Explosive Nucleosynthesis in Core-collapse Type II Supernovae: Constraints from isotopic compositions of presolar supernova grains

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The chemical composition of our Solar System reflects Galactic chemical evolution (GCE) in the local interstellar medium (ISM) over the past ~9 Ga. While the incorporated ISM dust was mostly destroyed during the Solar System formation, a small fraction of the ISM dust, known as presolar grains, is preserved in pristine extraterrestrial materials and identified by their exotic isotopic compositions, pointing to their formation in gas outflows or explosions of ancient stars. Since their stellar birth at more than 4.6 Ga, presolar grains have borne witness to a huge array of astrophysical and cosmochemical processes. Presolar grain analysis has become an important component of the study of nuclear astrophysics as it allows for isotope analysis of bona fide stellar material in the laboratory at a precision that far exceeds what can be achieved by spectrographic measurements using state-of-the-art telescopes (Zinner 2014; Nittler & Ciesla 2016; Liu 2024).

The talk will discuss how we can leverage the isotopic compositions of presolar grains to refine our understanding of physical mixing processes within stars, stellar nucleosynthesis, and dust formation. Specifically, I will focus on the unique role of presolar grains derived from Type II core-collapse supernovae (CCSNe) in constraining explosive nucleosynthesis and the dynamic mixing processes occurring during the explosion. Drawing from our recent studies, I will present new isotope data for presolar CCSN silicon carbon (SiC) and silicon nitride (Si_3N_4) grains. Our new isotope data specifically point to the contributions of materials from distinct regions within a CCSN, including the Fe/Ni core, inner Si/S zone, and He/C zone, to the CCSN ejecta for the SiC and Si_3N_4 grain formation. This inferred mixing scenario, as suggested by the CCSN grain data, aligns with recent 3D hydrodynamic model simulations of CCSN explosions. The incorporation of materials from distinct supernova regions into these grains thus enables the investigation of a variety of nucleosynthesis processes, including alpha-rich freezeouts, neutrino-nucleus reactions, and neutron burst process. Detailed comparisons of the grain data with CCSN model calculations will be presented at the meeting.

References:

Liu N. (2024) Presolar Grains. Chapter in the Book Treatise on Geochemistry (Third Edition), *in press* (arXiv preprint arXiv:2406.14694).

Nittler & Ciesla (2016) Astrophysics with Extraterrestrial Materials. *Ann. Rev. Astron. Astrophys.* **54**, 53.

Zinner, E. (2014) Presolar Grains. Chapter in the Book Treatise on Geochemistry (Second Edition), 181.