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Ammonium is a significant reservoir of nitrogen in the Orgueil meteorite

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Nitrogen in comets and carbonaceous chondrites is considered to be mainly present in the refractory organic material [1]. However, nitrogen in the form of ammonium has been detected in comet 67P/Churyumov-Gerasimenko [2], may be present on several asteroids [2, 3] and possibly in the Ryugu samples [4]. Therefore, a significant portion of nitrogen could be in the form of ammonium in these objects, and in carbonaceous chondrites.

In 1864, ammonium was detected in the Orgueil meteorite just after its fall, but never reported again [5-8]. We have quantified the ammonium and measured the isotopic composition of its nitrogen in three samples of Orgueil (named OM, OF1 and OF2), stored under different conditions and presenting different degrees of terrestrial alteration (OM being more altered than OF1&2). We developed a contamination-free cryogenic extraction protocol (Figure 1) and have successfully detected water-soluble ammonium at a mean concentration of 0.067 ± 0.008 wt%, corresponding to a mean proportion of 26 ± 3% of the total nitrogen (Figure 2).

The $\delta^{15}N$ value of the ammonium's nitrogen contained in OM (+124 ± 57‰) differs from OF1 (+203 ± 57‰) and OF2 (+199 ± 57‰), suggesting that OM experienced isotopic exchanges whereas OF1&2 were best preserved (note that these values have been updated compared to those presented earlier [9], following new calibrations). For all samples, the isotopic composition of the ammonium's nitrogen is significantly different from the insoluble organic matter's nitrogen (IOM, +33.4 ± 0.2‰), suggesting that these nitrogen-bearing phases sampled different nitrogen reservoirs and/or had different evolutions changing their isotopic compositions.

Our results confirm the presence of extra-terrestrial ammonium in Orgueil at a significant concentration. Therefore, a part of the nitrogen may have been present in the protoplanetary disk and delivered to the planetesimals under the form of ammonium.

References:

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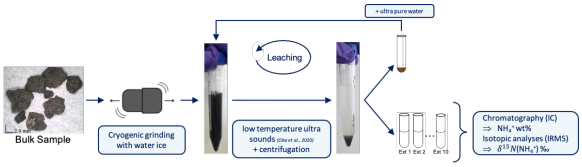

Figure 1: *Illustration of the contamination-free cryogenic extraction protocol of ammonium*

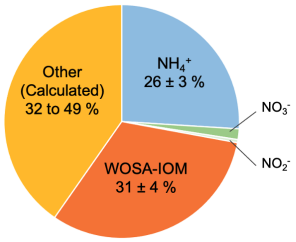

Figure 2: *Average distribution of the nitrogen-bearing phases measured in the Orgueil meteorite. WOSA-IOM stands for Water, Organic Solvents and Acids Insoluble Organic Matter*