COMETARY ORGANIC MACROMOLECULES IN INTERPLANETARY DUST PARTICLES ?
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Introduction: Many interplanetary dust particles (IDPs) show both large deuterium excesses and nitrogen-15 excesses [1]. It has been shown that the largest D-excesses are related to several organic macromolecules with various C/H ratios (from 1 to 3, [2]) indicating various components of various aliphaticities and aromaticities. In two particles with well-individualized organic components, part of the largest ^{15}N excesses are also associated to these D-rich organic phases [3]. An interstellar origin of these phases has been postulated [1,2]. Here we report determinations of the nitrogen concentration of these phases and comparison of their global properties (C/H; D/H; $^{15}N/^{14}N$ ratios and [N]) with a summary of cometary observations including recent measurements of N isotopes in the CN radical [4,5].

Analytical techniques: N concentrations were measured using the CN^-/C^- ratio in the two IDPs of interest, L2021K1 and L2036E22, using ion microprobe scanning imaging of C^- and CN ions with a 1.5 µm Cs+ primary beam. N concentrations were calibrated by measuring the CN^-/C^- ratio of several standards of solid organic materials of known N concentrations in various analytical conditions (from 5 pA to 1 nA). The N concentrations in the standards range from 0.4 wt% up to ~40 wt%. The measured compounds included synthetic HCN polymers (azulmic acid), natural analogs of carbonaceous chondrite insoluble organic matter (type III kerogen), concentrated coal resinite and highly graphitized materials (anthracite). The linear relationship observed in Fig. 1. indicates that in solid organic phases, the CN^-/C^- ratio is proportional to the N concentration within at worst a factor 1.5 precision, and that also in imaging analyses. Litterature data on thymine and hydroxybenzotriazole are in agreement with our calibration within a factor 2 [6,7], though obtained on different instruments with different settings

$^{14}N/^{15}N$ ratios were determined in the CN radical in the coma of two different comets (C/1995 O1 Hale-Bopp and C/2000 WM1 LINEAR) by UV spectroscopy with the NOT telescope (Hale-Bopp) and with the ESO VLT (LINEAR) [4,5].

Results: The N concentrations of the deuterated components from L2021K1 and L2036E22 determined by reference to the type III kerogen measured in imaging mode range from 10 to 20 wt%. Within a factor 1.5, this is significantly larger than the usual concentration measured in chondritic insoluble organic matter which usually ranges from 1 to 3 wt%.

$^{14}N/^{15}N$ measured in CN in both Hale-Bopp and LINEAR is 140±30, which is significantly lower than the 272 terrestrial value indicating a ^{15}N excess of about a factor 2, i. e. about +1000 ± 400‰ in $\delta^{15}N$ notation.

Summary of IDP observations. In two IDPs we have identified 3 micrometric macromolecular organic components labelled OM1, OM2, OM3 (for Organic Matter 1,2 and 3).

OM1. D/H = 2.5 x 10^{-4}, C/H = 1.5, $\delta^{15}N$ = +200‰, [N] = 10-20 wt%. Major similarities with carbonaceous chondrites insoluble organic matter with exception of the large N concentration.

OM2. D/H = 1.5 x 10^{-3}, C/H = 1.0, $\delta^{15}N$ = +400‰, [N] = 10-20 wt%. No counterpart in carbonaceous chondrites, C/H ratio indicates a highly substituted dominantly aliphatic material.

OM3. D/H = 2 x 10^{-3}, C/H = 3.0, $\delta^{15}N$ = +400‰, [N] = 10-20 wt%. No counterpart in carbonaceous chondrites, C/H ratio indicates a highly aromatic material.

Summary of cometary observations. The study of organic components from several comets gave the following observations.

Solid organic grains were observed in Halley, the so-called CHON grains [8].

CHON grains are true organic phases mixed at the micrometer scale with non-carbonaceous phases such as in IDPs [9].

C/H ratios in CHON grains are between 0.1 and 20, (average = 3.4, median = 1.0) [10].

[N] in CHON grains are between 1 and 40 wt%, (average = 10 wt%, median = 2 wt%) [10].

HCN in Hale-Bopp. D/H = 2.3 x 10^{-3} [11], $\delta^{15}N$ = -150‰ [12]. Origin of HCN: nuclear ices [13-15].

CN in Hale-Bopp and LINEAR. $\delta^{15}N$ = +1000‰. Origin: HCN ice + photofragmentation of large N-rich polymers [14].

Discussion. The large D-excesses observed in IDPs organic macromolecules suggest an interstellar origin. By comparison the organic chemistry of cometary ices is consistent with an interstellar origin of cometary organic phases (e.g. D/H in HCN [11] or the proportions of parent organic molecules [15,16]). This first point suggests that IDP and cometary organic phases have a dominantly interstellar origin.

However the measured IDP organic phases are macromolecular solid phases and thus cannot be directly compared to cometary ices but rather to the solid organic grains detected in Halley, the CHON grains. Both large C/H ratios and a large N concentration in IDP organic matter are consistent with the upper range of C/H ratios and N concentrations observed in CHON grains (Fig. 1).

The CN radical is a cometary species for which a dual origin has been proposed: (i) HCN_{ice} and (ii) fragments of N-rich polymers [14]. Since HCN is depleted in ^{15}N [12], the recent observation of large ^{15}N excesses in CN thus suggests that the CHON grains are indeed ^{15}N-rich, such as observed for OM2 and OM3.

Unfortunately, the D/H ratio is not available for the CHON grains. Given that several processes can lead to D-enrichments in the insterstellar medium, including grain processes [17,18], it is not unreasonable to assume comparable D/H ratios in solid organic phases and in gas phase species that can be found in comets condensed as nuclear ices.

The discrepancy between the ^{15}N excesses observed in solid organic grains in IDPs and their absence in cometary ices and in interstellar gas phase HCN and NH_3 [19] can potentially be explained by the grain surface chemistry which could lead to significant ^{15}N enrichments by contrast to the gas-phase ion-molecule reactions, such as recently proposed by Charnley and Rodgers [20]. Starting from a protosolar $\delta^{15}N$ value of –300‰ estimated from the measurements of solar wind in Lunar soils [21] and from NH_3 in the Jovian atmosphere [22], their 1.8 enrichment factor is consistent with IDP $\delta^{15}N$ values of +400‰.

Conclusion. A number of uncertainties remain, such as the extent of ^{15}N excesses (large error bars in both IDP and comet measurements), or the knowledge on N grain chemistry in the interstellar medium. However it is proposed here that the combination of N and H concentrations and isotopic composition in macromolecular organic phases is potentially a good tracer of cometary origin of IDPs. The study of such cometary IDPs can bring useful informations on cometary nuclei and give research directions for the return of the Stardust mission in 2006.

References: [1] Messenger (2000) *Nature 404*, 968-971. [2] Aléon et al. (2001) *GCA 65*, 4399-4412. [3] Aléon et al. (submitted) *GCA*. [4] Arpigny et al. (2000) *BAAS 32*, 1074 (abstract). [5] Arpigny et al. (2002) *Asteroids, Comets, Meteors Conf.* (abstract). [6] Zinner et al. (1989) *GCA 53*, 3273-3290. [7] Hoppe et al. (1995) *GCA 59*, 4029-4056. [8] Jessberger et al. (1988) *Nature 332*, 691-695. [9] Lawler and Brownlee (1992) *Nature 359*, 810-812. [10] Fomenkova et al. (1994) *GCA 58*, 4503-4512. [11] Meier et al. (1998) *Science 279*, 1707-1709. [12] Jewitt et al. (1997) *Science 278*, 90-93. [13] Wright et al. (1998) *Astron. J. 116*, 3018-3028. [14] Woodney et al. (2002) *Icarus 157*, 193-204. [15] Irvine et al. (1996) *Nature 383*, 418-420. [16] Mumma et al. (1996) *Science 272*, 1310-1314. [17] Tielens et al. (1983) *A&A 119*, 177-184. [18] Sandford et al. (2001) *Meteorit. Planet Sci. 36*, 1117-1133. [19] Dahmen et al (1995) *A&A 295*, 194-198. [20] Charnley and Rodgers (2002) *ApJ 569*, L133-L137. [21] Hashizume et al. (2000) *Science 290*, 1142-1145. [22] Owen et al. (2001) *ApJ 553*, L77-L79.

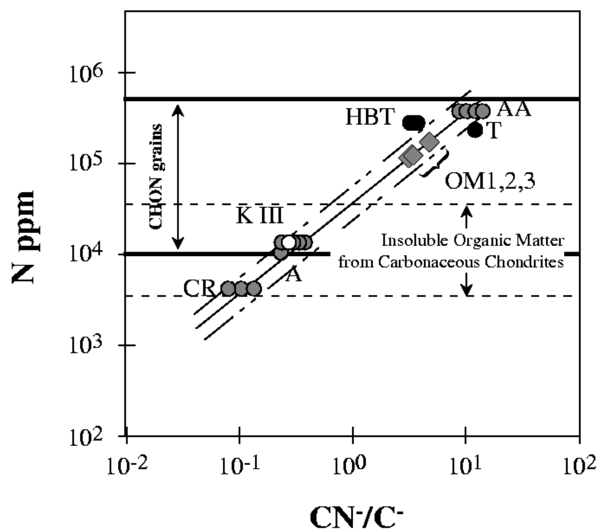

Figure 1. Determination of the N concentration in solid organic matter by ion microprobe. CR stands for Coal Resinite, A for Anthracite, K III for type III kerogen, HBT for Hydoxybenzotriazole [6,7], T for Thymine [6] and AA for azulmic acid. The white dot is K III measured by imaging and dashed lines show a factor 1.5 precision. IDP organic phases OM1, OM2 and OM3 have been reported as diamonds. Dotted lines limit the field of Insoluble Organic Matter in carbonaceous chondrites and plain solid lines limit the field of cometary CHON grains, as measured in Halley [10].