EPSC Abstracts
Vol. 5, EPSC2010-496, 2010
European Planetary Science Congress 2010

Infrared spectroscopy of the ν_1 transition of HCN molecule in comets.

M. Lippi (1), G. L. Villanueva (2), M. A. DiSanti (2), B. P. Bonev (2), M. J. Mumma (2), H. Boehnhardt (1)
(1) Max Planck Institute for Solar System research, Katlenburg-Lindau, Germany (2) Goddard Space Flight Center, Washington DC, USA (lippi@mps.mpg.de/ +49-5556-979-240)

Abstract

We report observations of hydrogen cyanide (HCN) in comets 8P/Tuttle (hereafter 8P) and C/2007 W1 (Boattini) (hereafter C/2007 W1), performed using the CRyogenic InfraREd Spectrometer (CRIRES) at VLT. Gas production rates, mixing ratios and rotational temperatures have been retrieved using a new developed model that describe the ν_1 transition for this molecule.

1. Introduction

Comets are believed to be the remnants of our Solar System formation, and their study is fundamental to understand the origin and the evolution of the proto-planetary disk, from which planets formed. A number of parent gas species sublimating directly from the nucleus surface can be investigated in the mid-IR, between 3 and 5μm, using high resolution spectroscopy. (see for example [1, 2, 3]). Hydrogen cyanide (HCN) is a linear molecule present in cometary nuclei; it represents a key intermediary for synthesis of biochemical compounds on Earth, and, in presence of water, it could have leaded to amino acid formation, and then to life as we know it. Information obtained for this molecule, together with the ones obtained from other parent molecules, can give important hints for understanding the chemical and physical property of the proto-planetary disk, where comets formed, and for better understanding the role that comets played in delivering important compounds to the early Earth.

2. Observations and data reduction

2.1. Observations

The observations were performed using CRIRES, the high resolution infrared echelle spectrometer at the Very Large Telescope (VLT) in Paranal, Chile. The high resolving power achieved by this instrument allows us to resolve the rotational structure of the molecular spectra, to study the excitation temperature, and to distinguish cometary (Doppler shifted) emission lines from atmospheric features. Moreover, the VLT adaptive optics (AO) system, permits to increase the spatial resolution as well as the signal-to-noise ratio. In Tab. 1 we summarize the observing dates and the relative orbital parameters for each comet.

Table 1: Ephemeris for the observed comets. In the table, R_h and Δ, both in AU, are the heliocentric and geocentric distances respectively, while $d\Delta/dt$ in km/s is the comet-Earth relative velocity. For each observing run, a standard star was observed to ensure a correct flux calibration.

Comet	Date	R_h	Δ	$d\Delta/dt$
8P	28 Jan 08	1.028	0.54	24.71
C/2007 W1	30 May 08	0.97	0.24	-7.04

2.2. The model

The observed frames were first analyzed following standard processing steps (flat fielding, cosmic rays cleaning, flux calibration, see for example [5, 6]). Cometary spectral extracts were compared to a newly developed HCN fluorescence model, whose development can be summarized in four steps: 1) calculation of the rotational energy distribution of the two considered vibrational levels; 2) calculation of the initial or equilibrium population, in the ground vibrational state; 3) pumping rates are calculated from all rotational levels in the ground vibrational state to the excited state, respecting the selection rules; 4) emissions from the excited to the equilibrium ground state are calculated, considering the correct rotational branching ratios. Molecular production rates and rotational temperatures for the HCN molecule were retrieved using the newly calculated emission fluorescence g-factors. Due to the relative motion of the comet with respect to the Sun, the solar flux received by the comet, and consequently the emission g-factors, change during time (Swings Effect, [4]). Corrections for this effect have been considered for each observed comet.

2.3. Results and discussion

Fig. 1, shows a selection of spectra for the observed comets; in Tab. 2 we summarize the obtained production rates and rotational temperatures. The two observed comets displayed important differences, with comet 8P (a Halley type comet) containing a very low abundance of HCN with respect to comet C/2007 W1 (classified as a dynamically new comet). As we have observed in our taxonomical surveys (e.g. [2]), there is no clear relationship between dynamical class and molecular abundances. On the other hand, as shown in Tab. 3, Oort Cloud comets appear to show higher HCN abundances relative to Halley type and Jupiter family comets, in this limited sample of comets. The enrichment of HCN observed in comet C/2007 W1 and depletion in 8P is consistent with this grouping.

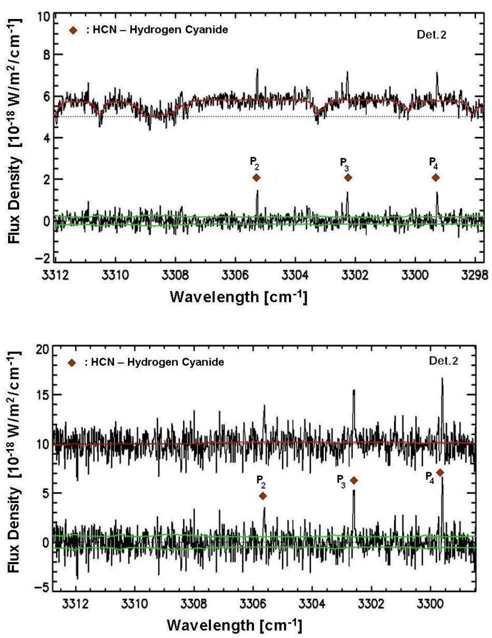

Figure 1: Detection of HCN in comets 8P (upper panel) and C/2007 W1 (lower panel). For both panels, the red trace represents the cometary continuum convolved with a synthetic transmittance spectrum of the terrestrial atmosphere, while the lower spectrum is obtained by subtracting the modeled continuum from the measured spectral extract. The two green lines represent the $\pm 1\sigma$ noise envelope.

3. Summary and Conclusions

We retrieved production rates, mixing ratios and rotational temperatures for comet 8P/Tuttle and comet C/2007 W1 Boattini, using a newly developed fluorescence molecular model describing the HCN-ν_1 band. The retrieved abundances, revealed that these two comets, belonging to two different dynamical types, are particularly different. Comet 8P, a Halley type comet, can be considered HCN depleted. On the contrary, comet C/2007 W1, a dynamically new comet, is characterized by a high HCN mixing ratio, among the highest ever measured.

Table 2: Retrieved production rates (10^{26} mol/s), mixing ratios (based on water production rates measured during the same observing runs) and rotational temperatures (K) for the observed comets.

Comet	P.R.	M.R.	T_{rot}
8P	(0.28± 0.03)	(0.05±0.02)	64^{+6}_{-5}
C/2007 W1	(0.52± 0.6)	(0.50±0.06)	88^{+30}_{-18}

Table 3: Comparison of the observed comets with other comets. For each class the maximum and minimum value for the mixing ratio for HCN molecule is indicated (values are from [2], and the original papers referenced therein).

Comet	M.R.
Oort cloud	0.10 ÷ 0.60
Halley type	0.18 ÷ 0.20
Jupiter family	0.18 ÷ 0.28
8P/Tuttle	0.05±0.02
C/2007 W1	0.52± 0.6

Acknowledgements

We thank the VLT science operations team of the European Southern Observatory for efficient execution of the observations. This work was supported by the International Max Planck Research School, NASA's Planetary Astronomy Program, Astrobiology Program and Postdoctoral Program and the German-Israeli Foundation for Scientific Research and Development.

References

[1] D. Bockelee-Morvan et al. (2004), Comets II, 391-423.

[2] M.A. DiSanti and M. J. Mumma, (2008), Sp. Sci. Rev., 138,127-145.

[3] H. Boehnhardt et al. (2008), Ap. J., 683, L71-L74.

[4] P. Swings, (1941), Lick Observatory bulletin, 19, 131-136.

[5] B. P. Bonev, (2005), PhD Thesis.

[6] G. L. Villanueva et al. (2009), Ap. J., 690, L5-L9.