RNAAS RESEARCH NOTES OF THE AAS

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To cite this article: Jarod A. DeSpain *et al* 2024 *Res. Notes AAS* **8** 140

Draft version May 17, 2024
Typeset using LaTeX default style in AASTeX631

Discovery of Jupiter Family Comet 2011 UG_{104} Through AI-Enhanced Citizen Science

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ABSTRACT

We report the discovery of cometary activity from minor planet 2011 UG_{104}, which we classify as a Jupiter Family Comet (JFC). This discovery was aided by our Artificial Intelligence (AI) classification system: `TailNet`. JFC's, short-period comets with eccentric Jupiter-crossing orbits, originate from the Kuiper belt and thus give us unique insight into the composition and distribution of volatiles in the outer solar system, past and present. Our AI assistant `TailNet` first classified 2011 UG_{104} as active, which was affirmed by Citizen Scientists on our NASA Partner Program *Active Asteroids*. Through further archival image searches our science team found evidence of activity on 2011 UG_{104} on three separate observations from 2021 February to 2021 April ($81.8° < f < 95.0°$).

Keywords: Asteroids (72), Comae (271), Comet tails (274), Convolutional neural networks (1938)

1. INTRODUCTION

Jupiter-family comets (JFCs) are minor planets that show comet-like traits (e.g. coma, tail). JFCs have a Tisserand parameter relative to Jupiter in the range of $2 < T_J < 3$, short orbital periods (< 20 years), and low inclinations relative to the ecliptic ($i < 30°$) (Levison 1996). 2011 UG_{104} ($T_J = 2.695$, $i = 29.58°$), first discovered on 2012 April 7th[1], falls under this category. JFCs originate from the Kuiper belt, having been redirected into the inner solar system by the gravitational influence of Neptune (Lowry et al. 2008). Since JFCs originate from the outer solar system they

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[1] http://www.aerith.net/comet/catalog/2011UG104/2020.html

provide a unique opportunity to understand the composition and distribution of volatiles within the solar system (Cheng et al. 2015).

2. METHODS

To assist in the search for active objects, we collaborate with volunteer Citizen Scientists via our NASA Partner program, *Active Asteroids*[2]. We upload batches of archival Dark Energy Camera (DECam) images to the Citizen Science website *Zooniverse* for volunteers to classify, seeking signs of activity (Chandler et al. 2024a). When a volunteer identifies potential activity they classify it as active, and if a sufficient number of people report the object is active, it is flagged for further investigation. We then confirm the object's activity through follow-up observations using ground-based telescopes and cross-referencing astronomical image archives for additional data.

The project has engaged over 10,000 volunteers who have completed more than 8.5 million classifications to date, but this is only a fraction of the amount of data that still needs classification. So, to further aid in our screening process of image data and enhance volunteer experience we employ the help of an Artificial Intelligence (AI) assitant: `TailNet`, a Convolutional Neural Network (CNN) (Chandler et al. 2024b; Sedaghat et al. 2024).

3. RESULTS

`TailNet` first identified DECam images of 2011 UG_{104} (semi-major axis $a = 3.992$ au, eccentricity $e = 0.407$, inclination $i = 29.6°$, perihelion distance $q = 7.978$ au, aphelion distance $Q = 5.619$ au) as potentially active. With further investigation into archival DECam image data we uncovered three separate observations (Figure 1) in which the object exhibits activity. In all images of activity the tail is broad and spans the anti-motion and anti-solar directions.

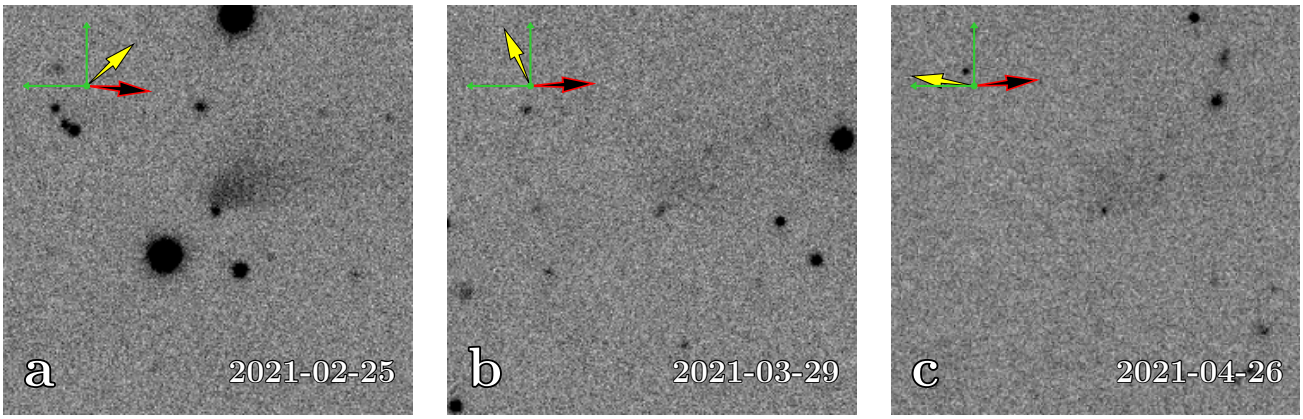

Figure 1. 2011 UG_{104} (center in each image) is shown in these archival DECam images. The field of view is $63'' \times 63''$, with north up and east left. The anti-motion (red arrow) and anti-solar (yellow arrow) directions are marked. **(a)** UT 2021 February 25, 90 s i-band (Prop. ID 2019A-0305, PI Drlica-Wagner, observers J. Carballo, D. James). A prominent tail is pointed primarily in the anti-solar direction. **(b)** UT 2021 March 29, 150 s Y-band (Prop. ID 2021A-0149, PI Zenteno, observer A. Zenteno). **(c)** UT 2021 April 26, 67 s Y-band (Prop. ID 2021A-0149, PI Zenteno, observer A. Zenteno).

Because 2011 UG_{104} has both a Tisserand parameter in respect to Jupiter of $T_J = 2.695$ and cometary activity, we classify 2011 UG_{104} as a Jupiter-family comet. 2011 UG_{104} has just passed aphelion ($f = 182.9°$ on UT 2024 May 16) and is inbound for its next perihelion passage on UT 2028 March 18.

[2] https://activeasteroids.net/

ACKNOWLEDGEMENTS

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

We thank Elizabeth Baeten (Belgium) for moderating the Active Asteroids forums. A special thanks to the *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 (Czeladź, 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 ongoing 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 the NASA Solar System Observations program (grant 80NSSC19K0869). W.J.O. acknowledges support from NASA grant 80NSSC21K0114. This work was supported in part by NSF award 1950901. This research received support through Schmidt Sciences. Chandler and Sedaghat 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.

Computational analyses were run on Northern Arizona University's Monsoon computing cluster, funded by Arizona's Technology and Research Initiative Fund.

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).

Facilities: CTIO:4m (DECam)

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

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