Highlights of Astronomy, Volume 14
IAU XXVI General Assembly, 14-25 August 2006
Karel A. van der Hucht, ed.

doi:10.1017/S1743921307010927

Joint Discussion 11
Pre-solar grains as astrophysical tools

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Preface

With the first discovery of surviving pre-solar minerals in primitive meteorites in 1987 a new kind of astronomy emerged, based on the study of stellar condensates with all the detailed methods available to modern analytical laboratories. The pre-solar origin of the grains is indicated by considerable isotopic ratio variations compared with Solar System materials, characteristic of nuclear processes in different types of stars.

The astrophysical implication comes from the laboratory studies of such pre-solar grains from meteorites. The studies have provided new and often unique information on galactic chemical evolution, on nucleosynthesis in a variety of stellar objects, on grain formation in stellar outflows, and on the survival of grains in the instellar medium, in the solar nebular, and in meteorite parent bodies.

The full scientific exploitation of pre-solar grains is only made possible by the development of advanced instrumentation for chemical, isotopic, and mineralogical microanalysis of very small samples. Unique scientific information derives primarily from the high precision (in some cases $< 1\%$) of the measured isotopic ratios of various elements in single stardust grains. Known pre-solar phases include diamond, SiC, graphite, Si_3N_4, Al_2O_3, $MgAl_2O_4$, $CaAl_{12}O_{19}$, TiO_2, $Mg(Cr,Al)_2O_4$, and most recently, silicates. Subgrains of refractory carbides (e.g., TiC), and Fe-Ni metal have also been observed within individual pre-solar graphite grains. These grain types represent a wide range of thermal and chemical resistance. Many new breakthroughs are expected in the near future as it is now technically possible to extend isotopic laboratory studies to individual particles down to scales of < 100 nm.

The papers presented here illustrate that the laboratory studies of pre-solar grains provide crucial contributions to several important areas of astrophysics. For example, studying isotopic compositions of grains that condensed from the ejecta of dying stars provide essential boundary conditions for numerical models of stellar nucleosynthesis. The grains disclose information about nucleosynthesis sites of different elements and the relative abundances of different stellar inputs to the Galaxy (e.g., the supernova II/Ia ratio), as well as constraining the degree of mixing of material from diverse stars in the interstellar medium and the types of minerals produced by stars of different metallicity. The grains also probe the conditions of the solar nebula accretion disk during the earliest stages of Solar System formation.

The results from isotopic studies are currently those that bear strongest on other fields of astrophysics. For one, they allow us to pinpoint the grains' stellar sources among which Red Giants stars play a prominent role. In addition, given the precision of the laboratory isotopic analyses, which far exceeds whatever can be hoped to be achieved in remote analyses, they have strong implications for, e.g., the need for an extra mixing process (cool bottom processing) in Red Giants and provide detailed constraints on the operation of the s-process in Asymptotic Giant Branch (AGB) stars. Indeed, they are the only way to provide isotopic abundances for many species, especially for trace elements. A non-standard neutron capture process (neutron burst) may be implied by the small part of the silicon carbide grains which originate from supernovae. The progress in analytical techniques promises more important and exiting results in the near future.

May the next pages be a compass to guide your journey into the facinating discoveries that have come from the studies of pre-solar grains up to now.

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Anja C. Andersen and John Lattanzio, co-chairs SOC,
Copenhagen and Monash, November 1, 2006

https://doi.org/10.1017/S1743921307010927 Published online by Cambridge University Press