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1I/2017 U1 (`Oumuamua), a Portrait

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Abstract

We present here the analysis of the data we obtained on 1I/2017 U1 (`Oumuamua), combined with data from other teams. We summarize our derived physical characteristics in terms of surface and bulk properties[1], rotational state[2] and orbit[3].

1. Discovery

The Pan-STARRS1 survey detected the object on 2017 Oct. 19; by Oct. 22, additional observations from the Canada-France-Hawaii Telescope (CFHT) and pre-discovery images from Oct. 18 indicated that the object was on a hyperbolic orbit, originating from outside our Solar System[1]. We immediately started a campaign to characterize this unique object during its short period of observability using the CFHT, the ESO VLT, Gemini, Keck, UKIRT and HST.

2. Rotational State

The object presented extremely wide brightness variations, with a range of 2.5 mag. Combining our data with additional photometry published by other authors[4,5,6,7,8,9] (summarized in Fig. 1), we performed a detailed analysis of the rotational state of the object[2], indicating an excited spin state with two fundamental periods at 8.67±0.34 h and 3.74±0.11 h. The object could be spinning in the Short Axis Mode (where the short principal axis of the object circulates around the total angular momentum vector, TAMV), or in the Long Axis Mode (where the long axis circulates around the TAMV). Interestingly, 1I could be either an elongated cigar-shaped object, in which case it would be in a state close to its lowest rotational energy, or an extremely oblate spheroid, pancake-shaped, close to its highest energy for its angular momentum.

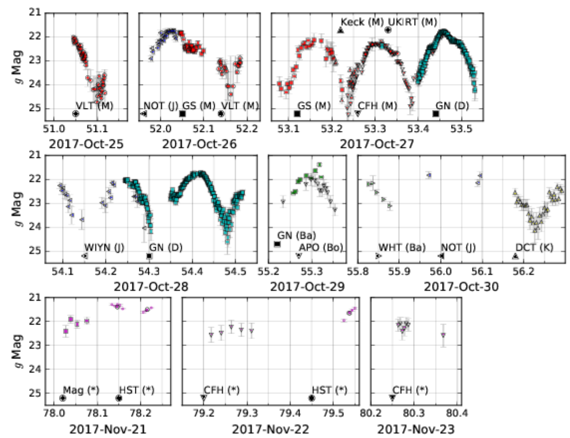

Figure 1. The photometric data used for this study, converted to g band and corrected for geometry and light-travel time to 2017 Oct. 25. Figure from [2].

3. Surface properties

The colours of 1I's surface were measured[1] (g-r = 0.84 ± 0.05, g-i = 1.15 ± 0.10, g-z = 1.25 ± 0.10, g-Y = 1.60 ± 0.20); they correspond to a spectral slope $S_v = 23 \pm 3\%/100$ nm, which is similar to D-type asteroids and comets from our Solar System (see Fig. 2). While our measurements are consistent with a uniform colour over the whole object, Fraser et al. [7] report that one side of the object could be redder.

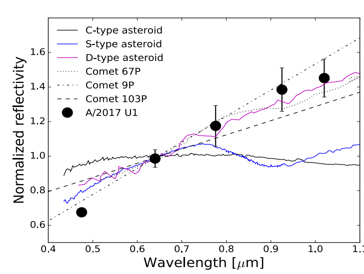

Figure 2. Reflectivity of the surface of 1I/2017 U1 (`Oumuamua) matching that of D-type asteroids and comets (from [1]).

4. Size, shape and density

For a standard cometary albedo of 0.04 and a 0.04 mag/deg solar phase function, the median *g*-band magnitude converts into an effective radius of 102±4 m[1]. Assuming that the light curve is dominated by the shape of the object, its 2.5 mag range corresponds to an elongation of the order of 10:1 (with the solar phase effect tending to decrease this value, and the uncertainty on the geometric aspect increasing it). The third dimension of the object will not be directly constrained by the photometry until the complex light curve is totally solved[2], but the rotation analysis indicates that a cigar-shape object (~10:1:1 axes ratio) is plausible, as is a pancake-shaped object (10:10:1). Scanning over a range of densities and size of the object in the 3rd dimension, we found out that 1I must have some very modest but non-zero internal strength (at least 3 Pa) if its density is comet-like. A long-axis rotator could be held together by gravity only for densities > 1500 kg/m^3 [1].

5. Cometary activity

We searched deep stacked images of the object for hints of a dust coma surrounding it. The photometric profile of 1I matches that of field stars, and various image enhancement techniques failed to reveal any extended source. The most constraining stack sets a limit of 1 kg of 1 μm-sized dust grains in the direct vicinity of ‘Oumuamua (<2.5" or <750 km from the nucleus) on October 25-26, based on the dust limiting magnitude for dust g > 29.8 mag $arcsec^{-2}$. A much larger dust production could be present, but only if the mass is concentrated in large dust grains.

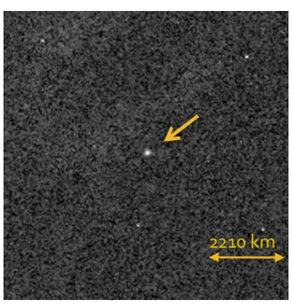

Figure 3. Composite HST image obtained on Nov. 17, 2017 at 1.89 au from the Sun and 1.22 au from Earth. There was no evidence of coma to g > 29.8 mag $arcsec^{-2}$

6. Orbit

We are measuring the astrometric position of all our ground-based and Hubble data, and we will combine them with published astrometry in order to refine and characterize the orbit of 1I using the longest possible observational arc. The recent publication of the Gaia DR2 catalogue could open possibilities of identifying –or at least constraining– the stellar system where 1I originated.

References

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