Chemical Nucleosynthesis

The Origin of the Solar System Elements

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&MSE Chemical Nucleosynthesis SWG
The Emergence of the Periodic Table

The abundance of the elements in the Solar System

Abundance of Si is normalized to $10^6$
The Emergence of the Periodic Table

Only H, He, and Li is from Big Bang Nucleosynthesis.
The Emergence of the Periodic Table

Burbidge et al 1957
-Hydrogen burning
-Helium burning
-Alpha process
-Slow neutron-capture
-Rapid neutron-capture

Image credit: Jennifer Johnson
Science Highlights

- $i$-process and CEMP-$r/s$ stars
- Metal-poor stars
- AGB stars
- Cosmological lithium problem
- $r$-process
- Dwarf galaxies
Metal-Poor Stars

The oldest and most chemically primitive stars are fossils, which contain nuclear ashes of the first stars to be born in the Universe.

→ MSE offers an unparalleled competitive advantage in the discovery and analysis of metal-poor stars. MSE will study unprecedented numbers of these objects to probe the properties of the very first supernovae and chemical enrichment events in the Universe.
Cosmological Lithium Problem

Big Bang Nucleosynthesis (BBN) produced hydrogen, helium, and lithium. The lithium abundances in metal-poor stars are inconsistent with BBN by a factor of 2-4.

→ With MSE we can determine pre-galactic Li abundances in outer halo stars and high velocity clouds to disentangle lithium depletion from internal stellar processes or depletion in of the ISM lithium abundances due to Pop III stars.
The fraction of carbon enhanced metal-poor (CEMP) stars increases at low metallicity. The CEMP-\(r/s\) subclass are particular puzzling, and may be produced by the intermediate neutron-capture process.

→ **MSE will enable large-scale long-term radial velocity monitoring campaigns to check for radial velocity variations (i.e., binarity) of CEMP-\(r/s\) stars which is essential for shedding more light on their possible origin(s).**
AGB stars are the main contributor of slow (s-process) neutron capture elements. Most abundance measurement come from progeny of AGB stars. But recent advances in stellar atmosphere modeling facilitate abundance measurement of elements from C to Pb directly in post-AGB star.

→ **MSE will provide high-resolution spectra of a significant sample of post-AGB stars to quantify the contribution from low and intermediate-mass stars to the chemical enrichment of the Universe**
The rapid neutron-capture process (r-process) produces half of the heavy elements. The astrophysical site(s) is still subject of intense debate.

The key challenge is the small sample sizes. MSE will study the r-process element abundances in unprecedented numbers of stars across our galaxy.
Dwarf Galaxies

Local Group dwarf galaxies have independent chemical enrichment histories, allowing us to study how nucleosynthesis varies with galaxy formation and environment.

→ The ideal facility has wide field, high-resolution, multi-object spectrographs with blue coverage on a large aperture telescope MSE.

Ji et al. 2016
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