The Extraordinary Multi-tailed Asteroid P/2013 P5

Annika Gustafsson[1,2], Nicholas Moskovitz[2], Stephen Levine[2]

[1] University of Oregon, Eugene, OR
[2] Lowell Observatory, Flagstaff, AZ

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.

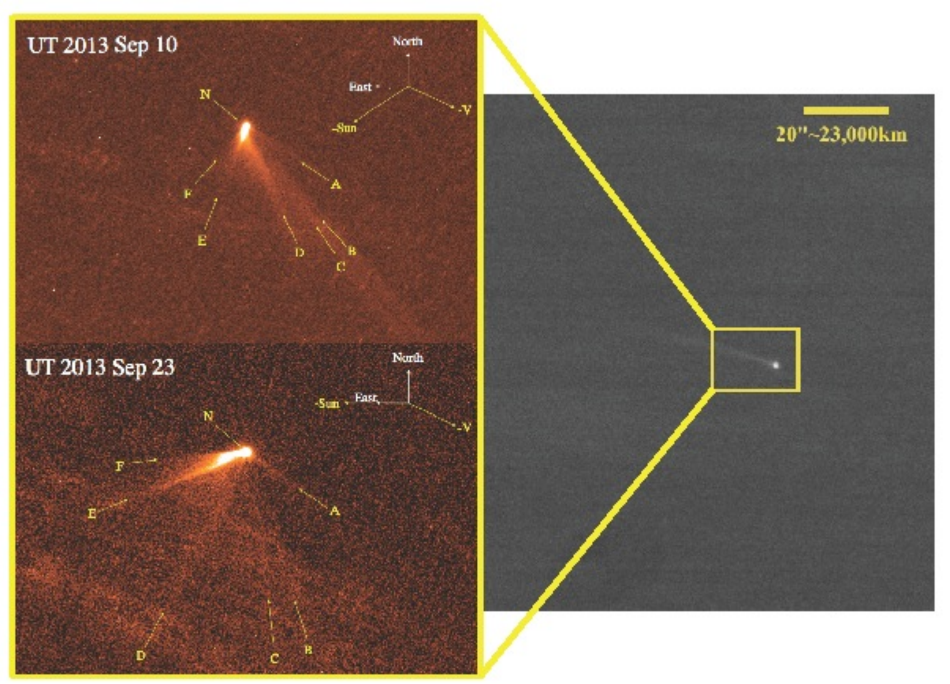


Figure 1: HST image of P/2013 P5 taken on September 10th, 2013 (top) and September 23rd, 2013 (bottom). The two images reveal very different appearances in the object with the six unique tails (A-F) growing both in length and brightness. The width of the image is 28" (23,000 km) with the tails extending approximately 25" (Jewitt et al., 2013).

Hypothesis

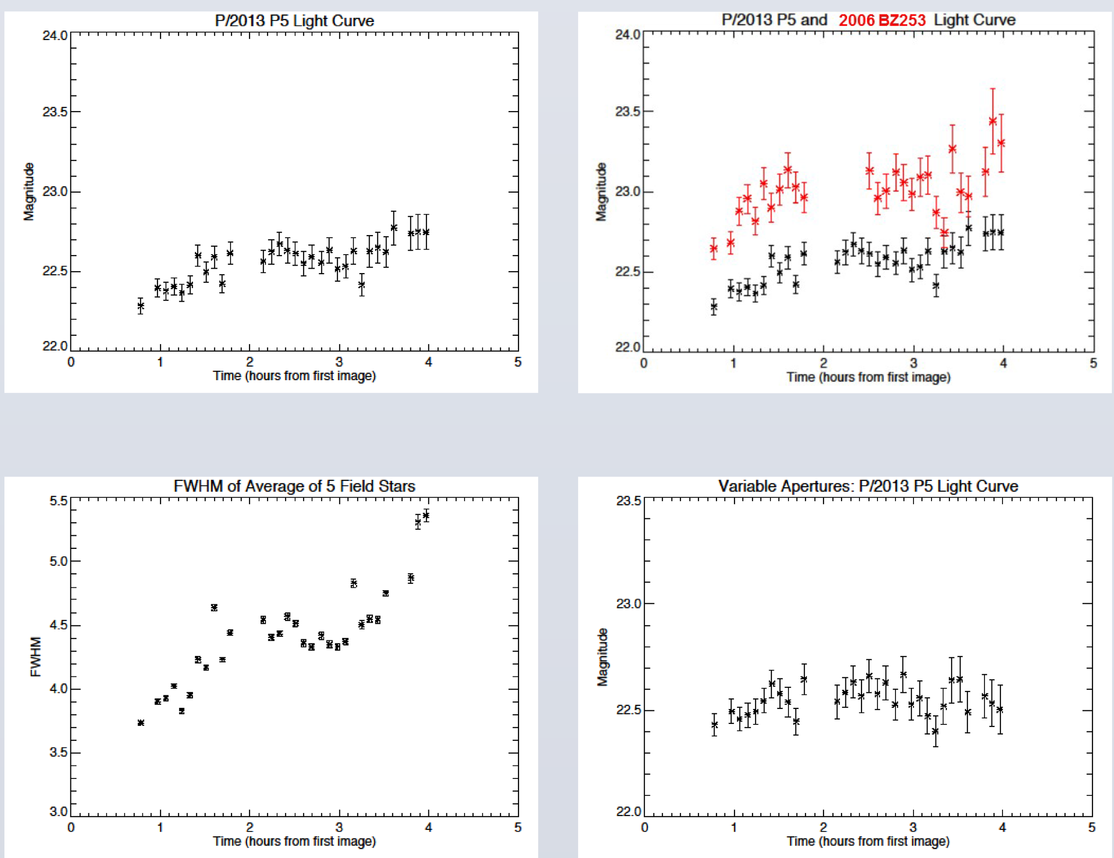
- The cause of the unique activity is unlikely a product of near-surface ice sublimation. P/2013 P5 is predicted to be a member of the Flora family, which indicates that the asteroid contains little to no volatile material.
- Collision is an unlikely cause of activity for the asteroid with the Jewitt 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).



(2a) (2b) (2c) (2d)

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).

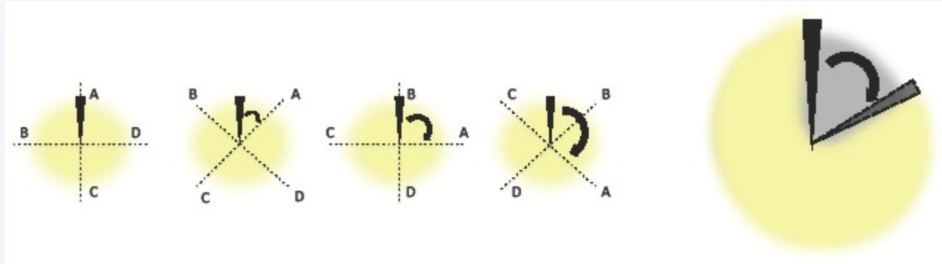


Figure 3

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.

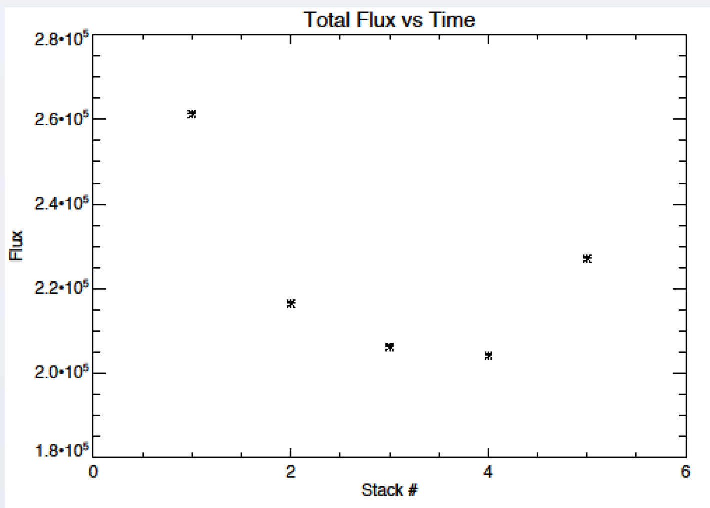


Figure 4: The total flux in a 90° wedge for each of the five mini stacks. The errors are at the level of 0.21% of the mean while the variance is at the level of 10% of the mean.

Radial profiles were plotted of the four 90° wedges for each of the five mini stacks to track the brightness changes more precisely with time (Figure 5). The flux of each wedge was calculated to rank its brightness from 1:4 with respect to the other 90° wedges in the stack.

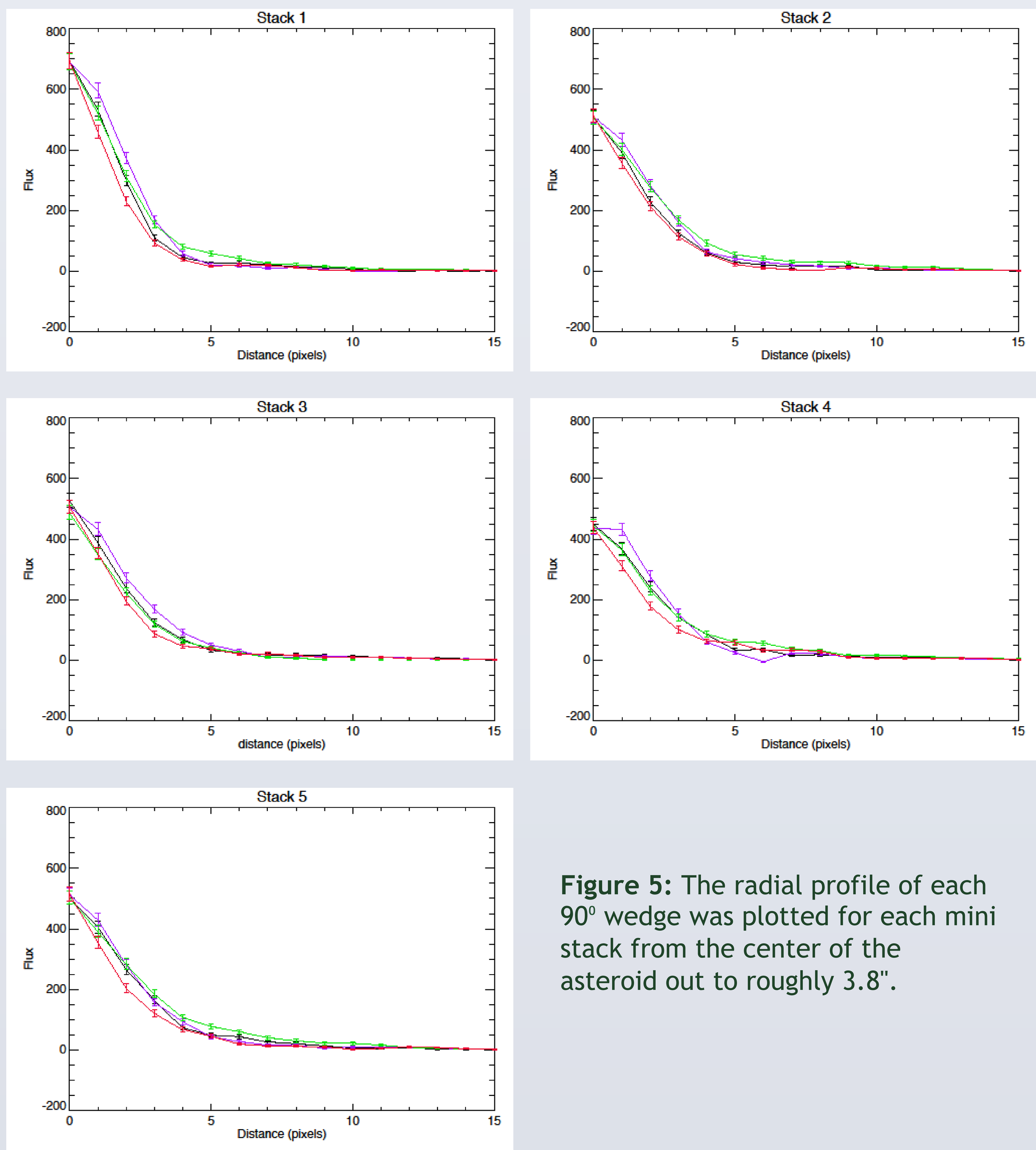


Figure 5: The radial profile of each 90° wedge was plotted for each mini stack from the center of the asteroid out to roughly 3.8".

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).

Wedge #	1901	1902	1903	1904	2901	2902	2903	2904	3901	3902	3903	3904	4901	4902	4903	4904	5901	5902	5903	5904
Flux	1783.1	1948.7	1942.9	1585.6	1422.5	1588.2	1675.8	1324.7	1482.1	1614.7	1313.7	1312.8	1429	1454.1	1514.6	1272	1575.9	1607	1744.7	1379.6

Figure 6

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).

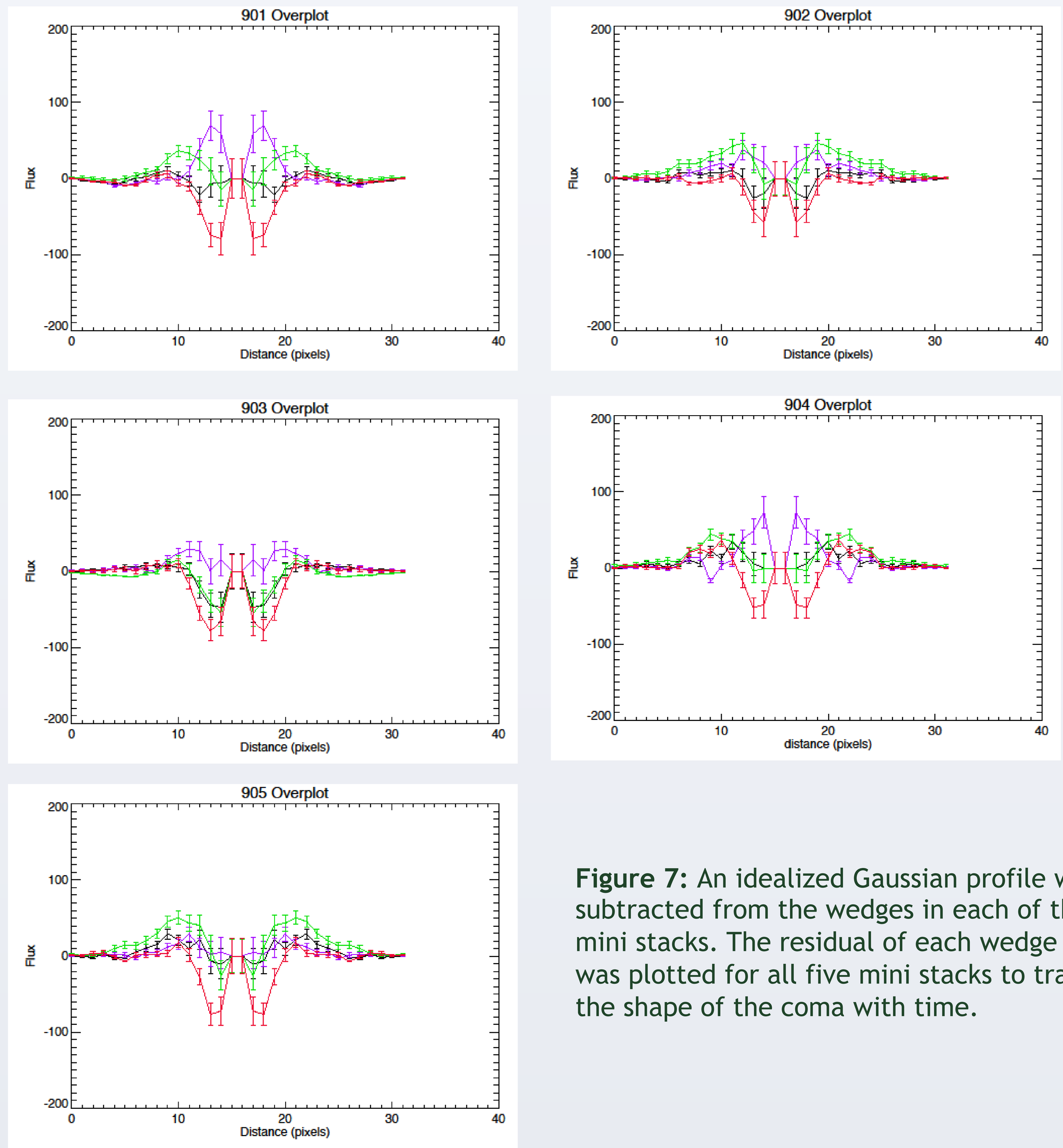


Figure 7: An idealized Gaussian profile was subtracted from the wedges in each of the mini stacks. The residual of each wedge was plotted for all five mini stacks to track the shape of the coma with time.

The different colored boxes represent the different 90° wedges within a stack. The absolute value of each coma profile was calculated to rank the residuals from largest to smallest (Figure 8).

Wedge #	1901	1902	1903	1904	2901	2902	2903	2904	3901	3902	3903	3904	4901	4902	4903	4904	5901	5902	5903	5904
SD	7.16	24.46	14.25	26.27	9.77	11.97	15.9	17.37	17.84	10.45	17.13	28.35	9.72	22.54	15.33	23.34	11.13	7.87	20.71	26.97

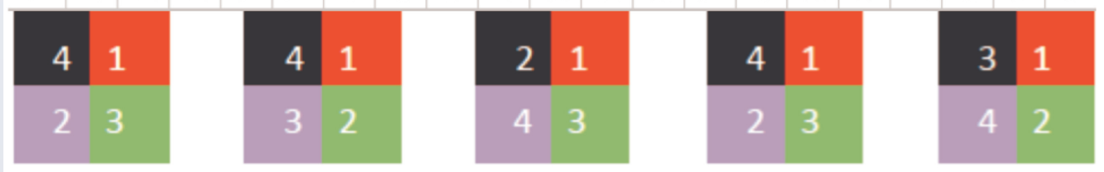


Figure 8

Conclusions

Photometry and morphological changes in structure and brightness of the coma-nucleus system of P/2013 P5 were investigated to search for signs of rapid rotation. Conclusions regarding the rotational properties of P/2013 P5 determined from DCT observations are as follows:

1) At an apparent magnitude of V=22.5 magnitude, we found no significant variability in the light curve at the level of 0.15 magnitudes.
2) Total flux of the first 90° wedge of each of the mini stacks reveals a smooth pattern of the coma-nucleus system of P/2013 P5 changing with variation on the level of 10%.
3) Radial profiles of the 90° wedges for each mini stack further support the observation of changes in the brightness of P/2013 P5. There is no observed pattern to these changes over time.
4) Plots of the "residual" (coma) also reveal changes with time. There is no observed pattern to these changes either.

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).

References

Hsieh, H.H., & Jewitt, D. 2006, Science, 312, 561
Jewitt, D. 2012, AJ, 143, 66
Jewitt, D.C., Agarwal, J., Weaver, H., Mutchler, M., & Larson, S. 2013, ApL, 778

NSF Grant AST-1004107

Contact: Annika Gustafsson, University of Oregon
annika@uoregon.com