Ultracarbonaceous Antarctic Micrometeorites recovered from snow at the Dome C - CONCORDIA station. C. Engrand[1], J. Duprat[1], N. Bardin[1], G. Slodzian[1], E. Dartois[2], K. Benzerara[3], H. Leroux[4], E. Quirico[5], L. Remusat[3], E. Dobrică[6], L. Delauche[1], D. Baklouti[2], R. Brunetto[2], M. Godard[1], Y. Kakazu[1], T.-D. Wu[7], J.-L. Guerquin-Kern[7].
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Introduction:

Ultracarbonaceous Antarctic Micrometeorites (UCAMMs) are unique cosmic dust particles that have been identified in the Japanese and French Antarctic micrometeorite collections [1, 2]). They are dominated by carbonaceous matter containing large amounts of nitrogen (N/C atomic ratios up to 0.20) and showing elevated D/H ratios [2-6]. These characteristics are reminiscent of the CHON particles that were found as components of the comet Halley dust analyzed by the Giotto and Vega spatial missions in 1986 [e.g 7]. UCAMMs are then probable cometary dust particles. They provide well preserved samples of the external regions of the protoplanetary disk.

Methods:

Micrometeorites were collected in the central regions of Antarctica at Dome C, near the CONCORDIA station. This site provides unique conditions to collect micrometeorites well preserved from terrestrial alteration [8]. UCAMMs were identified among the CONCORDIA micrometeorite collection, using conventional scanning electron microscopy (SEM) equipped with EDX. Complementary microanalyses of these UCAMMs include Raman and Fourier Transformed infrared (FTIR) microspectroscopy, NanoSIMS, transmission electron microscopy (TEM) and 2 of them were cut into 200 nm thick FIB sections at IEMN (Lille) and analyzed by C- and N-XANES STXM on beamline 11.0.2 at the ALS in Berkeley.

Results and discussion:

UCAMMs represent a rare family of micrometeorites in the CONCORDIA collection (only a few percent). They contain up to 85% of organic matter in volume (Fig. 1), thus showing carbon contents up to 10 times that of the most C-rich carbonaceous chondrites [9-11]. Such concentrations of carbonaceous matter are comparable with that of the most C-rich IDPs [12, 13], and compatible with CHON grains detected in comet Halley by the Giotto and Vega spatial missions in 1986 [7, 14].

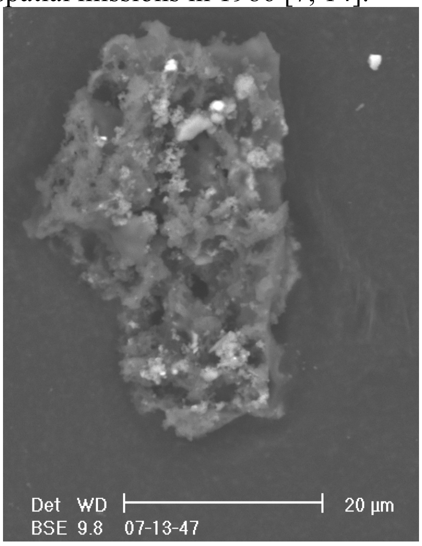

Fig. 1: Backscattered electron micrograph of a fragment of CONCORDIA Ultracarbonaceous Antarctic Micrometeorite (UCAMM). All dark grey patches are constituted of organic matter. Brighter flakes are silicates or Fe-Ni sulfides.

Although UCAMMs are dominated by organic matter (OM), they contain a small fraction of minerals. These minerals have been characterized by electron microprobe and TEM [6, 15, 16]. Crystalline phases are dominated by low-Ca, Mg-rich pyroxenes, Mg-rich olivines and low-Ni Fe-sulfides. Electron microprobe analysis in one UCAMM also revealed some low-iron, manganese-enriched (1.7 wt% MnO) pyroxenes (LIME pyroxenes) surrounded by large enstatite crystals that contain less than 0.5 wt% MnO. Exotic phases such as Mn-, Zn-rich sulfide and perryite have also been found as accessory minerals in UCAMMs. Abundant glassy phases are also present, such as Glass with Embedded Metal and Sulfides (GEMS). Crystalline materials represent at least 25% of mineral phases [16]. High abundance of presolar silicates have been found in one UCAMM [17, 18], but the abundance of crystalline phases measured by [16] is much larger than the upper limit of crystallinity measured in the diffuse interstellar medium (<2.2 wt%).

TEM, Raman, FTIR and NanoSIMS analyses have shown that the organic matter (OM) of UCAMMs is highly disorganized, is nitrogen-rich (atomic N/C up to 0.2), and that its H isotopic composition carry extreme D enrichments [3, 19, 20]. The nitrogen isotopic composition measured simultaneously with that of H, using polyatomic ions, suggest the presence of different carbonaceous phases [21].

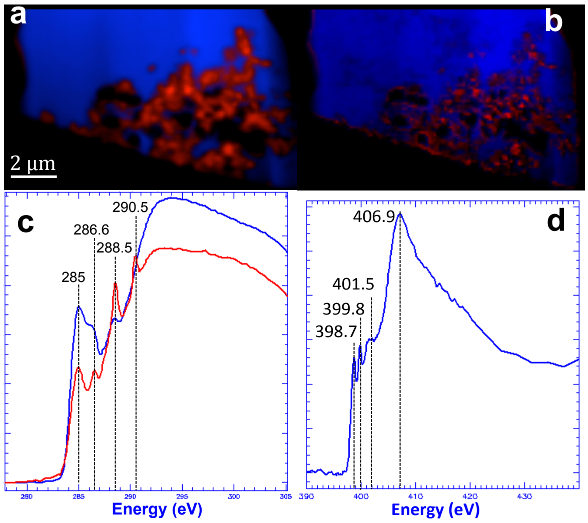

Fig. 2: [From Engrand et al. 6]. (a & c) False color C-XANES map and typical spectra for the smooth carbon (in blue) and for granular carbon in the mineral-rich region (in red). (b & d) False color N-XANES map and spectrum for smooth carbon in blue (the N abundance in the granular carbon is too low to identify the functional entities). The identification of functional groups at the C and N K-edges used the compilation by [22].

Two different carbonaceous phases are also evidenced by spectral deconvolution of hyperspectral XANES data at the C and N K-edges of UCAMMs. One carbonaceous phase is N-rich, while the other one is N-poor [5, 6] (Fig. 2). The XANES signatures at the C and N K-edges of the UCAMM OM are compatible with those of Stardust Samples [22 and refs. therein], reinforcing the cometary origin of UCAMMs. Engrand et al. [6] have shown that the N-rich OM is smooth and devoid of mineral phases whereas the N-poor OM seems associated to the minerals (Fig. 2). Being high temperature materials, the minerals were formed and processed in the inner regions of the protoplanetary disk, and later distributed up to the external regions by radial mixing [e.g. 23, 24]. The association of minerals with the N-poor OM suggests that the N-poor and N-rich organic matter of UCAMMs may have formed by different mechanisms and/or in different locale in the protoplanetary disk.

We have proposed that the N-rich organic matter of UCAMMs could be formed by irradiation of N-rich and CH_4-rich ices at the surface of icy bodies in the outer regions of the protoplanetary disk [3]. The N-poor OM of UCAMMs could possibly be related to the insoluble organic matter (IOM) extracted from carbonaceous chondrites.

Acknowledgments: This work is supported by ANR COSMISME (ANR-2010-BLAN-0502) and OGRESSE (ANR2011-BS56-026-01), CNRS, INSU, IN2P3, Univ. Paris Sud, DIM-ACAV, IPEV and CNES.

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