Spectroscopic study of Carbon-Enhanced Metal-Poor stars

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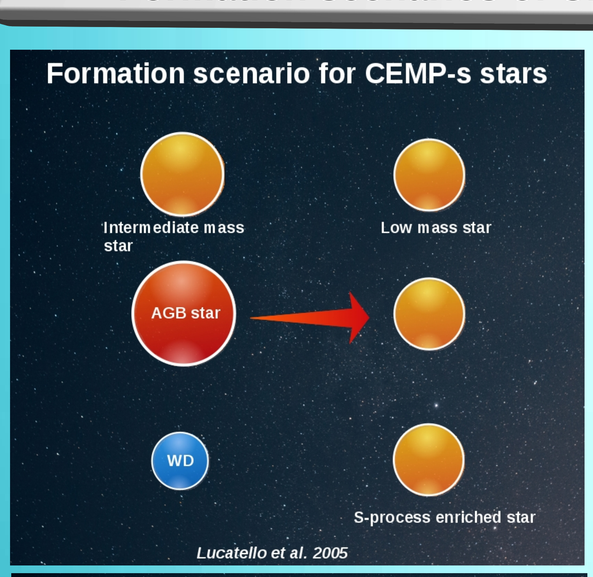
INTRODUCTION

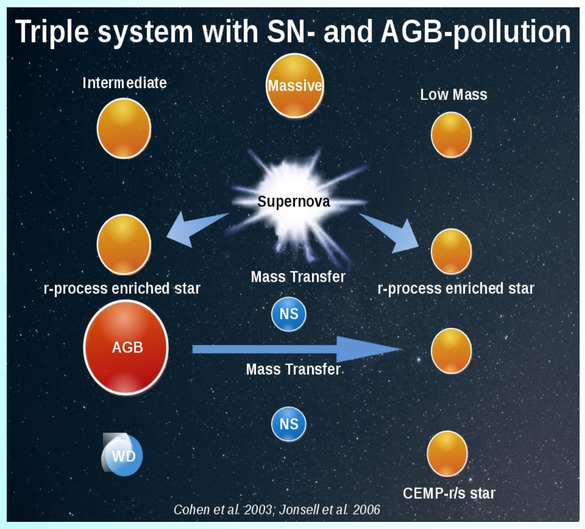
- Metal-poor stars carry imprints of the early nucleosynthesis and early Galactic chemical evolution.
- A fraction of metal-poor (CEMP, CH and Ba) stars exhibit enhanced abundances of heavy elements in their atmosphere.
- The origin of the enhanced heavy elements observed in CEMP-s stars are attributed to s-process nucleosynthesis occuring in a binary companion (McClure et al., 1980; Lucatello et al., 2005).
- The observed surface chemical composition of CEMP-r/s stars with enhancement of both s- and r-process elements remains a puzzle as far as their origin is concerned.
- For these stars, the heavy element abundances cannot be explained either by s- or r-process nucleosynthesis alone. An alternative process called 'i-process (intermediate process) nucleosynthesis' is suggested as a possible production mechanism.
- Through Chemical composition studies, we can understand the origin of heavy elements in CEMP-r/s stars. As a case study, we have performed detailed spectroscopic analysis of three stars (HD 145777, HE 2144-1832 and HE 0017+0055) based on High-Resolution Spectra obtained using **HCT/HESP**.

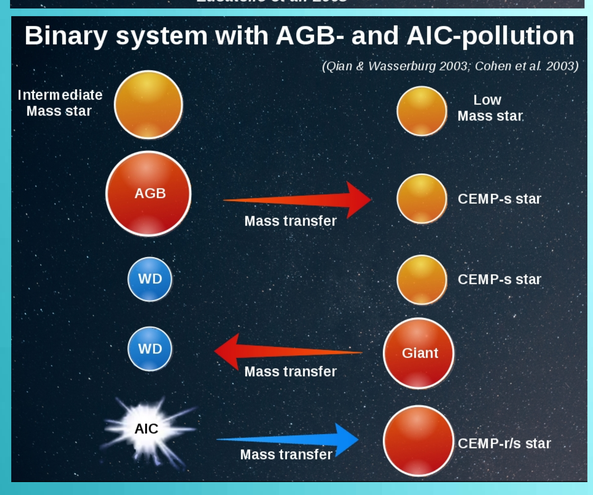
GOALS

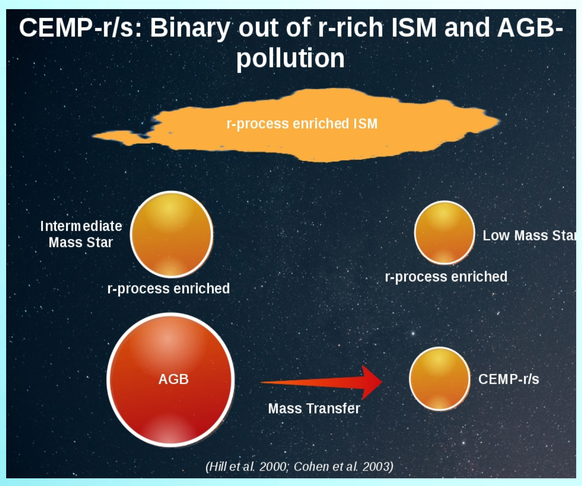
- To understand the origin of abundance peculiarities observed in CEMP-r/s stars through detailed chemical composition study, and hence, to understand the formation mechanisms of these stars and to examine whether i-process can reproduce the observed abundances in the CEMP-r/s stars HE 2144-1832 and HE 0017+0055.

Formation scenarios of CEMP-s and CEMP-r/s stars





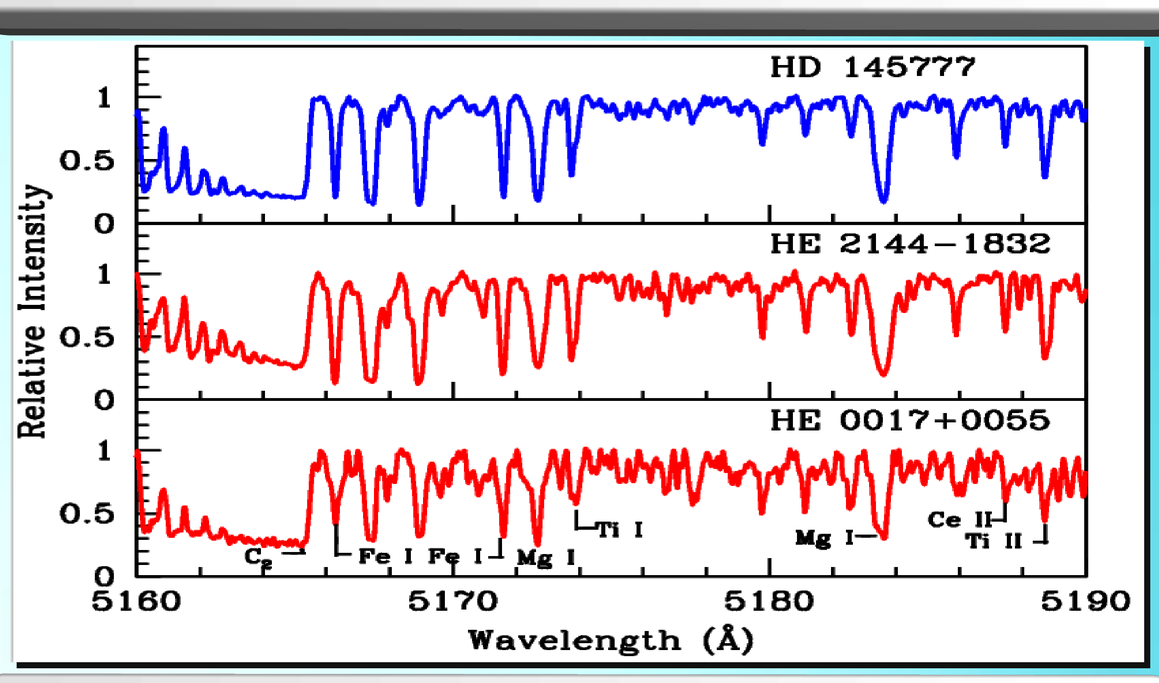




Neutron-capture Nucleosynthesis

s-process	i-process	r-process
$\tau_n >> \tau_\beta$	$\tau_n < \tau_\beta$	$\tau_n << \tau_\beta$
$N_n \approx 10^{7-10}/cm^3$	$N_n \approx 10^{11-15}/cm^3$	$N_n \approx 10^{20-25}/cm^3$
Sites → Low and Intermediate mass AGB stars	Sites → Low and Intermediate mass AGB stars	Sites → Supernovae and Neutron star mergers

Sample Spectra



RESULTS

Stellar atmospheric parameters, Metallicity and Radial velocity

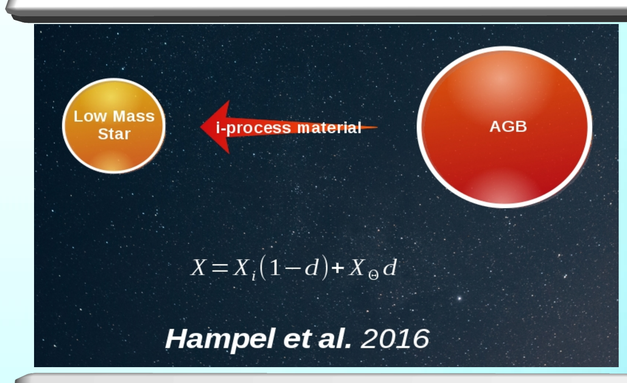
Star	T_{eff} (K)	log g	[Fe/H]	V_r (km/s)
HD 145777	4160	0.9	-2.17 ± 0.14	136.79 ± 0.64
HE 0017+0055	4370	0.8	-2.46 ± 0.19	15.95 ± 0.40
HE 2144-1832	4190	0.6	-1.63 ± 0.15	-80.73 ± 0.23

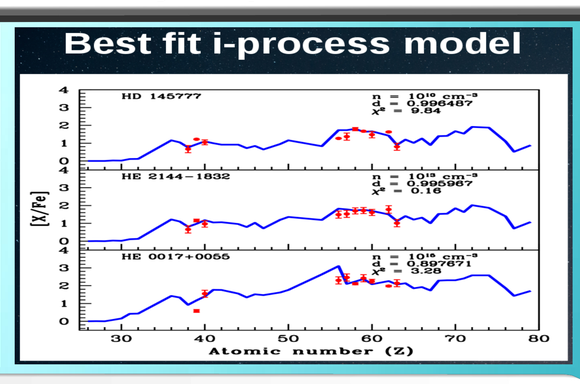
Derived Abundance Ratios and Star types

Star	[Fe/H]	[ls/Fe]	[hs/Fe]	[hs/ls]	$\frac{^{12}C}{^{13}C}$
HD 145777	-2.17	0.98	1.48	0.50	5.45
HE 0017+0055	-2.46	1.07	2.28	1.21	3.64
HE 2144-1832	-1.63	0.93	1.58	0.65	2.50

Star	[Fe/H]	[C/Fe]	[Ba/Fe]	[Eu/Fe]	[Ba/Eu]	Star type
HD 145777	-2.17	2.45	1.27	0.80	0.47	*CEMP-s*
HE 0017+0055	-2.46	2.73	2.30	2.14	0.16	*CEMP-r/s*
HE 2144−1832	-1.63	1.85	1.49	1.01	0.48	*CEMP-r/s*

Parametric model based study : i-process





CONCLUSIONS

- The absence of Tc lines and the low values of $\frac{^{12}C}{^{13}C}$ indicate the extrinsic nature of carbon and heavy elements of the stars. Hence, binary mass transfer scenario is the most probable scenario for the observed overabundance of the heavy elements.
- HD 145777 is found to show the characteristic properties of CEMP-s stars. The dominant process responsible for the observed abundances is found to be the s-process.
- HE 2144-1832 and HE 0017+0055 exhibit the characteristic properties of CEMP-r/s stars. The parametric model based studies of i-process can satisfactorily reproduce the observed abundances of heavy elements.

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