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Molecular composition and outgassing variability of 103P/Hartley 2 from mm and submm observations

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Abstract

Comet 103P/Hartley 2 is a Jupiter-family comet (JFC) which had a very favourable perihelion passage on 28 October 2010 as it came within 0.12 AU from the Earth a few days earlier. We used the Institut de RadioAstronomie Millimétrique (IRAM) and Caltech Submillimeter Observatory (CSO) facilities to observe HCN, CH_3CN, HNCO, CH_3OH, H_2S, CS, $H_2^{34}S$, H_2CO in this comet between 25 October and 9 November 2010. CH_3OH was also serendipitously observed on 30 October and 17 November with the Herschel Space Observatory in the frame of the "HSSO" key program [6]. The Odin submm observatory astronomy program was specially reactivated to monitor the water outgassing of the comet between 29 October and 1 November and on 21 November 2010. $H_2^{18}O$ was also observed. These observations aimed at understanding the composition and time variation of the activity of the comet in support to the flyby of the comet by the EPOXI spacecraft on 4.6 November 2010.

1. Observations

Comet 103P/Hartley 2 was observed shortly after its closest approach and around perihelion when its outgassing rate was expected to be the highest. Observations were also scheduled ahead of and during the EPOXI flyby of the comet nucleus in order to put the spacecraft data in the context of comet activity. The comet was first observed with the IRAM 30-m radio telescope on 5 consecutive nights between 25.0 and 29.2 October UT, the three next ones having been lost due to bad weather. We then observed it with the CSO in Hawaii on 7 out of 8 nights (one lost due to bad weather) between 2.4 and 9.7 November, including at the very time of the EPOXI flyby. Odin [7] observed the comet nearly continuously (55 min per 96-min orbit) from 29.4 October to 1.4 November and 20.6 to 21.1 November 2010. Two of its receivers were either tuned to the 556.9 GHz H_2O ($1_{10}-1_{01}$) or 547.5 GHz $H_2^{18}O$ ($1_{10}-1_{01}$) lines.

2. Production rates

Production rates were derived using the same model as previously used [2, 8]. Isotropic outgassing and a constant expansion velocity were assumed in a first step. The gas expansion velocity derived from line shapes varies between 0.60 and 0.68 km s^{-1}. The gas temperature inferred from methanol rotational lines is 50 K.

3. Molecular Abundances

Molecular relative abundances have been derived either from the simultaneous observation of several species or from the ratio of their mean production rate on close days. The preliminary H_2O:HCN:CH_3CN:CH_3OH:H_2S:CS:H_2CO:HNCO ratio is 100:0.15:0.03:3.6:1.2:0.05:0.5:0.06. In addition the HNC/HCN ratio has been estimated to be 3.5%. The isotopic ratios $^{34}S/^{32}S$ in H_2S and $^{18}O/^{16}O$ measured with Odin in H_2O are terrestrial. Upper limits on the CO, SO, HCOOH, OCS and HC_3N abundances were also obtained. 103P/Hartley 2 is enriched in H_2S, especially in comparison to the other JFCs observed so far [5].

4. Time variation

The time variation of the outgassing of a comet can be critical to derive accurate molecular abundances. Several comets previously observed [3, 4] have shown large time variations of their outgassing. Part of our objective was also to track a possible time variation of the outgassing of comet 103P/Hartley 2.

4.1. Variation of outgassing rate

The Odin satellite is particularly suited to monitor the activity of comets (e.g. [3]) since it can observe them nearly continuously and is not subject to any time variation in the calibration. Prior to the EPOXI flyby, we were able to observe a quasi periodic variation of the line intensity of the 557 GHz water line, with a period of ≈ 0.8 day (Figure 1). However, retrieving a precise outgassing rate of the nucleus itself is not so obvious since optical depth effects and dilution in the large beam size (12600 km) dampen significantly the signal variation. Large variations of the production rate (by a factor up to 3 from minimum to maximum) with a similar period are observed for many other molecules (e.g. HCN, H_2S)

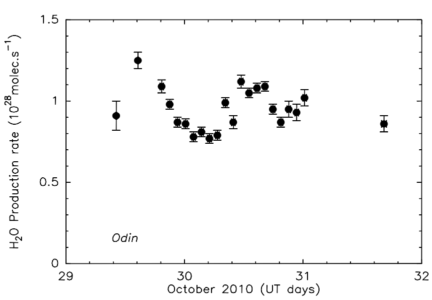

Figure 1: Evolution of the water outgassing by Odin (preliminary analysis).

4.2. Variation of composition

If some molecules show different time variations of their outgassing, this could highlight an heterogeneity in the composition of the nucleus. Time variation is assumed to be due to the rotation of the elongated nucleus [1] exposing different sides to sunlight. Data need to be analyzed in detail to compare the evolution of the different molecular species, especially as they have different characteristic scale lengths which may imply different apparent time behaviour of the line intensities. At first glance, significant variation of the outgassing rate is observed for all molecules. The variation seems in phase for most molecules although its amplitude might be different, e.g. smaller for CH_3OH.

5. Summary and conclusions

Eight molecules (H_2O, HCN, HNCO, CH_3OH, CS, H_2S, H_2CO, CH_3CN) were detected in comet 103P/Hartley 2 and two isotopic ratios measured ($^{34}S/^{32}S$ and $^{18}O/^{16}O$). Significant upper limits on the abundances of CO, OCS, SO, HCOOH and HC_3N have also been obtained. The comet appears to belong to the H_2S rich comet unlike other JFCs but like long-period comets C/1995 O1 (Hale-Bopp) and C/2001 A2 (LINEAR) [2]. The comet exhibited large time variation of its outgassing, by a factor of up to 3 on a short time scale (0.8 h to 0.4 h possibly double-peaked). The analysis is ongoing to identify possible clues on a chemical heterogeneity of the nucleus from this time variation.

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