TEMPORAL VARIATION OF THE MM/SUBMM EMISSION LINES IN COMET 103P/HARTLEY 2: WHAT DOES IT TELL US ABOUT THE NUCLEUS?

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Introduction: 103P/Hartley 2 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 [1], and becoming visible to the naked eye. Shortly after, on UT 2010 Nov. 4.6, the comet was visited by NASA's *EPOXI* spacecraft which provided detailed images and spectra [2]. 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 summarize the results of our intensive ground-based observations at mm/submm wavelengths, which we have used to quantify the nucleus rotation state [3] and to investigate the molecular sources and rotational temperature [4].

Observations: Between early September and late December 2010 we used all large single-dish ground-based mm/submm facilities operating around one millimeter and offering open time, to carry out spectral monitoring of HCN, which is a particularly good tracer of cometary rotation [5]. We analyze 438 individual 15-min spectra of the $J(3–2)$ and $J(4–3)$ rotational transitions collected with IRAM, JCMT, and CSO on 20 nights between UT 2010 Sep. 29.3 and Dec. 15.6.

Moreover, during 3 nights of monitoring at IRAM between UT 2010 Nov. 3.0 and 5.4, the HCN observations were accompanied by simultaneous measurements of CH_3OH. We analyze the two time series using 21 spectra of each molecule (7 per night) averaged in 1-hr blocks. All the spectra are velocity-resolved at 150 m s^{-1} with native spectral resolutions $> 2\times10^6$.

Results: Our data show strong temporal variation in the emission lines of both molecules, which we associate with the rotation of the nucleus. We use the variation in HCN as a tracer of 103P's spin state, compare the specific variability in HCN and CH_3OH to identify their molecular sources, and use CH_3OH to constrain time-resolved rotational temperature. Our results can be summarized as follows:

Nucleus spin state:

- decelerating at 1.00 ± 0.15 min day^{-1};
- $P_{rot} = 18.32 \pm 0.03$ hr at the *EPOXI* flyby;
- excited – the rotation modes approximately coincide every three fundamental rotation cycles.

Sources of HCN and CH_3OH:

- the molecules originate from three distinct outgassing sources – two jets (one *redshifted* and the other one *blueshifted*) and icy grains injected into the coma primarily through the *blueshifted jet*;
- the *redshifted jet* is compositionally similar to the icy grains but strongly depleted in HCN compared to the *blueshifted jet*;
- this large-scale chemical heterogeneity might have been produced by thermal evolution of the body;
- our "radio jets" can be plausibly identified with the jets observed by *EPOXI* [2] and in the ground-based images of CN [6];
- the average production rates are 2.1×10^{26} molec s^{-1} for CH_3OH and 1.25×10^{25} molec s^{-1} for HCN and their ratio of 17 is typical of comets [7].

Rotational temperature:

- the average rotational temperature is 47 K;
- the temperature shows short-term variations, presumably from the nucleus rotation, which are tentatively correlated with the varying production rate.

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