AN ARGUMENT FOR A KILOMETER-SCALE NUCLEUS OF C/2019 Q4

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ABSTRACT

C/2019 Q4 (Borisov), discovered by Gennady Borisov on August 30, 2019, is tentatively an interstellar comet. We show that a kilometer-scale nucleus would provide consistency with both 'Oumuamua and CNEOS-2014-01-08, resulting in a single power-law distribution with an equal amount of mass per logarithmic bin of interstellar objects.

INTRODUCTION

'Oumuamua was the first interstellar object detected in the Solar System by Pan-STAARS (Meech et al. 2017; Micheli et al. 2018). Its size was estimated to be 20m - 200m, based on Spitzer Space Telescope constraints on its infrared emission given its temperature (Trilling et al. 2018). CNEOS 2014-01-08 is tentatively the first interstellar meteor discovered larger than dust, with ≈1 m in size (Siraj & Loeb 2019). C/2019 Q4 (Borisov), discovered by Gennady Borisov on August 30, 2019, at the Crimean Astrophysical Observatory, is tentatively an interstellar comet (Guzik et al. 2019). According to a JPL press release, the radius of the nucleus has been estimated by Karen Meech and her team at the University of Hawaii to be 1 − 8 km.\textsuperscript{2} In this Note, we show that a kilometer-scale nucleus would provide consistency with both 'Oumuamua and CNEOS-2014-01-08, resulting in a single power-law distribution with an equal amount of mass per logarithmic bin of interstellar objects.

ORBIT

As C/2019 Q4 has yet to cross the plane of the ecliptic, previous planetary encounters in the Solar System are impossible. In addition, it is unlikely to have received a substantial non-gravitational kick from cometary exhaust due to its large distance from the Sun as well as its substantial size.

The orbit of C/2019 Q4 implies an excess heliocentric velocity of ∼30 km s\textsuperscript{−1} (Guzik et al. 2019). The heliocentric incoming velocity at infinity of the meteor in right-handed Galactic coordinates is \(v_\infty(U, V, W) \approx (21, -23, 1) \text{ km s}^{-1}\), which is ∼35 km s\textsuperscript{−1} away from the velocity of the Local Standard of Rest (LSR), \((U, V, W)_\text{LSR} = (-11.1, -12.2, -7.3) \text{ km s}^{-1}\) (Schonrich et al. 2010). The object’s speed likely reflects the speed of the parent star if it originated from the star’s Oort cloud.

Its orbit is inclined ∼15° to the Galactic plane, suggesting a possible origin in the Galactic disk. If C/2019 Q4 comes from the Galactic disk, then a stellar origin from a distance ≥ 1 kpc is most likely. Given the large distance to the parent star relative to the Galactic scale height, it is unlikely to find the parent star through backward trajectory extrapolation.

IMPLIED EJECTED MASS

A rough, order-of-magnitude estimate of number density assumes a search time of a few years with detection coverage out to ∼3 AU (giving a detection volume of ∼10\textsuperscript{2} AU\textsuperscript{3}), which an implied number density of a few \(10^{-3.75}\) AU\textsuperscript{−3} or a few \(10^{13.75}\) pc\textsuperscript{−3} (given 95% Poisson uncertainties). Such a number density is a factor of ∼10\textsuperscript{−2} of that implied by 'Oumuamua (Do et al. 2018), suggesting a power law index similar to Solar System bodies at those size scales (Ivezic et al. 2001).

Assuming a typical cometary density of 0.6 g cm\textsuperscript{−3} and the largest plausible radius of 8 km, C/2019 Q4 would have a mass of \(10^{18}\) g. Taken together with our estimate of implied number density, this implies a mass density of

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\textsuperscript{2} https://www.jpl.nasa.gov/news/news.php?feature=7498
Figure 1. Size distribution of interstellar objects, given ‘Oumuamua, CNEOS 2014-01-08, and C/2019 Q4, each with 95% Poisson confidence intervals. The two rightmost points indicate C/2019 Q4 with 1 km and 8 km radii, respectively. The blue dotted line indicates a slope of $\sim -3$, implying an equal amount of mass per logarithmic bin of interstellar objects.

$\sim 10^{31.75} \pm 0.75$ g pc$^{-3}$, or $\sim 10^{30.75}$ Jupiter masses ejected per star. This density is $\sim 10^{31.75}$ higher than that expected of Oort clouds (Weissman 1983). This would constitute an extremely surprising implication for the amount of ejected mass in the form of large comets. If the size of the nucleus were of order $\sim 1$ km, the required ejected mass per star would fall to the expected range for Oort clouds (a few $10^{28}$ g), comparable to the ejected mass implied by both ‘Oumuamua and CNEOS-2014-01-08 for their respective logarithmic bins (Siraj & Loeb 2019). Figure 1 shows the size distribution of interstellar objects with ‘Oumuamua, CNEOS 2014-01-08, and C/2019 Q4 (for radii of 1 km and of 8 km), with appropriate Poisson uncertainties.

Further measurements will be crucial for constraining the scale of the nucleus of C/2019 Q4 and the corresponding implications for ejected mass. We recommend spectroscopy of the cometary gases throughout the monitoring of C/2019 Q4 in the future. A combination of precision astrometry and spectroscopy of C/2019 Q4 will reveal its true origin, as well as its composition and internal structure, all of which are crucial for understanding the formation and constituents of exo-planetary systems.

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