

CHONDRULES FROM THE OUTER SOLAR SYSTEM: RESULTS FROM STARDUST. J. C. Bridges and L. J. Hicks, Space Research Centre, Leicester Institute for Space and Earth Observation, University of Leicester LE1 7RH, UK. j.bridges@le.ac.uk

Introduction: The *Stardust* mission sampled a Jupiter Family Comet 81PWild2 and brought back samples for analysis in 2006 [1]. The subsequent work has revealed mineralogical and isotopic affinities with carbonaceous chondrites. For instance, one of the major findings of *Stardust* has been the identification of chondrule and CAI fragments. As these are objects associated with localised melting in the inner Solar System, their presence in an object which originated within the Kuiper Belt was not expected. Here we describe the occurrence of chondrule fragments in Wild2 and their significance for models of the Early Solar System.

Chondrule Fragments in Wild2 Samples: Collection from the comet's coma at 6 kms⁻¹ means that the samples are necessarily fragmented. However, ~10s µm-sized terminal grains in aerogel keystones have preserved pristine mineral assemblages with limited effects from capture. Burchell et al. [2] showed that Type A tracks in aerogel contain strong materials, typically consolidated into a single, volatile-poor grain e.g. either olivine, pyroxene, or chondrule fragments. Transmission Electron Microscopy studies of Type A track terminal grains have revealed that a large proportion of the coarse grains (>2 µm) may be fragments of chondrules that bear some chemical and isotopic similarities to those found in chondrites e.g. [3,4].

Similarities to Meteoritic Chondrules: There are differences in the chemistry and mineralogy between Wild2 chondrule fragments and meteoritic chondrules. The most common type of meteoritic chondrules are rounded FeO- and volatile-poor chondrules (Type I), but no chondrule fragments with such chemistry have yet been identified in Wild2 [5]. In contrast, several examples of FeO-rich, volatile-rich chondrule fragments have been identified in Wild 2 (so-called Type II), but are relatively less common in meteorite samples [3]. Two chondrule-like particles named Iris and Callie, Track #74, are examples of the similarities to Type II chondrules [6]. The Iris particle, from Track #74, is similar to chondrules in CR chondrites. Plagioclase in the FeMg Wild2 particle, Pyxie (Track #81), was analysed for Mg isotopes. The inferred initial ²⁶Al/²⁷Al ratio of plagioclase in Pyxie is <5×10. The ²⁶Al/²⁷Al ratio and Δ¹⁷O resemble those of CR3 chondrules with Mg# <98 [6]. In addition, the presence of Al-rich chondrule fragments with Al-rich diopside and ¹⁶O-rich

compositions are very similar to those typical of carbonaceous chondrites [7].

Implications for the Early Solar System: In the presence of chondrules it is clear that Wild2 has preserved signs of high temperature processing. This complements the presence of CAIs [1] and magnetite formed by water-rock reaction on a parent body [8]. There is an absence of direct evidence in the chondrule fragments for extinct ²⁶Al [6, 9]. Assuming homogeneous distribution of ²⁶Al in the solar nebula, one FeMg chondrule fragment crystallized at least 3 Myr after the earliest Solar System objects [9]. Thus there is no obvious evidence that the heat source associated with these chondrules was ²⁶Al, though more sample analyses may change this conclusion.

The presence of abundant chondrule fragments has changed our understanding of the formation of comets and icy planetesimals. It has been interpreted as evidence for large scale movement of common asteroidal-type materials from the inner Solar System by radial drift [10]. However, radial drift models have yet to resolve whether the drift material could escape the gravitational well of the gas and ice giants, or whether the residence time of chondritic fragments in the outer Solar System would be sufficient to allow incorporation into cometary parent bodies [7]. Thus an alternative possibility is that chondrule formation also occurred within parts of the outer Solar System.

The *Stardust* samples have provided a unique opportunity to constrain models of the early Solar System, using the mineralogical analyses of chondrule fragments to inform new theoretical models.

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