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Sources of HCN and CH_3OH in Comet 103P/Hartley 2

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Abstract

In late 2010 the Jupiter-family comet 103P/Hartley 2 was intensively observed by the *EPOXI* spacecraft and from many Earth-based observatories. We joined this effort and obtained spectral time series of HCN and CH_3OH at millimeter wavelengths. Since the spectra were integrated simultaneously and they are velocity-resolved, we could identify and compare the sources of the two molecules. Our results provide insights into the compositional structure of the comet's nucleus and are readily comparable with the spatially-resolved molecular observations from *EPOXI* [1].

1. Introduction

103P/Hartley 2 (hereafter 103P) is a Jupiter-family comet which currently has a 6.47-year orbital period and perihelion at 1.06 AU. On UT 2010 Oct. 20.7 it reached the minimum geocentric distance of only 0.12 AU, making by far the closest approach to the Earth since its discovery [7], and becoming a naked-eye object. Shortly after, on UT 2010 Nov. 4.6, the comet was visited by NASA's *EPOXI* spacecraft which provided detailed images and spectra [1]. Both the Earth-based data, obtained at the unusually favorable geometry, and the unique observations carried out by the spacecraft, create an exceptional platform for new groundbreaking investigations.

In this work we investigate the sources of HCN and CH_3OH and derive implications for the compositional structure of 103P's nucleus.

2. Observations

Using the IRAM 30-m telescope on 3 nights between UT 2010 Nov. 3.0 and 5.4, we obtained velocity-resolved spectral time series of HCN and CH_3OH. The two molecules were observed simultaneously with the *EMIR* receiver: HCN at 265.9 GHz (E3 band) and CH_3OH at 157.2 GHz (E1 band). At these two frequencies the beam size of IRAM is distinctively different, and measures 8.8″ and 14.7″ in FWHM, respectively. Each spectrum of HCN covers 15 min, while the spectra of CH_3OH were averaged in 1-h blocks to improve the signal-to-noise ratio.

3. Results

We observed strong brightness variability in both molecules (Fig. 1) caused by the nucleus rotation [4]. The two lightcurves correlate remarkably well although the amplitudes are not the same.

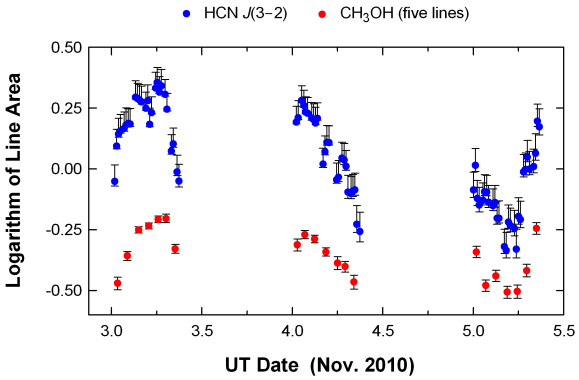

Figure 1: IRAM 30-m observations of brightness variability in HCN and CH_3OH.

The observed amplitude normally depends on the dispersion of sublimation moments of the molecules contributing to a single spectrum [3]. In this way the lower amplitude of CH_3OH seems to be naturally explained given the longer integration time and the larger beam size. But this cannot be the case since the maxima of both lightcurves coincide precisely and the minima are flat. Consequently, the timescale of variability appears sufficiently long to ensure that both profiles closely follow the instantaneous activity of the comet. This may indicate that the two diurnal amplitudes were

indeed different. However, even if they were the same, the different beam sizes would still differentiate them in the same way as observed if, for example, the minimum level was produced by a constant background with uniform brightness distribution.

4. Discussion

We have earlier established [4] that the variability of HCN was in phase with the variabilities in CO_2 and H_2O observed by *EPOXI* [1]. Consequently, also CH_3OH correlates with all the other molecules.

The variability profiles of HCN and CH_3OH show striking similarities with the profiles of CO_2 and H_2O. In both pairs the variability profiles are well correlated but have a factor of 2.5 different amplitudes. Even the absolute amplitudes[1], reaching a factor of 5 for HCN and a factor of 2 for CH_3OH, are the same as measured for CO_2 and H_2O, respectively [1].

Even though the variabilities of all the four molecules were in phase, the spatially-resolved molecular observations from *EPOXI* revealed different reservoirs of CO_2 and H_2O [1]. This indicates compositional heterogeneity of the comet's nucleus with respect to these two ices. The seeming similarity of the high-amplitude variability profiles of HCN and CO_2, and of the low-amplitude CH_3OH and H_2O, suggests that also HCN and CH_3OH might have originated from different reservoirs, perhaps the same as for CO_2 and H_2O, respectively. If true, the remarkable temporal correlation of all the molecules would require a non-trivial explanation.

Both homogeneous [2] and heterogeneous [5] compositions have been suggested for different comets. The first one may suggest formation in one place, and the second one from cometesimals originating from different regions in the protosolar nebula, although evolutionary reasons has been considered as well [6]. While the compositional heterogeneity with respect to CO_2 and H_2O can be possibly explained by the different sublimation temperatures (70 K and 133 K, respectively), the suspected heterogeneity in HCN and CH_3OH is truly surprising sice both have practically the same sublimation temperatures (95 K and 99 K, respectively). For the same reason also the suspected homogeneities with respect to CH_3OH and H_2O, and in HCN and CO_2, are difficult to explain.

[1]Note that due to excitation of the rotation state the pattern of variability repeats best every 3 rotation cycles [1, 4]. We observed the minimum and maximum levels during different rotation cycles but they correspond to the same *3-cycle* component (*Cycle C*). Nevertheless, due to the residual differences between the same *three-cycle* component observed at different times, the absolute amplitudes of HCN and CH_3OH should be interpreted with caution.

5. Future Work

The current analysis is based entirely on the brightness variability but our time series consists of velocity-resolved spectra. Therefore, we will further pursue the issue of molecular reservoirs in 103P using the radial-velocity information. First, we will resolve the ambiguity in the reason for the different amplitudes of HCN and CH_3OH. Then we will try to better identify their sources and compare them with the spatially-resolved observations of CO_2 and H_2O from *EPOXI* [1].

Acknowledgements

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