EPSC Abstracts
Vol. 6, EPSC-DPS2011-1713, 2011
EPSC-DPS Joint Meeting 2011

Rotation of Comet 103P/Hartley 2 from Spectroscopy at 1 mm

M. Drahus (1), D. Jewitt (1), A. Guilbert-Lepoutre (1), W. Waniak (2), J. Hoge (3), D. C. Lis (4), H. Yoshida (5), R. Peng (5), and A. Sievers (6)

(1) University of California at Los Angeles, Los Angeles, CA, USA (mdrahus@ucla.edu), (2) Astronomical Observatory, Jagiellonian University, Kraków, Poland, (3) Joint Astronomy Centre, Hilo, HI, USA, (4) California Institute of Technology, Pasadena, CA, USA, (5) Caltech Submillimeter Observatory, Hilo, HI, USA, (6) Instituto de Radio Astronomìa Milimétrica, Granada, Spain

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 monitored emission lines of HCN using several ground-based mm/submm telescopes. The spectral time series shows strong line variability caused by the rotation of cometary jets, and provides evidence for excitation and rapid deceleration of the nucleus rotation state. Based on these measurements we derive immediate consequences for the rotational stability of comet 103P/Hartley 2 and also broad implications for the population of comets.

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 present our published results [6] which quantify the rotation state of 103P's nucleus.

2. Observations

Between early September and mid 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. This molecule is a particularly good tracer of cometary rotation [5] thanks to its well-established origin directly from the nucleus and because it has by far the brightest emission lines in the 1-mm atmospheric windows. Our campaign was the first at these wavelengths specifically designed to investigate the rotation state of a comet, and thus provided an unprecedentedly rich and dense velocity-resolved spectral time series of a cometary parent molecule. In this work we use 438 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.

3. Analysis

The spectral time series shows strong line variability caused by the rotation of cometary jets. We first removed (to the first order) all the trivial instrumental, topocentric, and transition-specific differences, and then investigated the periodicity using novel *Dynamized Structural Periodicity Analysis* (DSPA). The technique measures the frequency of variability and simultaneously the temporal evolution of frequency [4] (assumed linear at this stage) analyzing changes in the input line profiles.

4. Results and Discussion

We obtained the rotation period 18.32 ± 0.03 hr and the rate of change in the period $+1.00 \pm 0.15$ min day^{-1} (both applicable at the epoch of the *EPOXI* encounter).

In Fig. 1 we show the variability of HCN production rate phased according to this solution. It follows a sinusoidal trend and is consistent with a single strong active area being the primary source of HCN. As the *EPOXI* encounter occurred at the rotation phase 0.5, when the HCN production rate was shortly before the diurnal maximum, we suppose that this area coincides with the strongest jet observed by the spacecraft [1].

Interestingly, an even better solution is found at the third multiple of the above periodicity, which corresponds to a triple-peak variability profile. Given the inconsistency with the *EPOXI* data, it cannot be accepted as the real diurnal pattern, but shows that the profile of HCN production repeats best every three rotation cycles. We consider this as an indication of excitation of the rotation state, which was close to a 3:1 or 3:2 resonance between the rotation modes.

The measured rate of change in the rotation period indicates a rapid spin-down of the nucleus. If the pattern of mass loss remains unchanged, this implies rotational disruption [3] from spin-up[1] after ~ 30 orbits, and is by far the shortest timescale limiting the lifetime of this object. Nevertheless, the process efficiency is surprisingly low: the measured *effective moment arm* [8, 4] is only 0.04%, i.e. two orders of magnitude lower than the model prediction [8] and the measurement in comet 9P/Tempel 1 [2].

An intriguing hypothesis arises then, that small and active short-period comets may survive only if they have unusually low spin-up efficiencies. We expect that the great bulk of such small and active nuclei routinely experience rotational instability and disruption shortly after being injected to the sublimation zone yet before being discovered. These dead comets contribute their dust to the Zodiacal Cloud and can possibly explain the observed flat size distribution of comet nuclei [9]. With its tiny and active nucleus [1], 103P appears as a lucky survivor, protected for some limited time from rotational disruption by the remarkably low effective moment arm. Clearly, non-periodic comets, arriving directly from the Oort Cloud, are less affected by this selection process, and therefore should change their rotation periods much faster compared to analogous nuclei of "old" periodic comets.

Acknowledgements

This project was supported by NASA through a Planetary Astronomy Program grant to D. Jewitt. The observations were carried out with the IRAM, JCMT, and CSO telescopes. IRAM is supported by INSU/CNRS (France), MPG (Germany), and IGN (Spain). JCMT is operated by Joint Astronomy Centre and supported by STFC (UK), NRC (Canada), and NWO (Netherlands). CSO is operated by Caltech and supported through NSF grant AST-0540882 (USA).

[1] If the direction of torque is constant, a spinning-down body will stop rotating and start spinning up in the opposite direction.

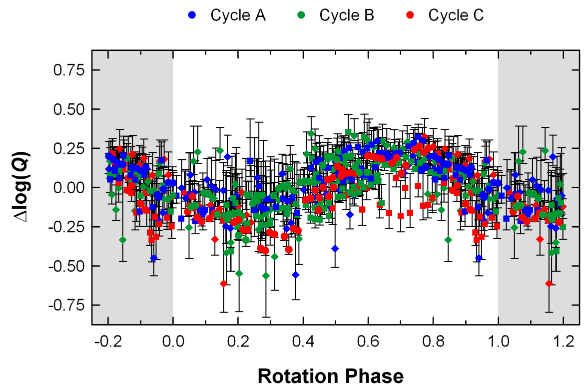

Figure 1: Production-rate variations of HCN about the mean-diurnal level. The three colors indicate three consecutive rotation cycles, and show that one cycle (*Cycle C*) has a slightly different profile. The data were taken at IRAM (circles), JCMT (squares), and CSO (diamonds).

References

[1] A'Hearn, M. F., Belton, M. J. S., Delamere, W. A., et al., 2011. *EPOXI at comet Hartley 2.* Science, in press.

[2] Belton, M. J. S., Meech, K. J., Chesley, S., et al., 2011. *Stardust-NExT, Deep Impact, and the accelerating spin of 9P/Tempel 1.* Icarus **213**, 345–368.

[3] Davidsson, B. J. R., 2001. *Tidal splitting and rotational breakup of solid biaxial ellipsoids.* Icarus **149**, 375–383.

[4] Drahus, M., and Waniak, W., 2006. *Non-constant rotation period of comet C/2001 K5 (LINEAR).* Icarus **185**, 544–557.

[5] Drahus, M., Küppers, M., Jarchow, C., Paganini, L., Hartogh, P., and Villanueva, G. L., 2010. *The HCN molecule as a tracer of the nucleus rotation of comet 73P-C/Schwassmann-Wachmann 3.* A&A **510**, A55.

[6] Drahus, M., Jewitt, D., Guilbert-Lepoutre, A., Waniak, W., Hoge, J., Lis, D. C., Yoshida, H., Peng, R., and Sievers, A., 2011. *Rotation state of comet 103P/Hartley 2 from radio spectroscopy at 1 mm.* ApJL **734**, L4.

[7] Hartley, M., 1986. *Comet Hartley (1986c).* IAUC 4197.

[8] Jewitt, D., 1999. *Cometary rotation: an overview.* EM&P **79**, 35–53.

[9] Snodgrass, C., Fitzsimmons, A., Lowry, S. C., and Weissman, P., 2011. *The size distribution of Jupiter Family comet nuclei.* MNRAS, in press.