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Detailed photometric characterization of ‘Oumuamua with Gemini North

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Abstract

‘Oumuamua is the first astronomical object known to science to have entered the Solar System from the interstellar space, having been ejected from its original planetary system. Using the Gemini North telescope in Hawaii, our team obtained the most detailed photometric characterization of this unique body. A combined ultra-deep image shows no signs of cometary activity, implying that the body is physically an asteroid, and an accurate light curve reveals an enormous range of brightness variation, suggesting a highly elongated shape. We also discovered that ‘Oumuamua is a non-principal-axis (or tumbling) rotation state, which is consistent with an ancient collision that occurred in the body’s home planetary system.

1. Introduction

‘Oumuamua is the long-awaited first bridge between extrasolar planetary systems and our own Solar System. The body was discovered with the Pan-STARRS telescope on 19 October 2017 UT and became intensively observed nearly immediately after. The visit of ‘Oumuamua was hardly a surprise, though. That is because almost all the original small Solar System bodies have been lost to the interstellar space as a result of dynamical perturbations, and thus free-floating minor objects ejected from other planetary systems should also be abundant.

2. Observations

Our the team was awarded 12 hr of observation time on the Gemini North telescope in Hawaii — the longest run ever allocated to observations of ‘Oumuamua on a telescope of this class. On 27 and 28 October 2017 UT, we obtained over 400 images suitable for accurate time-resolved photometry, having an effective integration time of 3.58 hr and spanning a total of 8.06 hr [1].

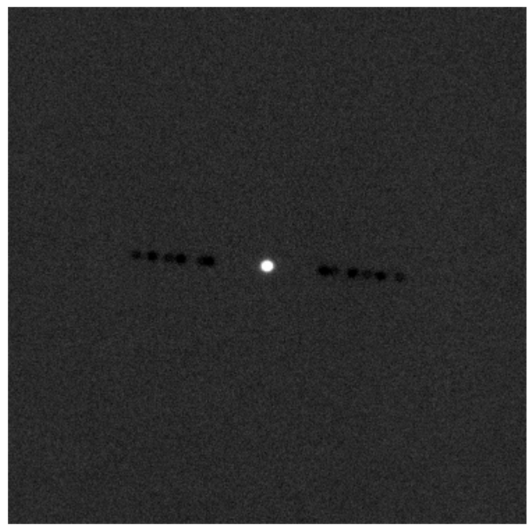

Figure 1: Deep stack of the r′-band imaging time series of ‘Oumuamua. The negative images of the target to the left and right of the positive image are artifacts produced by our background subtraction algorithm and do not affect the photometry. The presented region is 1.0×1.0 arcmin. North is to the top and east is to the left. Despite having a very high surface brightness sensitivity of 28.2 mag arcsec^{-2} measured in a 1 arcsec^2 region, the image does not show any signs of cometary activity.

3. Results

A combined ultra-deep image of ‘Oumuamua (Fig. 1) shows no signs of cometary activity, providing the most stringent limit to ice sublimation and the most compelling evidence that the object is physically an asteroid. This means that — contrary to general expectations — interstellar minor bodies might predominantly be comets. An accurate light curve reveals an enormous range of brightness variation with a full range reaching 2.6 ± 0.2 mag, suggesting a highly

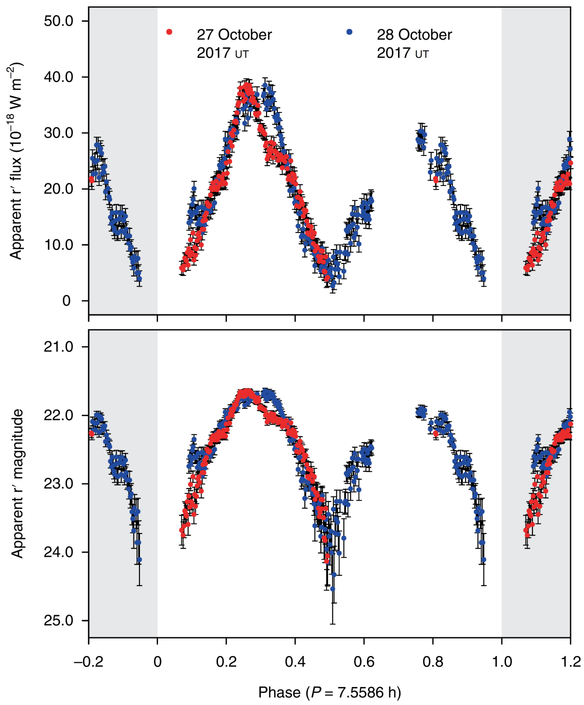

Figure 2: Changes in ‘Oumuamua’s brightness over two subsequent nights. The top panel shows the brightness in the linear flux scale and the bottom panel shows the brightness in the logarithmic magnitude scale. The grey areas indicate replicated data. It is evident that the light curve does not repeat exactly from one night (27 October 2017 UT) to another (28 October 2017 UT), consistent with a non-principal-axis rotation state, or tumbling.

elongated shape of the body with the long-to-short axis ratio of > 4.9. We also determined the effective rotation period to be 7.56 ± 0.1 hr, the equivalent size to be ~ 150 m, and we found that the density —- contrary to previous reports by other teams —- may not be different from the typical density of Solar System’s asteroids. The light curve also revealed an imperfect repeatability of the changes in brightness between the subsequent rotation cycles, implying that ‘Oumuamua is a non-principal-axis rotation state. ‘Oumuamua’s tumbling is consistent with an ancient collision that occurred in the body’s home planetary system, suggesting that collisional processing of small body populations in other planetary systems might be common.

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References

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