CONTEMPORARY INTERSTELLAR DUST MEASURED BY CASSINI: A CHEMICALLY HOMOGENISED POPULATION, NOT CIRCUMSTELLAR DUST

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During the formation of our solar system, most presolar dust grains were destroyed or heavily processed. A minor population of circumstellar presolar grains survived processing in the protosolar disk and can be recognized by their extremely diverse isotopic composition [1], but it is unknown whether those grains are representative of the grain populations in the interstellar medium [2–4]. In 1992 the Ulysses spacecraft detected a stream of interstellar dust (ISD) grains passing our solar system [5]. In-situ analyses of the Cosmic Dust Analyser on-board the Cassini spacecraft obtained between 2004 and 2013 yielded the first mass spectra of grains from the Local Interstellar Cloud (LIC) [6]. These 36 interstellar grains can be clearly identified and distinguished from Saturn bound dust by their direction and high velocity, and their mean mass is consistent with the typical ISD size inferred from astronomical observations [6].

Surprisingly, each grain contains the major rock forming elements (Mg, Si, Fe, Ca) in roughly cosmic abundances, with only small grain-to-grain variations. Hence, compositional homogeneity extends down to small spatial scales of 100 nm. In this size regime, neither carbon rich grains (graphite, SiC) nor pure metal nor oxide grains were detected, which sets an upper limit of 8% at the 2 sigma confidence level for these grain species [6]. This finding is in contrast with the isotopically and compositionally diverse populations of circumstellar dust inherited from AGB Stars and supernovae, which typically consist of silicates (e.g., olivine, pyroxene), with minor contributions (few %) of oxides (e.g., corundum, hibonite) and carbonaceous grains, mainly silicon carbide (40) with an abundance of >20%, possibly up to 50% [7].

Moreover, the LIC-ISD grains detected by Cassini also differ in elemental composition, specifically, their variation of Mg/Si, Mg/Fe is significantly smaller. A more homogeneous composition can be explained by destruction, recondensation and equilibration processes in the ISM that homogenise an initially diverse population that started as circumstellar dust. This is supported by astronomical observations of the diffuse ISM demonstrating that the most condensable elements (atomic mass >23) are depleted in the gas phase and hence bound in solids, while the lifetime of interstellar grains against destruction by supernova shocks of about 0.5 Ga is much shorter than the average residence time of matter in the ISM of 2.5 Ga [4]. During this residence time, ISD grains frequently cycle between the hot interstellar medium (low density regions carved by supernovae), the warm diffuse medium (accessible by spectroscopic observations) and cold molecular clouds, which are star formation regions. Our study implies that searches for presolar interstellar grains in meteorites lead by isotopic anomalies could miss a population of isotopically inconspicuous presolar grains that recondensed in the ISM [e.g., 8,9].

Although our results indicate roughly cosmic element abundances of ISD grains, there seems to be a slight (20%) Si deficit, as well as a clear underabundance of S and C. A Si deficit is also supported by astronomical observations [10] and can be explained by a higher abundance of either oxides and/or metals, similar to grains returned by the Stardust mission [11]. Our dynamical analysis of the Cassini ISD grains is consistent with occasionally high beta values, i.e. the presence of nanophase iron.

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