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C/2018 Y1 (Iwamoto): Measuring the volatile composition of a long-period comet shortly following its discovery

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Abstract

We used iSHELL [4,5], the powerful high-resolution ($\lambda/\Delta\lambda \sim 40{,}000$) cross-dispersed IR spectrograph at the NASA-IRTF to measure the native ice composition of moderately bright, long-period comet C/2018 Y1 (Iwamoto) within weeks of its discovery on 18 December 2018 [1]. We report production rates for H_2O, and production rates and abundance ratios relative to H_2O for eight trace molecules. Compared with mean abundances measured among comets, our study revealed significantly depleted CO and C_2H_2 yet enriched CH_3OH and C_2H_6, perhaps indicating highly efficient H-atom addition on interstellar grains prior to their incorporation into the nucleus. The combined high spectral resolving power and broad spectral coverage of iSHELL allows characterizing cometary composition using only three instrument settings.

1. Observations

Comet C/2018 Y1 (Iwamoto) (hereafter Y1) reached perihelion on 7 February 2019 (at heliocentric distance R_h = 1.290 AU). We recorded spectra with iSHELL toward the end of the night on three pre-perihelion dates, 13 January (R_h = 1.34 AU, geocentric distance Δ = 1.18 AU) and 4 and 5 February 2019 (R_h = 1.291 AU, Δ = 0.45-0.42 AU), during scheduled runs that concluded our campaign on Jupiter-family comet 46P/Wirtanen [2]. This allowed a suite of nine parent volatiles (including H_2O) to be measured on the February dates, using just three instrument settings between $\lambda \sim 2.8 - 5.2$ µm: Lcust, spanning 2.82 – 3.10 µm, Lp1 (3.28 – 3.66 µm), and M2 (4.5 – 5.2 µm). The 13 January observations afforded time only for Lp1; these were used to assess the hydrocarbon chemistry and to better plan for the February run near perihelion. For all dates, the geocentric radial velocity of Y1 was unusually large (-58.9 km s^{-1} on 13 January; -48.3 and -45.5 km s^{-1} on 4 and 5 February, respectively), Doppler-shifting lines of cometary CO and CH_4 well away from their opaque telluric counterparts and thereby into regions of highly favorable atmospheric transmittance.

2. Results

Preliminary results are listed in Table 1, and representative spectral extracts are shown in Fig. 1. When compared with abundances (relative to H_2O) found for a dominant group of comets from the Oort cloud (often referred to as "normal" or "typical" abundances), our study revealed depleted CO, C_2H_2, H_2CO, and NH_3, typical CH_4 and HCN, and enriched C_2H_6 and CH_3OH. A viable pathway for the production of CH_3OH and C_2H_6 is H-atom addition reactions to CO and C_2H_2, respectively, on the surfaces of interstellar grains at very low temperatures (~ 10 – 20 K; e.g., see [6]).

3. Conclusions

In this context, our results imply efficient conversion for grains that were assimilated into the nucleus of Comet Y1. Furthermore, among parent volatiles systematically measured in comets, CH_4 is second in volatility (after CO), and therefore its (nearly) "normal" abundance implies that thermal processing (e.g., in the proto-solar nebula) was likely not the dominant consideration in determining volatile abundances in Comet Y1. Our study demonstrates the ability to measure the volatile chemistry of a moderately bright comet, with iSHELL; our overall observing efficiency (time on source versus elapsed clock time) was approximately 75%.

Acknowledgements

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Table 1: Preliminary production rates and molecular abundances in C/2018 Y1 (Iwamoto)

UTDate/Setting/ToS[a] Molecule	Q(molec s^{-1})	X/H$_2$O[b]
Feb 04/M2/38.9		
H_2O	2.2±0.2E28	-------
CO	4.3±0.3E26	2.0 (4-6)
Feb05/Lcust/91.7		
H_2O	2.1±0.1E28	-------
HCN	4.1±0.2E25	0.20 (0.2)
C_2H_2	1.7±0.2E25	0.08 (0.2)
NH_3	< 5.8E25	< 0.28 (0.9)
Feb05/Lp1/63.8		
C_2H_6	1.9±0.1E26	0.93 (0.6)
CH_4	1.4±0.2E26	0.67(0.8-0.9)
CH_3OH	5.9±0.3E26	2.8 (2.2)
H_2CO	< 1.5E25	< 0.07 (0.3)

[a] UT date/iSHELL setting/accumulated on-source integration times (minutes) are shown in **bold**.

[b] Abundance ratios relative to H_2O are expressed in percent, with "normal" values in parentheses [from ref. 3]. Upper limits represent 3σ.

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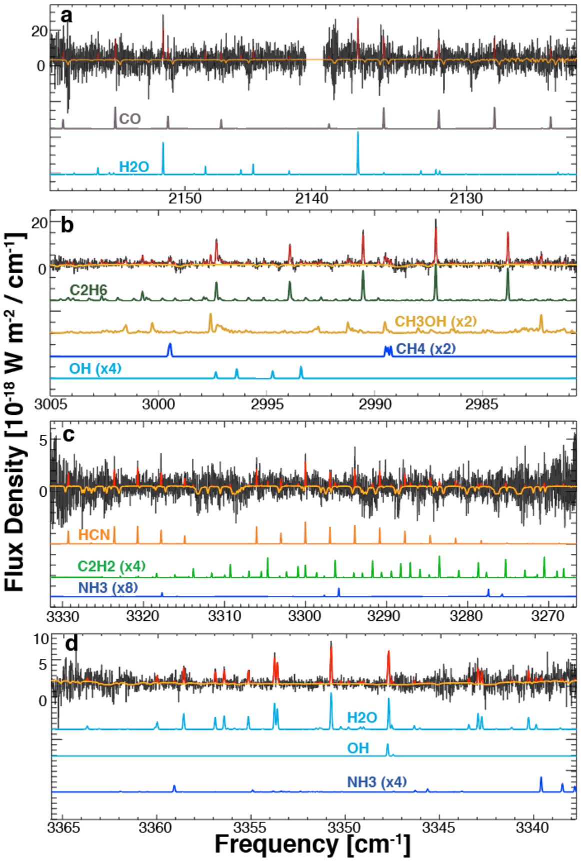

Figure 1: Spectral extracts (black traces) of C/2018 Y1 (Iwamoto) from selected iSHELL orders, with settings and on-source integration times listed in Table 1. In all panels, modeled fluorescence is color-coded by species, and g-factors are multiplied by modeled monochromatic atmospheric transmittance at each Doppler-shifted line position. The modeled continuum (scaled atmospheric transmittance function) is shown in gold overlying each extract, and the total modeled emission is shown in red. (**a**) M2 orders 111 (left) and 110 (right). (**b**) Lp1 order 155. (**c**) Lcust orders 172 – 170. (**d**) Lcust order 179, used to measure the rotational of H_2O molecules in the coma.