ASTEROIDS & COMETS – DID THE DIVERSITY OF NEBULAR SOLIDS DECLINE WITH DISTANCE FROM THE SUN?

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The discovery of chondrule and refractory inclusion fragments in Wild 2 comet samples, returned by the Stardust mission, showed that high-temperature nebular components found in meteorites were also transported to the cold regions of the solar nebula where ice-rich bodies accreted. We are using the compositional dispersion of the minor elements Mn and Cr in cometary olivine grains as a means of evaluating the nature of mixing of nebular components between the asteroid and comet accretion regions. The two order of magnitude variation in the abundance ratio of the volatile H_2O and supervolatile CO indicate that comets are a diverse bodies that formed over a range of nebular distances [1]. However, the comet olivine data suggest that rocky components may not have comet-to-comet diversity. The rocky components were transported over large distances and all comets may contain the same mix of rocky components.

Berlin et al. [2] showed that ferrous olivine in primitive chondrite classes have a strong correlation between Mn and Fe and that the compositional dispersion and mean Mn/Fe ratios differ between chondrite groups. Mn/Fe differs by a factor of two between ordinary and CO/CM chondrites. Frank et al. [2] showed that the chondrule olivine distributions also are generally matched by micron-sized matrix olivine grains in these bodies.

Combining TEM analyses from our work and that of Frank et al. [2] we now have Mn and Fe data on 200 Wild 2 cometary olivine grains. The MnO abundances of olivine from this comet show no correlation with Fe for FeO >10 wt %. MnO ranges from 0.1 to >1 wt % but with broad scatter up to the most Fe- rich grains (Fo_{50}). This distribution is quite distinct from what is seen in specific chondrite classes and may be a distinctive property of well-mixed outer nebula grain populations. The difference may be a result of asteroid accretion times being shorter than nebular mixing times while comets accreted slower than mixing times. Another factor is that nebular silicates formed near the asteroid region but not near comet formation regions [4].

To compare with the comet Wild 2 data, we have obtained a large set of minor element analyses of olivine grains from a large highly disaggregated (cluster) IDP that is thought to be of cometary origin [5]. The dispersion and range of Mn abundance versus Fe in this particle is indisguishable from what is seen for Wild 2 and clearly distinct from all chondrite groups. This striking finding suggests that comets may contain a similar mix of inner nebular materials that were well mixed as they were transported to edge of the solar nebula. Instead of a continumum between asteroids and comets, asteroids may retain specific regional identities such as oxidation state, olivine Mn contents and oxygen isotopic compositions while comets do not because their rocky components were not made locally but were derived from broad regions of the nebular disk.

References: [1] A'Hearn M. F. et al. (2012) *Astrophysical Journal* 758:29-37. [2] Berlin J, et al. (2011) *Meteoritics. Planetary Science. Sci.* 46:513-33, [3] Frank D. R. et al. (2014) *Geochimica. Cosmochimica Acta* 142, 240. [4] Brownlee D. E. *Annual Reviews Earth & Planetary Science* (2014) 42:179-205. [5] Pepin R. O. (2015) *Lunar and Planetary Science Conference* 46:1705-1706.