The Extraordinary Multi-tailed Asteroid P/2013 P5

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Introduction

To date, there are twelve known celestial bodies in the Solar System, labeled Main Belt Comets (e.g. Hsieh & Jewitt, 2006) or Active Asteroids (Jewitt, 2012), that exhibit both asteroid and comet-like properties. Among them is P/2013 P5, a comet-asteroid transition object discovered by Pan-STARRS in August 2013. Jewitt et al. (2013) further investigated this object with the Hubble Space Telescope (HST), and revealed six unique comet-like dust tails (Figure 1, left). Jewitt and colleagues observed the object on both September 10th, 2013 and September 23rd, 2013. In this two-week time span, P/2013 P5 displayed many differences in the appearance of its tails. Jewitt et al. (2013) concluded that each tail was the result of an individual event spanning a six-month period. Thus, asteroid P/2013 P5 has sustained mass loss over this period, giving the object comet-like features.

The current research was derived from data taken by Dr. Stephen Levine at the Discovery Channel Telescope (DCT) in November 2013 using the Large Monolithic Imager (LMI) to study the unique properties of P/2013 P5 and search for a mechanism to explain such activity (Figure 1, right). The findings will further the understanding of the evolution and disruption of rubble pile asteroids and, as a result, advance our understanding of the formation and evolution of the Solar System as a whole.

Hypothesis

- The cause of the unique activity is unlikely a product of near-surface ice sublimation. P/2013 P5 is predicted to be a member of the Flora family, which indicates that the asteroid contains little to no volatile material.
- Collision is an unlikely cause of activity for the asteroid with the Jewitt et al. conclusion that each tail is the result of a separate event.
- Jewitt et al. claimed that the most likely explanation for the cause of the six unique tails in P/2013 P5 is spin-up and rapid rotation of the asteroid caused by solar radiation forces and torques of the YORP Effects.

Methods

Sidereal and asteroid-rate tracked images were taken over the course of four hours using the LMI on DCT. Standard data reduction procedures were performed on all of the data files.

Results: Photometry

Photometry was performed on the asteroid-rate tracked images of P/2013 P5 using an aperture radius of 3 pixels (Figure 2a). Figure 2b shows the light curves of both field asteroid 2006 BZ253 and P/2013 P5, revealing similarity between the two. A cut was taken on the trailed field stars of the non-sidereal rate tracked images perpendicular to the direction of the star trails. A Gaussian profile was fit to each cut and the full width at half maximum value (FWHM) was plotted with time to quantify the focus and seeing changes throughout the night (Figure 2c). The FWHM vector was normalized to perform variable aperture photometry (Figure 2d).

Figure 2: (a) HST image of P/2013 P5 taken on September 10th, 2013 (top) and September 23rd, 2013 (bottom). The two images reveal very different appearances in the object with the six unique tails (a-f) growing both in length and brightness. The width of the image is 28” (3,000 km) with the tails extending approximately 25” (Jewitt et al., 2013).

Figure 3: The radial profile of each 90° wedge was plotted for each mini stack from the center of the asteroid out to roughly 3.8”.

Results: Brightness Changes

A 7.68”x7.68” box was extracted from each stack, with the nucleus-coma system located at the center. The array was rotated clockwise in increments of 5°. At each 5° rotation, a 5° wedge was extracted from the array (Figure 3). Larger wedges of 90° were created by summing together the 5° wedges to look for morphological changes (Figure 3).

To make an initial inspection of changes occurring in the asteroid, the total flux in one 90° wedge was calculated for each stack and plotted with time, revealing regular variation in the flux (Figure 4). The variation does not fit the trend of seeing throughout the night, which followed a positive linear trend (Figure 2c), giving us reason to further investigate this variability.

Results: Changes in the Nucleus

The nucleus-coma system is extremely complex and so it is difficult to extract the coma from the nucleus. Ideally, the nucleus acts like a point source that is fuzzed out by seeing conditions, the focus of the telescope, and effects of differential refraction. A Gaussian profile was created using field stars in the sidereal images to represent the seeing and focus conditions at the time of the image. With the Gaussian profile removed, the remaining information should represent the coma of P/2013 P5 (Figure 7).

Conclusion

The pattern of the brightness rankings of each 90° wedge is displayed below. Each set of boxes represents an image stack where the colored box symbolizes a 90° wedge in its correct location in the array. The colors of the boxes correspond to the colors in the plots, while numbers in each box are the brightness ranking of that 90° wedge (Figure 6).

References


Future Work

- Investigate the scale of the variance, change the size and position of the wedge, and characterize the extinction.
- Field asteroid 2006 BZ253 can also be used as a direct comparison following the same wedge procedure.
- We might investigate using a well written program to search for faint coma, tail, and any morphological changes (Sonnett et al., 2013).

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