PHOTOMETRIC FOLLOW-UP OF INTERSTELLAR COMET 2I/ BORISOV SINCE ITS DISCOVERY

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Introduction: Comets and asteroids have always attracted the attention of humanity, but in written history all described ones belonged to the Solar System, until the discovery of 1I/2017 U1 ('Oumuamua) in 2017. A careful study of this previous visitor revealed that it was a dark and extremely oblong shape body, more probably an asteroid [1]. On August, 2019 Gennady Borisov discovered the first interstellar comet using a 0.65 m telescope, from which the provisional object 2019 Q4 received the official assignation of 2I/ Borisov [2]. This significant achievement, obtained when this comet was fainter than +18 magnitude, was made by an amateur [3]. The comet have a hyperbolic orbit, with an eccentricity >3 with the distance of 2.98 au from the Sun [4,5]. The spectroscopic observations certified that the comet has a featureless spectrum [6]. The radius of the nucleus was estimated to be between 0.7 km and 3.3 km by observation [7].

This is clearly emphasizing that semiprofessional observatories have something to say in front of the more systematic searchers made nowadays by professional automatic surveys. Then, this triumph of small-telescope astronomy in the field of solar system minor bodies suggest that there is room for amateur research, not only in the systematic follow-up of interesting objects that experience unexpected photometric changes [8-9].

From Catalonia we observed comet 2I/Borisov using *Telescopi Joan Oró (TJO)*, a 1m-class telescope working in a completely unattended manner. It operates in the Observatori Astronòmic del Montsec (OAdM: www.oadm.cat), a site devoted to host astronomical research facilities under dark skies. In fact, the TJO is the largest telescope in Catalonia and named after the famous Catalan biochemist and pioneer of astrobiology who promoted the construction of this facility. There is an obvious interest in increasing our understanding of the real nature of interstellar comets [8]. In this abstract we compile the photometric measurements made from Catalonia and Crimea in order to exemplify the relevance of a systematic photometric study of interstellar visitors using meter-class instruments.

Observations and reduction procedure: To study the photometric behavior of 2I/Borisov we have used the 0.8 m in diameter Joan Oró robotic telescope, and other small-size instruments compiled in Table 1. TJO CCD detector is an iKon XL camera, with a back-illuminated 4k×4k chip manufactured by Andor. This CCD camera provides a FoV of about 27.5 x 27.5 arcmin, with a resolution of 0.4 arcsec given the given pixel size of 15 μm. The 0.65 m telescope used a FLI ML16803 camera in the Johnson V, R and I filters.

Given the faintness of this comet, we decided to made unfiltered CCD imaging, and the photometry was made using LAIA (Laboratory for Astronomical Image Analysis) and Astrometrica software successfully tested for obtaining high-precision stellar photometry [10]. The data reduction process basically consists of bias subtraction, flat-field correction and flux calibration. We have used similar reduction procedures than in the previous papers [9], but this time the photometry was measured for a circular aperture of about 20 arcmin centered in the comet false nucleus [11]. Using these standards, we were able to quantify the typical data accuracy to be better than 0.1 mag (for further details see [9]).

Table 1. Observatories and instruments used in this study.

Observatory	MPC code	Telescope
MARGO Astron. Obs., Ukr.	051	SC 65 f/10
TJO, Montsec (OAdM), Cat	C65	RC 80 f/9.6
Montseny, Cat	B06	SC 25 f/10

Discussion: The comet has shown a uniform photometric behavior, with no clear anomalies. Every night the comet seems to suffer small fluctuations of about 0.2-0.3 magnitudes that are attributable to small differences in contrast, change in reference stars and night variations in the sky brightness, but for the rest very minor changes (Fig. 1). In reference to its morphology

the appearance of Q4 did not change either between the different nights of observation (Sept.-Dec. 2019). No clear jets were found in our imagery, althought the resolution of our instruments during the observational period in the inner coma was typically larger than one arcsec. Sky subtraction was used to negate the effects of changing atmospheric extinction. After this correction, no convincing photometric variability was found according to our data.

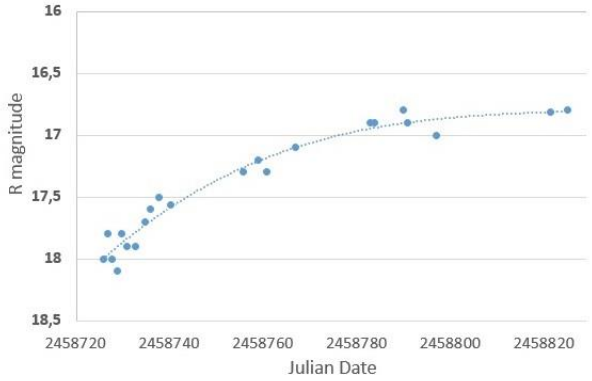

Figure 1. Unfiltered "R" magnitude for comet 2I/Borisov as a function of the Julian Date. Accuracy is about 0.1 magnitudes.

Conclusions: Interstellar comet 2I/(2019 Q4) Borisov has shown since its discovery an uniform behavior without changes in its morphology. We have noticed little changes in its comma or tail during the few months in which we performed this photometric follow-up. We still need to reduce some of the data collected from TJO, but the general behavior is similar. The comet R magnitude increases slightly following a common pattern (see Fig. 1). The small 0.2-0.3 magnitude changes between successive images that we noticed some nights can be considered the effect of changing atmospheric extinction and stellar fields. In our opinion, there is not convincing photometric variability detected within each night, neither along the observed period. Obviously, given the aperture measurements made for 20 arcsec surrounding the false nucleus, it is likely that any photometric variations are systematically damped. Now the comet is moving to the Southern hemisphere, and will be finally lost in space for ever so not other observations will be made. In view of the results that we have obtained, we can say that the first interstellar comet appearance occurred without sorrow or glory. In any case, it is a clear confirmation that interstellar comets also exist.

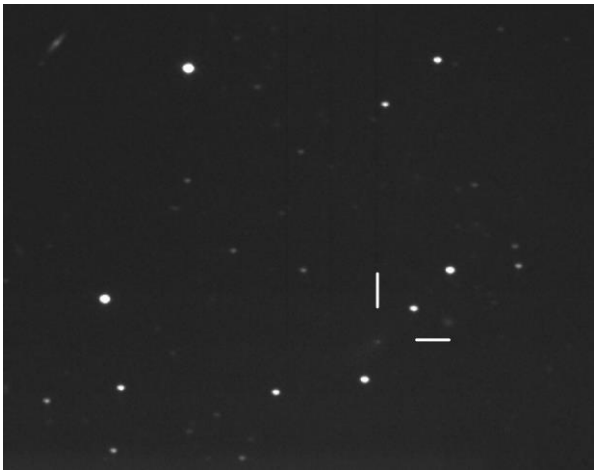

Figure 2. A 12 minutes exposure stacked image of comet 2I/Borisov as recorded from TJO, at Montsec Astronomical Observatory in Catalonia on 11.16 September 2019.

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References: [1] Meech K.J. et al. (2017) *Nature* 552, 378-381. [2] Jewitt D. and Luu J. (2019) ApJL 886, L29 [3] Bolin, B.T., et al., 2019. arXiv preprint arXiv:1910.14004. [4] Guzik, P., et al., 2019. Nature Astronomy, pp.1-5. [5] Opitom, C., et al., 2019. A&A, 631, p.L8. . [6] de León, J., et al., 2019. Research Notes of the American Astronomical Society, 3. [7] Fitzsimmons, A., et al., 2019. The Astrophysical Journal Letters, 885(1), p.L9. [8]Trigo-Rodríguez J.M. et al. (2008) Astronomy and Astrophysics 485, 599-606. [9] Trigo-Rodríguez J.M. et al. (2010) Mon. Not. Royal Astron. Soc. 409, 1682-1690. [10] Juan-Samsó, et al., 2005. A&A, 434(3), pp.1063-1068. [11] Stetson, P.B., 2000. Publications of the Astronomical Society of the Pacific, 112(773), p.925.