupiter. We encourage additional study of this interesting object to further characterize the nature and morphology of the activity.

ACKNOWLEDGEMENTS

Many thanks to Arthur and Jeanie Chandler for their ongoing support.

We thank Elizabeth Baeten (Belgium) for *Active Asteroids* forum moderation, and H. Fukuyama for Japanese translation. Special thanks to *Active Asteroids* Superclassifiers: Angelina A. Reese (Sequim, USA), Antonio Pasqua (Catanzaro, Italy), Carl L. King (Ithaca, USA), Dan Crowson (Dardenne Prairie, USA), @EEZuidema (Driezum, Netherlands), Eric Fabrigat (Velaux, France), @graham_d (Hemel Hempstead, UK), Henryk Krawczyk (Czeladż, Poland), Marvin W. Huddleston (Mesquite, USA), Robert Zach Moseley (Worcester, USA), Thorsten Eschweiler (Übach-Palenberg, Germany), and Washington Kryzanowski (Montevideo, Uruguay). Thanks to Cliff Johnson (Zooniverse), Chris Lintott (Oxford), and Marc Kuchner (NASA) for Citizen Science guidance.

This material is based upon work supported by the NSF Graduate Research Fellowship Program under grant No. 2018258765 and grant No. 2020303693. C.O.C., H.H.H., and C.A.T. acknowledge support from NASA grant 80NSSC19K0869. W.J.O. and C.A.T. acknowledge support from NASA grant 80NSSC21K0114. C.A.T. and C.O.C. acknowledge support from NASA grant 80NSSC24K1323 and NSF award 2408827. W.A.B. acknowledges support from NSF award 1950901. W.J.O. acknowledges support from NASA grant 80NSSC21K0114. This research received support through Schmidt Sciences. Chandler, Sedaghat, Frissell, Bernardinelli, and Kurlander acknowledge support from the DiRAC Institute in the Department of Astronomy at the University of Washington. The DiRAC Institute is supported through generous gifts from the Charles and Lisa Simonyi Fund for Arts and Sciences, and the Washington Research Foundation. J.K. thanks the LSST-DA Data Science Fellowship Program, which is funded by LSST-DA, the Brinson Foundation, and the Moore Foundation. Computational analyses were run on Northern Arizona University's Monsoon computing cluster, funded by Arizona's Technology and Research Initiative Fund.

Facilities: Bok:2.3m (90prime), CTIO:4m (DECam), MARGO:0.3m

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

[2] https://www.facebook.com/groups/astronochi.ru/permalink/1435105736635501

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