Interstellar and Solar Nebula Materials in Cometary Dust

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Laboratory studies of cometary dust collected in the stratosphere and returned from comet 81P/Wild 2 by the Stardust spacecraft have revealed ancient interstellar grains and molecular cloud organic matter that record a range of astrophysical processes and the first steps of planetary formation. Presolar materials are rarer meteorites owing to high temperature processing in the solar nebula and hydrothermal alteration on their asteroidal parent bodies. The greater preservation of presolar materials in comets is attributed to their low accretion temperatures and limited planetary processing. Yet, comets also contain a large complement of high temperature materials from the inner Solar System. Owing to the limited and biased sampling of comets to date, the proportions of interstellar and Solar System materials within them remains highly uncertain.

Interstellar materials are identified by coordinated isotopic, mineralogical, and chemical measurements at the scale of individual grains [1]. Chondritic porous interplanetary dust particles (CP IDPs) that likely derive from comets are made up of 0.1 – 10 μm-sized silicates, Fe-Ni-sulfides, oxides, and other phases bound by organic material [2]. As much as 1% of the silicates are interstellar grains that have exotic isotopic compositions imparted by nucleosynthetic processes in their parent stars. Crystalline silicates in CP IDPs dominantly have normal isotopic compositions and probably formed in the Solar System. 81P samples include isotopically normal refractory minerals that resemble Ca-Al rich inclusions and chondrules common in meteorites [3]. The origins of sub-μm amorphous silicates in IDPs are not certain, but at least a few % of them are interstellar grains [4]. The remainder have isotopic compositions consistent with Solar System origins and elemental compositions that are inconsistent with interstellar grain properties, thus favoring formation in the solar nebula [4]. The organic component in comets and primitive meteorites has large enrichments in D/H and $^{15}N/^{14}N$ relative to terrestrial materials. These isotopic signatures are probably due to low temperature chemical processes in cold molecular clouds or the outermost reaches of the protoplanetary disk. The greatest isotopic anomalies are found in sub-μm organic nanoglobules that show chemical signatures of interstellar chemistry [5].

The observation that cometary dust is mostly composed of isotopically normal minerals within isotopically anomalous organic matter is difficult to reconcile with the formation models of each component. The mineral component likely formed in high temperature processes in the inner Solar System, while the organic fraction shows isotopic and chemical signatures of formation near 10 K. Studying more primitive remnants of the Solar System starting materials would help in resolving this paradox. Comets formed across a vast expanse of the outer disk under differing thermal and collisional regimes, and some are likely to be better preserved than others. Finding truly pristine aggregates of presolar materials may require return of a pristine sample of comet nucleus material.

Refs: [1] Zinner E. (2014) In *Treatise on Geochemistry (2nd Ed.),* pp. 181-213. [2] Messenger S. et al. (2014) Dust in the Solar System: Propertioes and Origins. In Proc. of Sci. [3] Brownlee D. E. (2014) Ann. Rev. Earth Planet. Sci. 4 2:179–205 [4] Keller L. P. and Messenger S. (2011) *GCA* 75:5336-5365. [5] Nakamura-Messenger K. et al. (2006) Science 314, 1439-1442.