On mixing as overarching principle for elemental and isotopic variability in early solar system materials

C. BURKHARDT[1] , N. DAUPHAS[2], U. HANS[3], B. BOURDON[4], T. KLEINE[1]

[1]Institut für Planetologie, University of Münster, 48149 Münster (burkhardt@uni-muenster.de)
[2]Origins Laboratory, The University of Chicago, Chicago, IL.
[3]EMPA, Department for Advanced Materials and Surfaces, Dübendorf, Switzerland.
[4]Laboratoire de Géologie de Lyon, Lyon, France.

When interpreting meteorite data for reconstructing the processes and timescales of the formation and evolution of the Solar System it is generally assumed that the solar nebula from which the materials formed had an overall uniform 'solar' composition; *i.e.*, any offset from the 'solar' composition must be related to a fractionation process. While this concept overall has been proven extremely useful for our understanding of the early solar system, it comes to it's limits when looking at nucleosynthetic isotope anomalies, in particular when comparing the isotopic signatures of CAIs, the solar systems earliest formed solids, with later-formed materials.

By combining multi-elemental concentration and isotope anomaly data for presolar grains, CAIs, chondrules, fine-grained matrix, and bulk meteorites here we show that relaxing the assumption of a homogeneous solar nebula, and instead allowing for a subtle change in the isotopic composition of the infalling molecular cloud material can –in combination with recent disk evolution models [1,2]– explain major elemental and isotopic features of the meteoritic record by simple two component mixing.

In essence, early infalling cloud material with a CAI-like isotopic composition is transported to the outer part of the disk by viscous spreading, while later infalling material with an isotopic composition more similar to the NC meteorites is dominating the inner parts of the disk. During disk processing both types of material are furthermore fractionated by volatility. Variable mixing of the so processed material in the disk naturally explains the observables in the meteorite record, *e.g.*, the excess of refractory elements and the higher amount of unprocessed material in the CC reservoir, the presence of isotopically NC-like materials with CAI-like condensation features in NC chondrites [3], and, last but not least the distinct isotopic composition of the NC and CC meteorites [4].

References:[1] Yang and Ciesla (2012) *MAPS* **47**, 99-119. [2] Pignatale et al. (2018) *ApJL* **763**, L40. [3] Ebert et al. (2018) *EPSL* **498**, 257-265. [4] Nanne et al. (2019) *EPSL* **511**, 44-54.