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Cometary Activity in Near–Earth Asteroid (3552) Don Quixote

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Abstract

The near–Earth object (NEO) population is thought to comprise a number of "dormant" short–period comets [1]. One of the most promising NEO candidates for a cometary origin is (3552) Don Quixote, due to its comet–like orbit and albedo.
We present the discovery of cometary activity in (3552) Don Quixote based on thermal–infrared observations made with the Spitzer Space Telescope. Our observations clearly show the presence of a coma and a tail which we identify as molecular line emission from CO_2 and thermal emission from dust. Our discovery indicates that more NEOs may harbor volatiles than previously expected.

1. Introduction

The NEO population is replenished from collisional fragments from main belt asteroids and short–period comets. Short–period comets have dynamical lifetimes that are expected to far exceed their active lifetimes [2]. Hence, it is likely that the NEO population includes a significant number of "extinct" or "dormant" comets, which have finally or at least temporarily, ceased being active [1].

NEO (3552) Don Quixote was discovered in 1983 as an asteroid. Don Quixote's orbit, having a period of 8.68 yrs and a Tisserand parameter with respect to Jupiter of $T_J = 2.313$, resembles very much the orbit of a typical short–period comet, which is supported by dynamical simulations [3]. Thermal models based on thermal–infrared observations of Don Quixote [4] derive a diameter of 18.7 km and a geometric V–band albedo of 0.02, which makes Don Quixote the 3rd–largest known NEO. The low albedo, which agrees well with the classification of Don Quixote as a D–type asteroid [5, 6], is typical for cometary nuclei. Of all NEOs, Don Quixote is the prime candidate for having a cometary origin, although activity has never been observed.

2. Observations

Don Quixote was observed by the Infrared Array Camera (IRAC, [7]) on-board the Spitzer Space Telescope on August 22, 2009. The observations in the 3.6 and 4.5 μm bands were taken within the ExploreNEOs program [8], which performs thermal–infrared observations of ~600 NEOs. Don Quixote was observed 18 days prior to its perihelion passage. The observations were found to be saturated in both bands (see Figure 1, top row). In order to estimate the object's flux, we applied a technique of subtracting a calibrated PSF from the data [9]. A check of the residual images (Figure 1, bottom row) revealed extended emission surrounding the core of the object at 4.5 μm, but not at 3.6 μm.

3. Results and Discussion

The radial surface brightness profile of the extended emission at 4.5 μm follows a reciprocal relation, which is typical for the free expansion of gas. We interpret the extended emission as a halo and a tail, caused by cometary activity of the object. The existence of extended emission at 4.5 μm and the lack of a clear detection at 3.6 μm suggests the activity to be caused by the sublimation of CO_2 ice: CO_2 emits line emission at 4.3 μm caused by photo–dissociation and has been observed in a number of short–period comets [10]. We

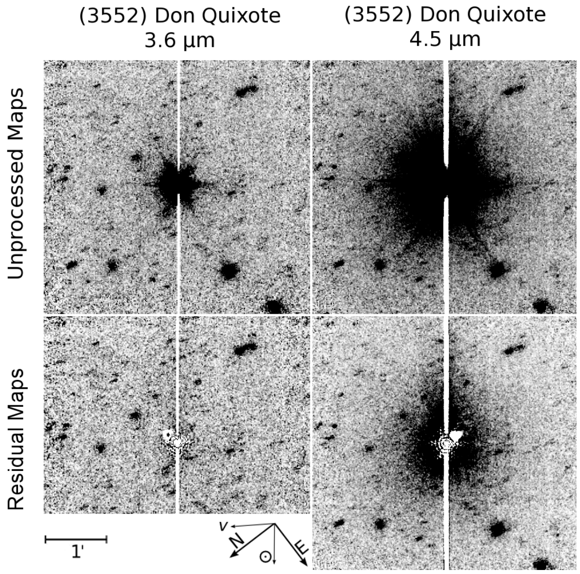

Figure 1: Inverted IRAC observations of Don Quixote. The 4.5 μm residual map shows extended emission that is elongated in the anti–sunward direction. Orientation and scale are illustrated in the bottom left panel. The white vertical bars are caused by the well–understood "muxbleed effect" [12].

determine estimates on the CO_2 and dust production rates from our data.

Extensive testing and comparison to IRAC observations of saturated calibration stars makes us confident that the observed features are real and not image artifacts, background sources, or saturation effects.

We search the literature for additional observations of Don Quixote in the optical and thermal–infrared wavelengths. However, none of the literature data are accurate enough to unambiguously confirm or rule out the existence of cometary activity.

The combination of all available thermal–infrared data and thermal modeling using the Near–Earth Asteroid Thermal Model [11] enables the determination of Don Quixote's physical properties: we derive a diameter of 18.5 ± 0.4 km and an albedo of $0.03^{+0.02}_{-0.01}$. Our results agree with the measurements of [4] and confirm Don Quixote to be the third–largest known NEO.

The discovery of cometary activity triggered by sublimation of CO_2 ice in Don Quixote implies the preservation of volatile material in this body over a long time, even in near–Earth space. The fact that Don Quixote has been known as an asteroid for nearly 30 years before revealing its cometary nature suggests that more NEOs than previously expected might show hidden cometary activity.

The cause and longevity of Don Quixote's activity can only be speculated upon. The lack of accurate observation data besides the IRAC observations precludes a further investigation of both questions. Future observations will be necessary to shed light on these questions.

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