ISOTOPIC RECORDING OF OUTER DISK WATER ICES IN CM CHONDRITES

Lionel G. Vacher[1], Yves Marrocchi[1], Maximilien J. Verdier-Paoletti[2], Johan Villeneuve[1] & Matthieu Gounelle[2], [1] CNRS-CRPG UMR 7358, Université de Lorraine, 54501 Vandoeuvre-Lès-Nancy, France, [2] IMPMC, MNHN, Sorbonne Universités, UMR CNRS 7590, 57 rue Cuvier, 75005 Paris, France.

CM carbonaceous chondrites recorded intense episodes of hydrothermal alteration that have strongly modified their primitive petrography. The origin of this water is controversial, but two principle sources are generally considered: (i) a local origin and (ii) an outer disk origin [1]. However, the respective proportions of local and outer disk water ices accreted into chondrites are still a matter of debate. The recent discovery of the least altered CM Paris [2] offers a unique opportunity to quantitatively estimate the contributions of the (i) D-poor and ^{16}O-rich local and (ii) D-rich and ^{17,18}O-rich outer Solar System water ices.

The O-isotopic compositions of Paris Ca-carbonates vary widely, from 24.2‰ to 40.8‰ in δ^{18}O and 11.6‰ to 23.8‰ in δ^{17}O and reveal the existence of two distinct populations of carbonates. The O-isotopic compositions of CM carbonates define two statistically different trends: (i) the ISS-trend (Δ^{17}O < 0, slope of 0.65) and (ii) the ISM-trend (Δ^{17}O > 0, slope > 1).

The main ISS-trend defines a continuous trend that result from the isotopic equilibration between ^{17,18}O-rich fluids and ^{16}O-rich anhydrous minerals [3]. The fluid from which the ISS-carbonates precipitated had near terrestrial Δ^{17}O values, demonstrating that most water ices accreted by CM chondrites had a dominantly local origin from the inner solar system (i.e., Δ^{17}O ≈ 0) [4]. On the contrary, the significant ^{17,18}O enrichment of ISM carbonates implies the presence of outer water ices with Δ^{17}O >> 0 within CM chondrites [5]. The contribution of outer water ices can be quantitatively calculated from isotopic mass balance calculations. Our results demonstrate that ISM-carbonates precipitated from fluids that accommodated 8-35% of ^{17,18}O-rich outer water ices. This estimation is confirmed by the bulk D/H ratio of Paris that shows significant D enrichment (i.e., D/H = 175×10^{-6}) relative to the mean (D/H) of CM chondrites (139×10^{-6}). This interpretation is also supported by the recent *in situ* analyses of the hydrogen isotopes in the least altered lithology of Paris that preserved D-rich water (-69 ± 163 ‰) compared to the other CM chondrites (-350 ± 40 ‰) [6]. The detection of outer water ice in Paris could be linked to its low H_2O content relative to other CMs (i.e., 4.8 wt.% vs. ≈ 9 wt%; [7]), which would preclude the dilution of ^{17,18}O- and D-rich water ices by local water during the alteration processes. The occurrence of outer water ices in CM chondrites requires inward radial transport in the protoplanetary disk, suggesting that this transport tooks place early in the history of the Solar protoplanetary disk.

References: [1] Lunine J. I. (2006) *MESS II,* 309. [2] Hewins R. H. et al. 2014. *GCA,* 124:190-222. [3] Vacher L. G. et al. (2017) *GCA,* 213:271-290. [4] Alexander C. M. O. et al. (2012) *Sci.* 337:721-723. [5] Vacher L. G. et al. (2016) *ApJ,* 827:L1. [6] Rubin A. E. (2007) *GCA* 71:2361-2382. [7] Piani L. et al. (2018) *Nat. Astr.*, http://dx.doi.org/doi:10.1038/s41550-018-0413-4.