

CONSTRAINTS ON THE WATER-PRODUCTION RATES OF INTERSTELLAR COMET 2I/BORISOV FROM ARECIBO RADIO OH OBSERVATIONS. K. N. Ortiz Ceballos^{1,2}, A. H. Colón Cesani^{1,3}, E. S. Howell⁴, A. Méndez¹, Y. R. Fernandez^{5,6}, A. J. Lovell⁷, C. A. Schambeau⁵, N. Pinilla-Alonso^{6,8}, M. Womack^{5,6} and G. Ferrer-Imbert^{1,2}. ¹Planetary Habitability Laboratory, University of Puerto Rico at Arecibo, Arecibo, PR, USA (kevin.ortiz22@upr.edu), ²Department of Physics, University of Puerto Rico, Río Piedras Campus, San Juan, PR, USA, ³Department of Physics, University of Puerto Rico, Mayagüez Campus, Mayagüez, PR, USA, ⁴Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, ⁵Department of Physics, University of Central Florida, Orlando, FL, USA, ⁶Florida Space Institute, University of Central Florida, Orlando, FL, USA, ⁷Agnes Scott College, Decatur, GA, USA, ⁸Arecibo Observatory, University of Central Florida, Arecibo, PR, USA

Introduction: Comet 2I/Borisov was first observed September 8, 2019 and was quickly identified as originating from outside the Solar System due to its highly eccentric, hyperbolic orbit. This is only the second such body that has been detected after 1I/Oumuamua, which unlike Borisov showed no coma. Radio observations can measure the presence of the hydroxyl (OH) radical, a photodissociation product of water, in the comet's coma, quantifying the comet's activity. We used the Arecibo Observatory to study interstellar comet 2I/Borisov as it passed over its field of view in the fall of 2019.

Observations: We observed interstellar comet 2I/Borisov on eight occasions in 2019 between September 22 and November 9 until it was no longer visible from Arecibo. The 1612, 1665, 1667 and 1720 MHz OH lines were observed. The OH lines were not detected. We find 3σ upper limits to the possible line flux for the 1667 MHz line, which is expected to be strongest [1].

Results: We did not detect any emission or absorption of OH at the 1667 MHz line in our observations above 3σ . 2I/Borisov was not reported to undergo any significant outbursts during the observing period.

Using the upper limits on the line flux, we find upper limits to the OH and H₂O production rates of

improved precision to previously reported results for September and October 2019, with the lowest limits at $Q_{OH} < 7.4 \times 10^{26}$ mol/s and $Q_{H_2O} < 6.3 \times 10^{26}$ mol/s for late September. Our results agree with reported ultraviolet, optical and radio observations of 2I/Borisov, which are consistent with low water production [2, 3, 4, 5, 6].

Full preliminary results are reported in Table 1. r_H gives the heliocentric distance in AU. The inversion is given by i , and is taken from Despois et al. [7]. The 3σ flux limit is determined from three times the standard deviation of the measured noise in the spectra for the 1667 MHz OH spectral line. Maximum possible spectral line intensity I_{OH} is found by multiplying the flux limit by an assumed linewidth of 1.6 km/s, derived from an assumed expansion velocity of 0.8 km/s for the OH parent molecules in 2I/Borisov. Finally, the upper limits on Q_{OH} and Q_{H_2O} are presented; these were derived following the symmetrical radial outflow model of Schloerb & Gerard [8], using the 1667 MHz-specific approximation determined by Tacconi-Garman et al. [9], and employing the empirical relation given by Schleicher et al. [10].

Figure 1 presents the Arecibo results in comparison with other reported measurements of Q_{H_2O} , with respect to days from perihelion and heliocentric distance. As shown in the figure, the Arecibo

Table 1. OH and H₂O production rates for comet 2I/Borisov

2019 UTC Date	r_H (AU)	i	3σ flx. lim. (mJy)	Max. I_{OH} (mJy km/s)	Q_{OH} (mol./s)	Q_{H_2O} (mol./s)
Sep-22 12:15	2.631	0.380	4.17	6.67	<1.12E+27	<9.42E+26
Sep-23 12:15	2.617	0.392	2.97	4.74	<7.72E+26	<6.49E+26
Sep-26 12:00	2.575	0.424	3.17	5.08	<7.57E+26	<6.42E+26
Sep-27 12:00	2.562	0.433	3.18	5.09	<7.40E+26	<6.30E+26
Oct-06 11:30	2.445	0.495	3.77	6.04	<7.44E+26	<6.47E+26
Oct-19 11:30	2.293	0.452	4.83	7.72	<9.85E+26	<8.86E+26
Nov-04 11:00	2.145	0.216	6.69	10.70	<2.62E+27	<2.43E+27
Nov-09 10:45	2.108	0.048	5.95	9.51	<1.02E+28	<9.53E+27

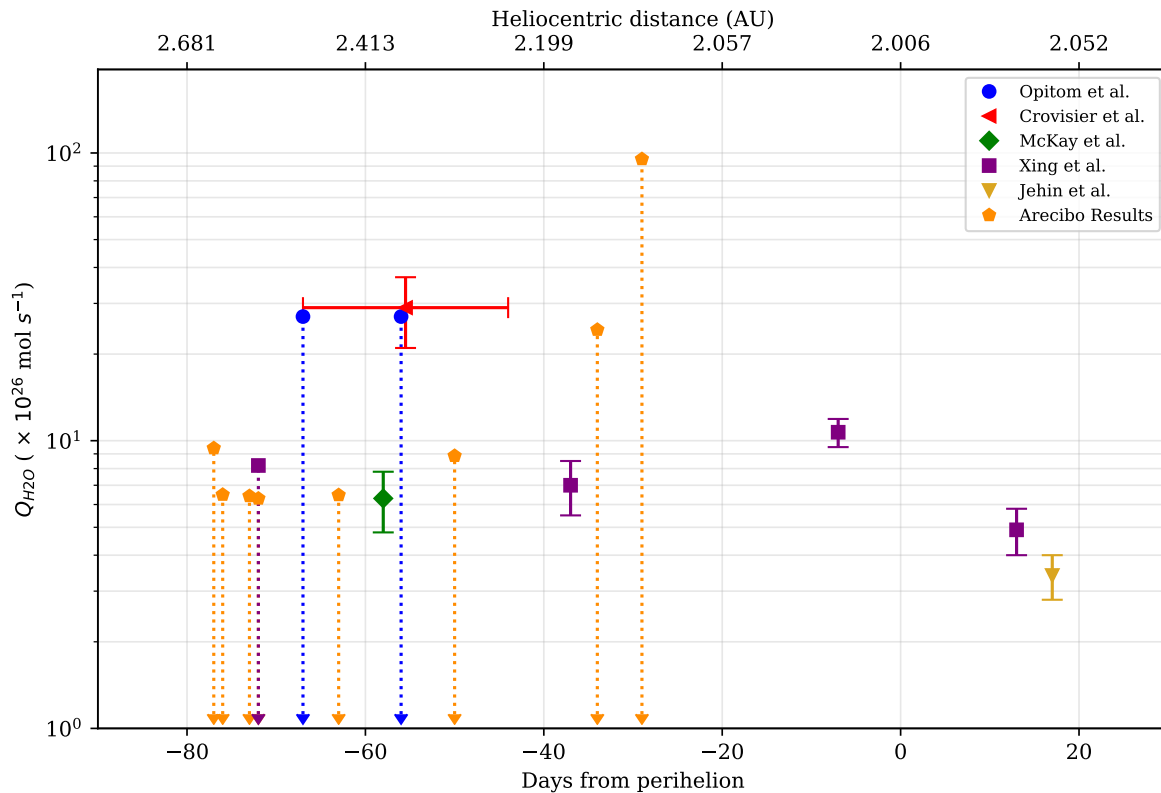


Figure 1. Water production rates of 2I/Borisov over time from various reported observations. Values for Q_{H_2O} from Opitom et al. [3] and Crovisier et al. [5] were produced using their respective results of Q_{OH} and converted by using an empirical relation from Schleicher et al. [10]. Dotted arrow lines indicate upper limits, while solid error bars indicate values obtained from direct detection of spectral lines.

constraints are consistent with and improve the precision of other presented results [2, 3, 4, 5, 6].

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