CARBON AND NITROGEN ISOTOPIC RATIOS IN COMETS.

E. Jehin[1], J. Manfroid[1], D. Hutsemékers[1], A. Cochran[2], , J.-M. Zucconi[3], R. Schulz[4], C. Arpigny[1], [1]Institut d'Astrophysique et de Géophysique, Sart-Tilman, B-4000, Liège, Belgium, (e-mail: ejehin@ulg.ac.be), [2]Department of Astronomy and McDonald Observatory, University of Texas at Austin, C-1400, Austin, USA, [3]Observatoire de Besançon, F-25010, Besançon, France, [4]ESA/RSSD, ESTEC, P.O. Box 299, NL-2200 AG Noordwijk, The Netherlands.

Introduction: Isotopic abundance ratios are excellently suited to probe the origin of solar system matter. Knowledge of these ratios is particularly relevant for small solar system bodies, as these were much less altered since their formation than the big planets and moons. Particularly comets are believed to have preserved unprocessed material of the solar nebula from the time of formation of the planetary system.

Observations: Over the past ten years the isotopic ratios of carbon ($^{12}C/^{13}C$) and nitrogen ($^{14}N/^{15}N$) have been determined for about 20 comets bright enough to allow obtaining the required measurements from ground. The observed comets belong to different dynamical classes, including dynamically-new as well as long-period comets, and short-period comets from the Halley- and Jupiter-Family [1,2,3]. In some cases the comets could be observed at various heliocentric distances [4]. The observations were collected in both the southern and northern hemispheres with telescopes at Paranal (ESO VLT), McDonald, Keck, and the Roque de los Muchachos (NOT) Observatories equipped with high resolution spectrographs (UVES, 2DCoudé HIRES, and SOFIN respectively).

The method: The ratios are derived from high signal-to-noise, high resolution spectra (R > 60000) of the CN coma measured in the B-X (0,0) emission band around 387 nm. Before the emission spectrum may be modelled, the continuum resulting from the sunlight scattered off the cometary dust is removed accurately. The emissions of the species $^{12}C^{14}N$, $^{13}C^{14}N$ and $^{12}C^{15}N$ are then modelled [Fig.1] separately and for each observing circumstance [1,2] using a fluorescence model of CN [5]. Only unblended lines within the R-branch are used.

The results: All values [6] determined for the carbon and nitrogen isotopic ratios are consistent within the error margin irrespective of the type of comet or the heliocentric distance at which it was observed. Our investigations result in average ratios of $^{12}C/^{13}C = 92 \pm 7$ and $^{14}N/^{15}N = 151 \pm 21$. Observations of comet 9P/Tempel 1 just prior to its impact with the Deep Impact NASA spacecraft and in the following few hours show no change in these isotopic ratios, within the error bars, suggesting that these ratios are the same in the interior and in the mantle [7]. Recently the quasi simultaneous millimeter and optical observations of the Jupiter-family comet 17P/Holmes performed soon after its huge outburst in October 2007, allowed us to show that carbon and nitrogen isotopic ratios derived from CN and HCN are in agreement with each other and with the above cited values [8]. These results are compatible with HCN being a prime parent of CN in cometary atmospheres.

Whilst the value for the $^{12}C/^{13}C$ ratio is in very good agreement with the solar and terrestrial value of 89 [9], the nitrogen isotopic ratio is very different from the telluric value of 272 [9]. The large ^{15}N excess in comets relative to the Earth atmospheric value indicates that N-bearing volatiles in the solar nebula underwent important nitrogen isotopic fractionation at some stage of the Solar System formation [10].

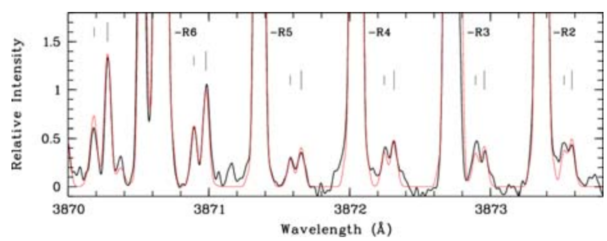

Fig.1.- A section of the spectrum of the CN (0,0) band in comet 88P/Howell, the first Jupiter Family Comet for which the carbon and nitrogen isotopic ratios have been determined [3]. *Thick line*: observed spectrum; *thin (red) line:* synthetic spectrum of $^{12}C^{14}N$, $^{12}C^{15}N$ and $^{13}C^{14}N$ with adopted carbon $^{12}C^{14}N/^{13}C^{14}N$ and nitrogen $^{12}C^{14}N/^{12}C^{15}N$ isotopic ratios of 90 and 140 respectively. The lines of $^{12}C^{15}N$ are identified by the short ticks and those of $^{13}C^{14}N$ by the tall ticks. The quantum numbers of the *R*lines of $^{12}C^{14}N$ are also indicated.

References: [1] Arpigny et al. (2003) Science, 301, 1522; [2] Jehin et al. (2004) ApJL, 641, 145; [3] Hutsemékers et al. (2005) A&A, 440, L21; [4] Manfroid et al. (2005) A&A, 432, L5; [5] Zucconi and Festou (1986) A&A, 158, 382; [6] but see « Optical spectroscopy of -B and -C fragments of comet 73P/ Schwassmann-Wachmann 3 at the ESO VLT » by E. Jehin et al., this conference; [7] Jehin et al. (2006) ApJL, 641, 145; [8] Bockelée-Morvan et al. (2008) submitted to ApJL; [9] Anders and Grevesse (1989) Geo. et Cosmo. Acta, 53, 197; [10] Charnley and Rodgers (2008), Space Sci. Rev. Accepted.