DIDYMOS AS AN ACTIVE ASTEROID. W. J. Oldroyd[1], C. O. Chandler[2,1], C. A. Trujillo[1], C. A. Thomas[1], M. M. Knight[3], and T. L. Farnham[4], [1]Department of Astronomy and Planetary Science, Northern Arizona University (woldroyd@nau.edu), [2]Department of Astronomy, the DiRAC Institute, and the LSST Interdisciplinary Network for Collaboration and Computing, University of Washington, [3]Physics Department, United States Naval Academy, [4]Department of Astronomy, University of Maryland.

Summary: In this work we analyze observational data of cometary features on DART mission target asteroid Didymos. This allows for comparison with other active asteroids using a well-constrained control case and provides insight into the origin of their activity as well as the effectiveness of active asteroid analysis techniques.

Introduction:

The binary, near-Earth asteroid (65803) Didymos-Dimorphos was the target of the NASA Double Asteroid Redirection Test (DART) mission [1]. On September 26, 2022, the DART spacecraft impacted Dimorphos, the satellite of Didymos, in an attempt to alter its orbital period. This planetary defense experiment was successful in that the orbital period of Dimorphos was reduced by 33 minutes [2] (prior to impact Dimorphos had an orbital period of 11.92 hr). In conjunction with this impact event, over 10^6 kg of material was ejected into space. The resulting ejecta are visible in the form of tails and a coma, features commonly identified with comets (Figure 1).

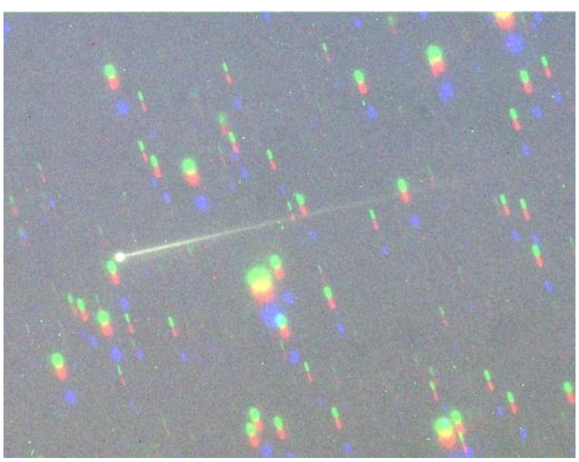

Figure 1. Stacked images of Didymos taken on November 18, 2022 at the 1.8 m Vatican Advanced Technology Telescope (VATT) at the Mount Graham International Observatory (MGIO) in Arizona, USA. These three 60 second images were taken in the Johnson-Kron-Cousins V, R, and I filters while tracking with the rate of motion of Didymos (Prop. ID S154, PI Chandler). A strong tail is clearly visible two months after impact.

Asteroids exhibiting tails or other cometary features are known as active asteroids. These objects are rare with only ~40 known thus far [3]. Explanations for the origin of the active asteroids invoke a variety of formation mechanisms including impact events, sublimation, rotational breakup, and thermal fracturing, however, it is often difficult to determine which mechanism is the dominant cause for activity [3]. Despite the unknowns surrounding the active asteroids, they provide a unique view into the distribution and transportation of volatile materials, such as water, throughout the solar system [4].

Methods: In order to study Didymos as an active asteroid, we utilized similar ground-based telescopes to those used for other active asteroid studies, for example, the 1.8 m Vatican Advanced Technology Telescope (VATT) and the 4.3 m Lowell Discovery Telescope (LDT), which are used for follow-up for the *Active Asteroids* Citizen Science project (a NASA Partner program, activeasteroids.net) [4]. The majority of images used were collected as part of an observation campaign carried out by the DART science team to study the Didymos system both before and after the impact.

To facilitate comparison between Didymos and other active asteroids, we employ similar analysis techniques on our observational data for Didymos as have been used for other active asteroids. The first of these is obtaining a radial profile of surface brightness to determine the extent of the coma surrounding the Didymos system. Next, we incorporate the coma extent into the calculation of the amount of dust produced [5], which, in turn, allows for an estimation of the total mass of the coma [6]. By calculating coma mass as a function of time since the impact, we quantify the rate of decay of the coma and, subsequently, the expected longevity of cometary features for an impact-induced active asteroid.

We continue by applying additional analyses to the Didymos system, such as dynamical simulations, thermophysical modeling, and wedge photometry. These techniques are typically used to aid in differentiating between the several causes for activity on active asteroids. These techniques allow for comparison with other known active asteroids and analysis of the effectiveness of these methods.

Dynamical simulations to determine the orbital history and expected dynamical lifetime of an active asteroid provide insight into recent changes in orbital class caused by interactions with the planets. These changes can place the object on an orbit where it experiences increased temperatures, thus, enabling appreciable sublimation to occur [4].

Thermophysical modeling is another useful tool for examining activity activation mechanisms. These models provide approximations for the lifetime of exposed volatiles on these bodies as well as reveal potential for mass loss caused by thermal fracturing of the asteroid [7]. Thermophysical and dynamical modeling used in conjunction also provide constraints on volatile species that could be abundant throughout the lifetime of an active asteroid [6].

An additional tool used for studying and identifying comet-like tails on active asteroids is wedge photometry, which compares averaged radial profiles "wedges" in polar coordinates centered on the target to detect brightness enhancements such as a tail [7]. This allows for the detection of even faint cometary features on an active asteroid (Figure 2).

Implications: By applying a wide range of active asteroid analysis techniques to Didymos, we establish a baseline comparison with known impact-induced activity. It can be difficult to disentangle the various factors that contribute to the activity of these enigmatic bodies, hence, the opportunity to study Didymos as an active asteroid provides a solid means for comparing the population against a control case.

Due to the precisely-known impact energy input into the system combined with the extremely thorough observational campaign by the DART science team, including spacecraft images resolving the system and ejecta, this control case will provide tight constraints which can be used to search for signatures for identifying impact-induced activity on other active asteroids. Additionally, these comparisons also allow us to determine the effectiveness of current analysis techniques for studying the active asteroids.

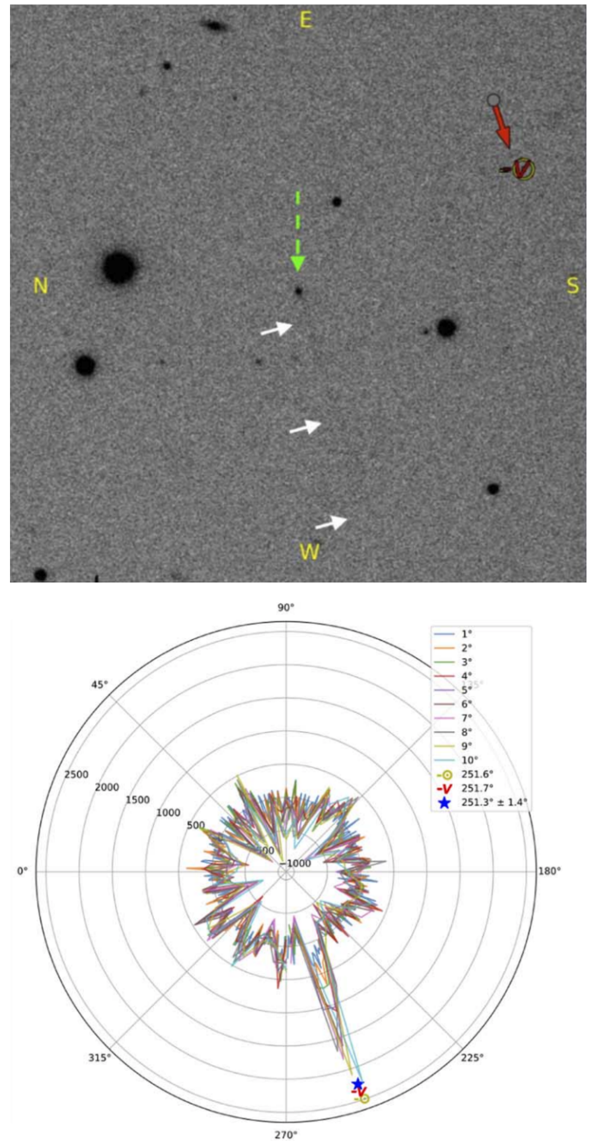

Figure 2. An example of Wedge Photometry (polar plot) used to detect a tail (white arrows) on active asteroid (248370) 2005 QN173 (dashed green arrow). Taken with the Dark Energy Camera on the 4 m Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile on July 22, 2016 (NOAO Prop. ID 2016A-0190, PI: Dey). Figure 1 in [7].

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