Supernova properties in the early universe

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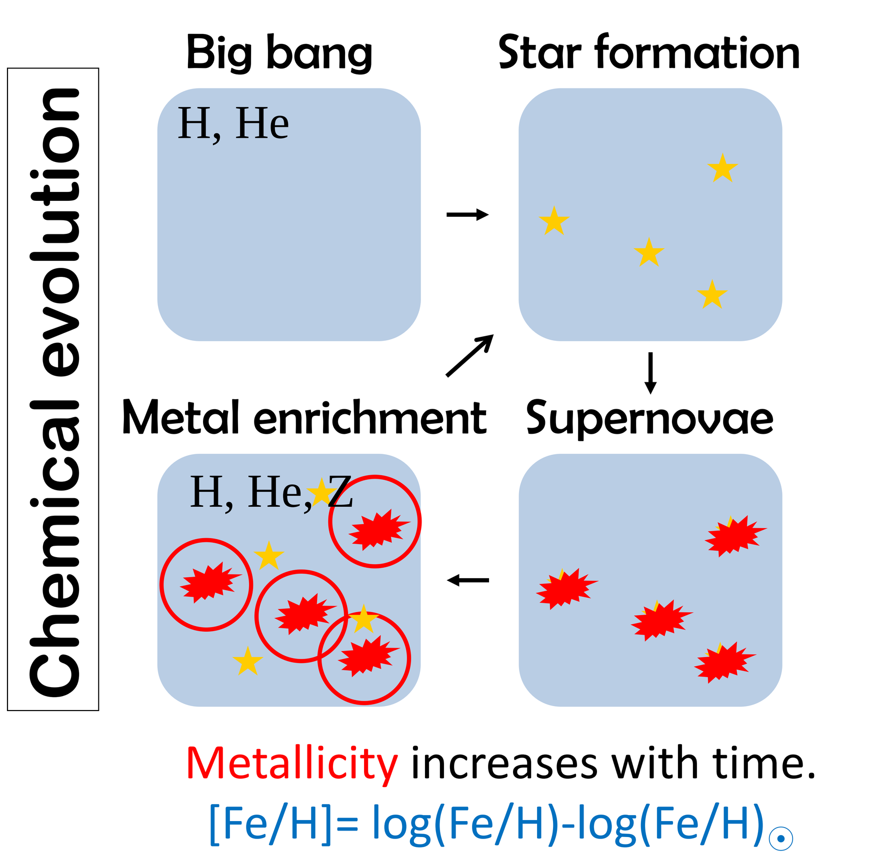
Reference
NT+07, ApJ, 657, L77;
NT+07, ApJ, 660, 516;
NT 09, ApJ, 690, 526; NT+, in prep.

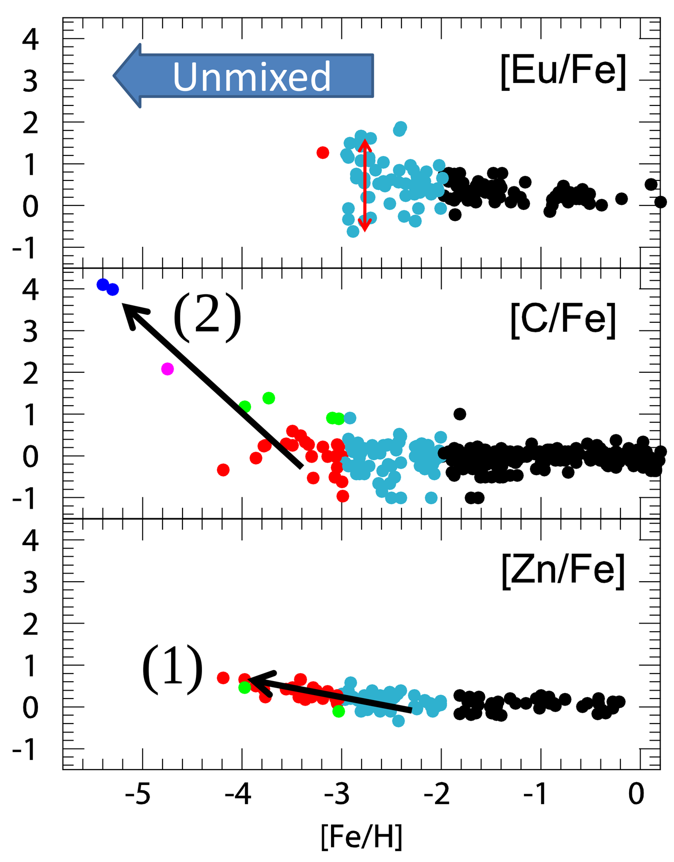
Abstract & Conclusion

The first metal enrichment in the universe was made by supernova (SN) explosions of population (Pop) III stars and the results are recorded in abundance patterns of the extremely metal-poor (EMP) stars. We investigate the properties of Pop III SNe with comparing their nucleosynthetic yields with the abundance patterns of the EMP stars. We present nucleosynthesis in SNe of stars with various main-sequence masses and explosion energies and jet-induced SNe with various jets and show that the variations of M_{ms}, E, and M(Fe), and $\dot{E}_{dep}$ can explain the observed trends of [Zn/Fe] and [C/Fe] in the EMP stars, respectively. The number of EMP stars is increasing recently. We focus on the most metal-poor 17 stars with [Fe/H]<-3.5 and present Pop III SN models reproducing well their abundance patterns. Adopting the SN models, the abundance patterns of EMP stars could be converted to SN properties, e.g., M(Fe) and M_{rem}, in the early universe. Large samples of EMP stars, obtained by ongoing and planning EMP star surveys, e.g., SEGUE and Skymapper, would clarify distributions of SN properties in the early universe.

Metal-poor stars tell us the early universe.



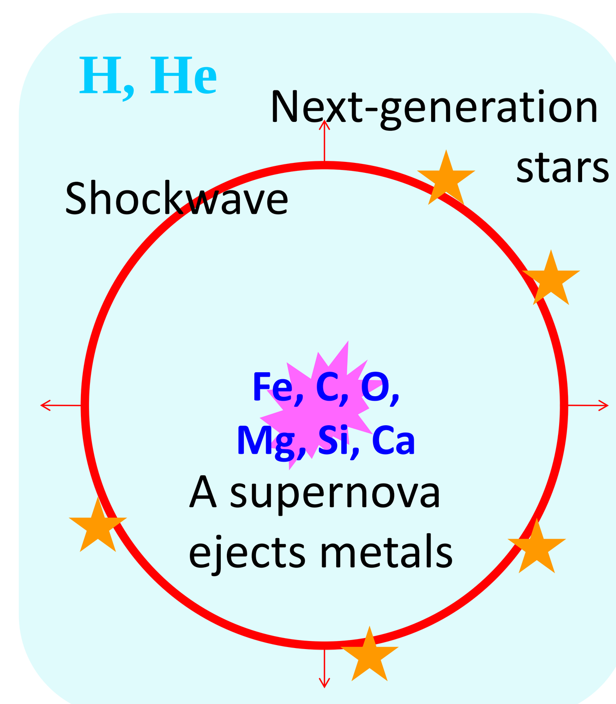
Metallicity increases with time.
[Fe/H]= log(Fe/H)-log(Fe/H)$_\odot$



Metal-poor stars formed in the early universe and preserve the chemical abundance of the early universe.
They have the following characteristics:
(1) higher [Zn/Fe] and (2) higher [C/Fe] for lower [Fe/H].

Supernova-induced star formation

(e.g., Cioffi et al. 1988)

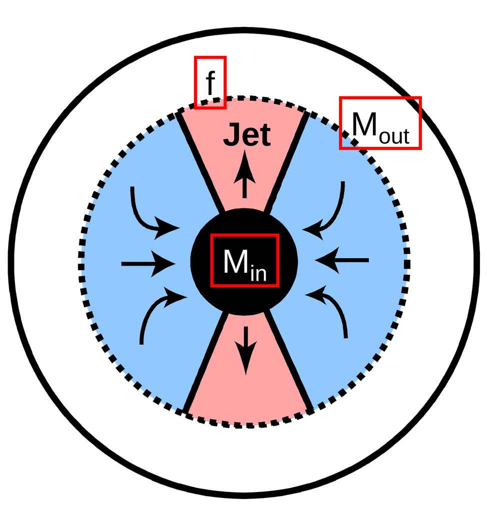


The SN shock compression trigger the formation of next-generation stars, which are made from the mixture of the matter ejected by the SN (Fe, C, O, etc.) and swept-up by the shockwave (H, He).

In the early unmixed universe, the enrichment by a single SN can dominate the preexisting metal contents (e.g., Audouze & Silk 1995).

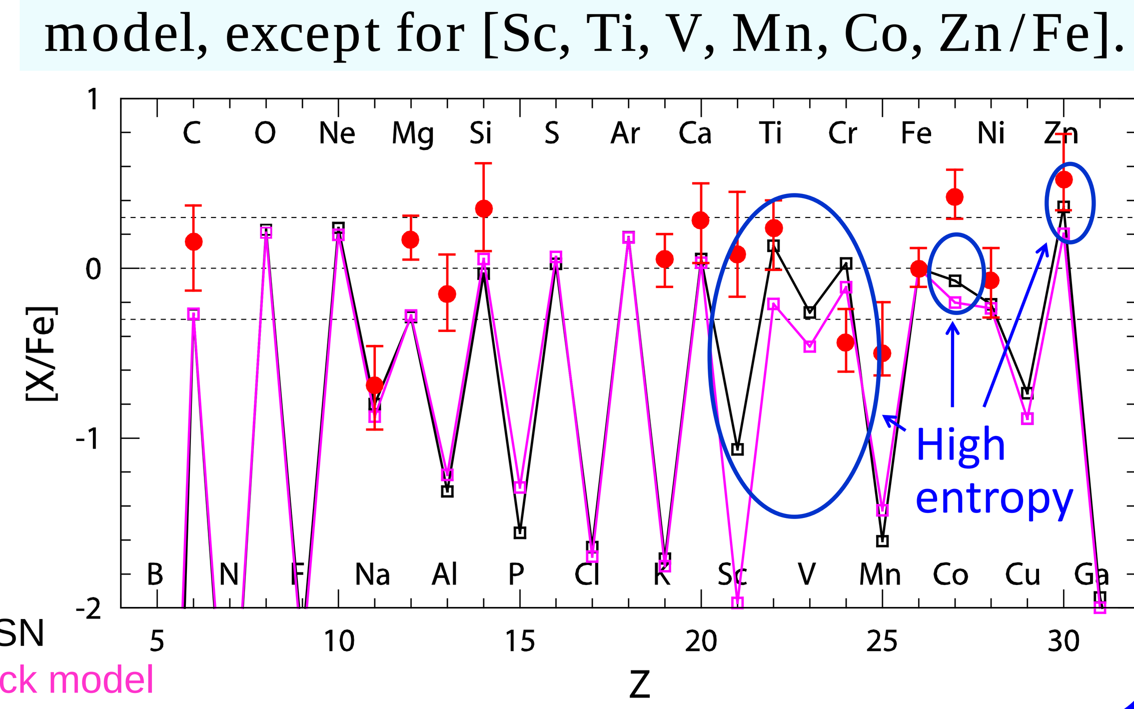
Abundance patterns of the next-generation stars constrain nucleosynthesis in the SN.

Jet-induced SN vs. Mixing-fallback model



3 parameters of mixing-fallback model
M_{in}, M_{out}, f

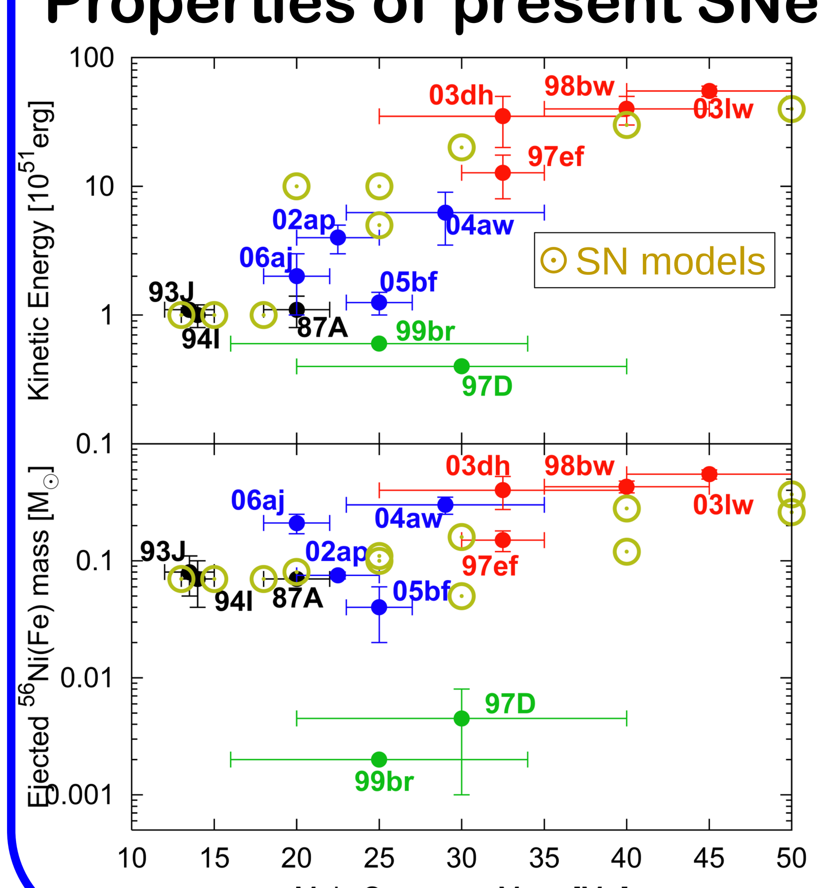
Abundance ratios of jet-induced SN models are well mimicked by the mixing-fallback model, except for [Sc, Ti, V, Mn, Co, Zn/Fe].

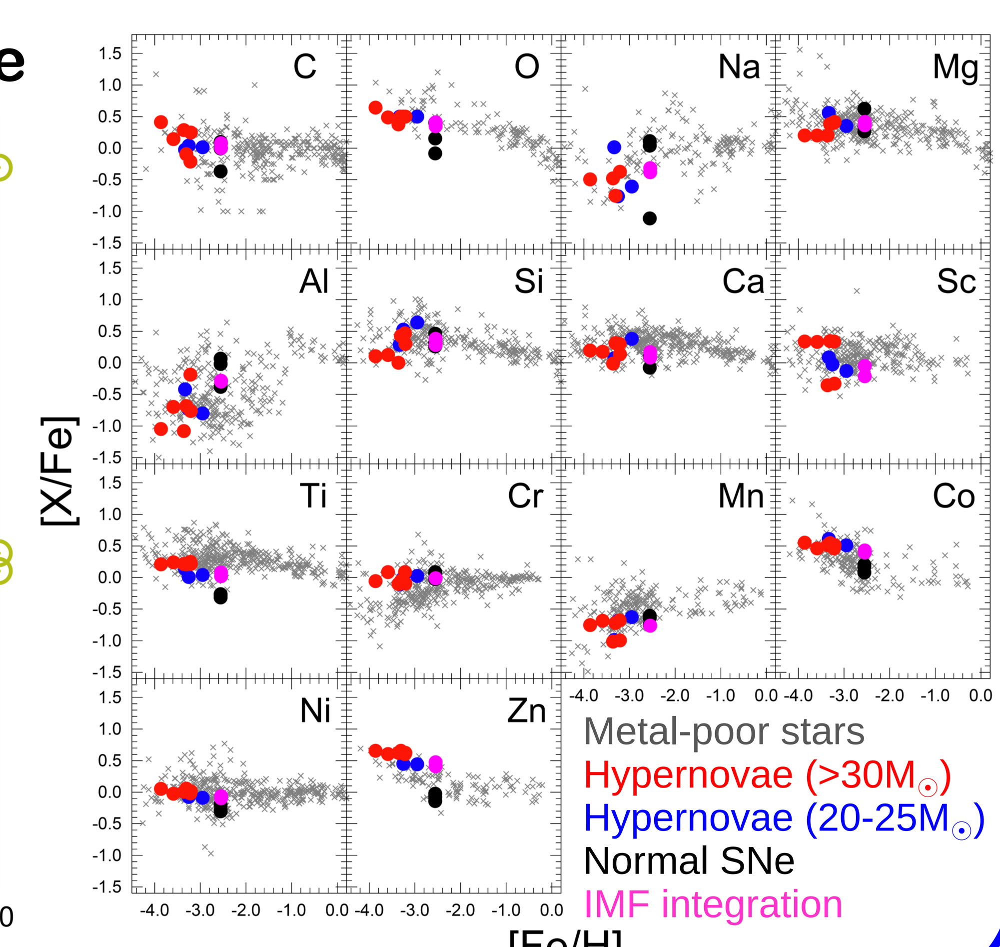


1. Higher [Zn/Fe] for lower [Fe/H]

The variations of M_{ms}, E, and M(Fe) observed in present SNe can explain the trends of [X/Fe] in EMP stars.

Properties of present SNe

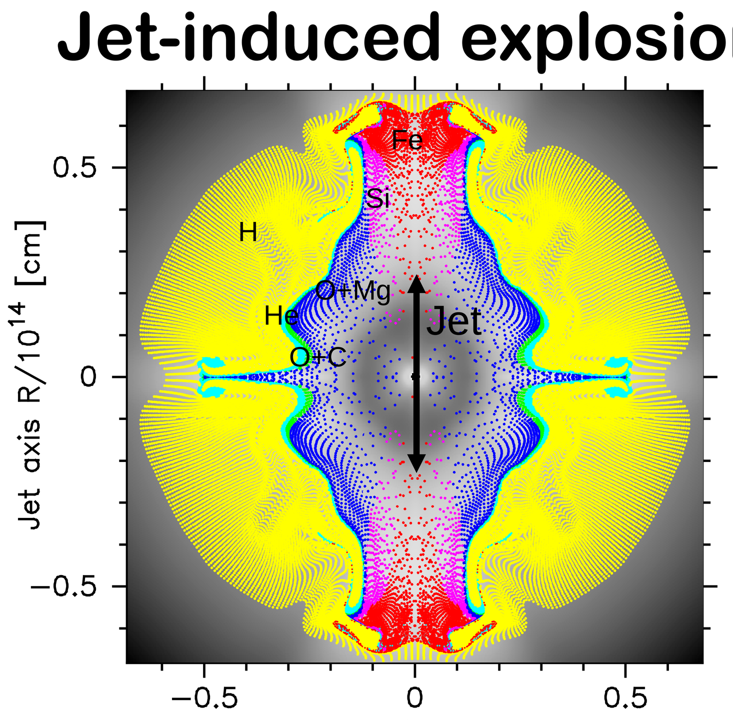


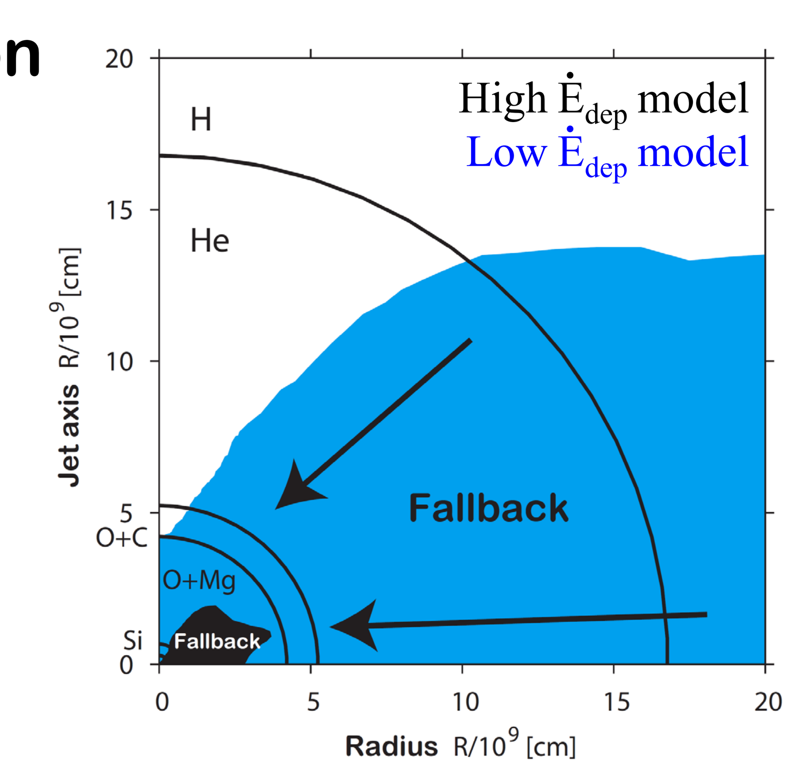


2. Higher [C/Fe] for lower [Fe/H]

The variation of energy deposition rate, that may relate to the variation of GRB luminosities, can explain the variations of M(Fe) and [C/(O, Mg, Fe)] and the abundance patterns of the EMP stars.

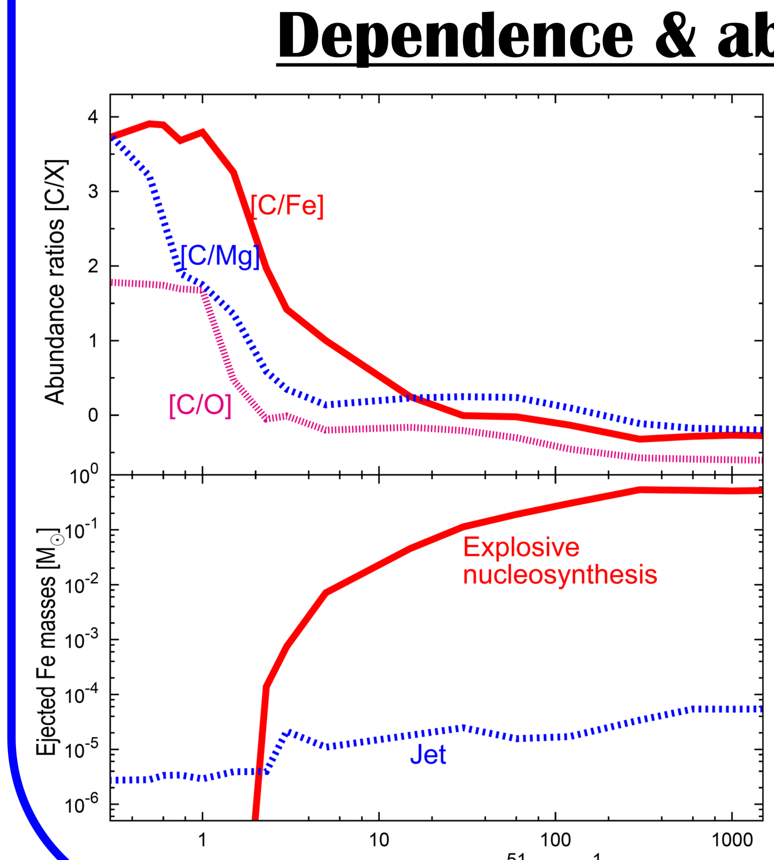
Jet-induced explosion

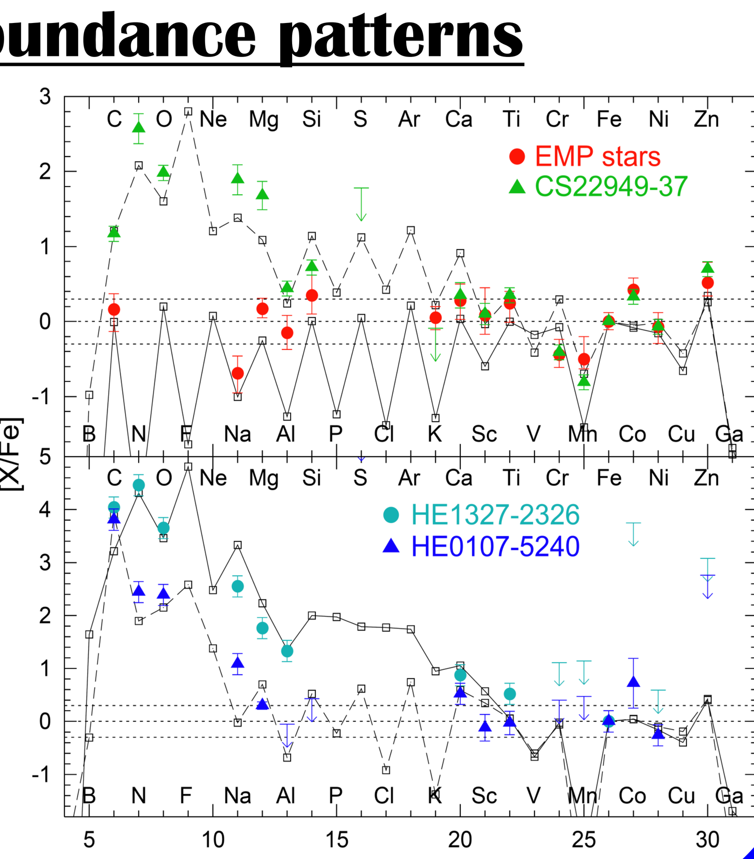




Fallback enhanced in explosions with low $\dot{E}_{dep}$ reduces O, Mg, and Fe masses more efficiently than C mass.

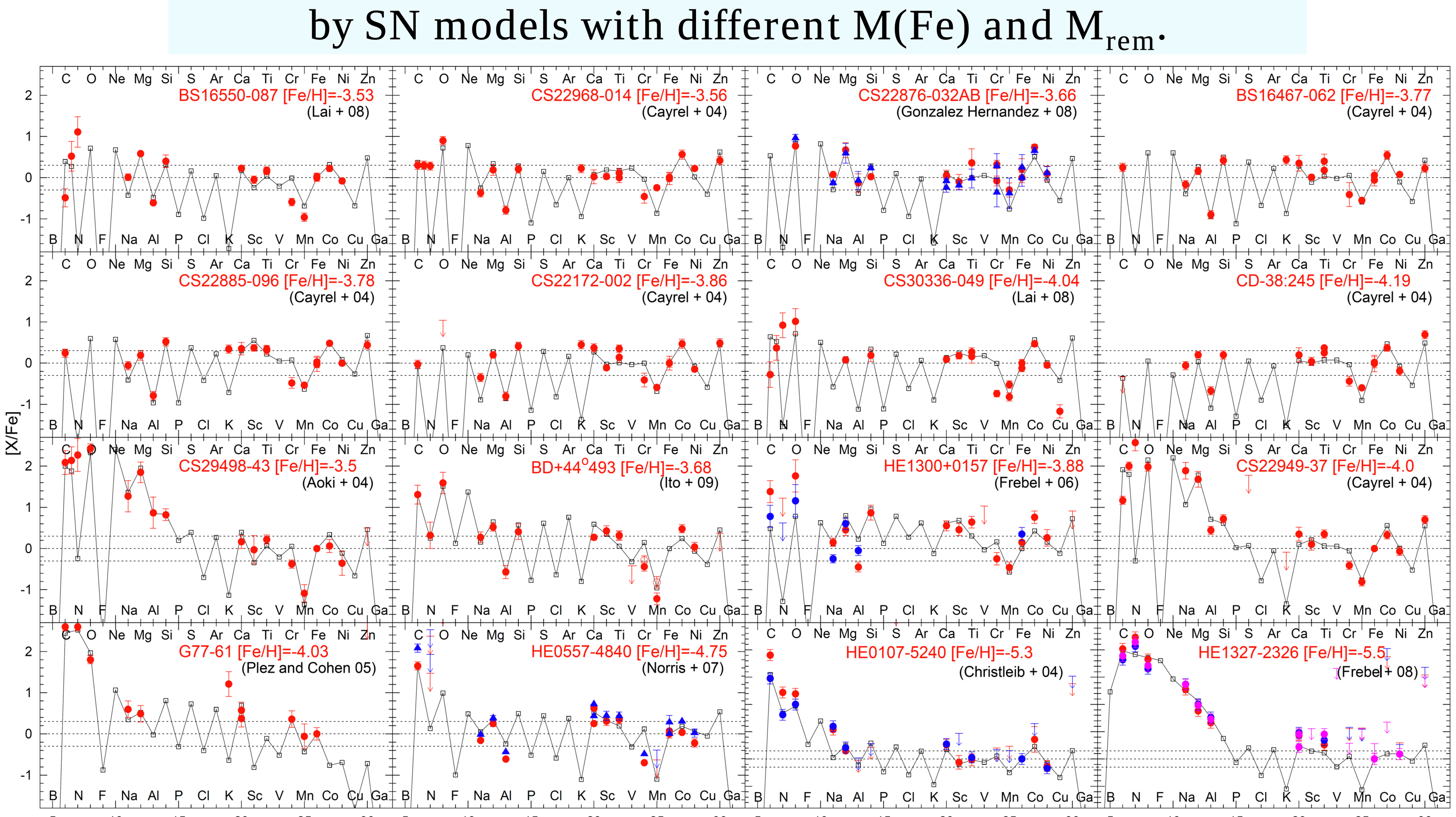
Dependence & abundance patterns



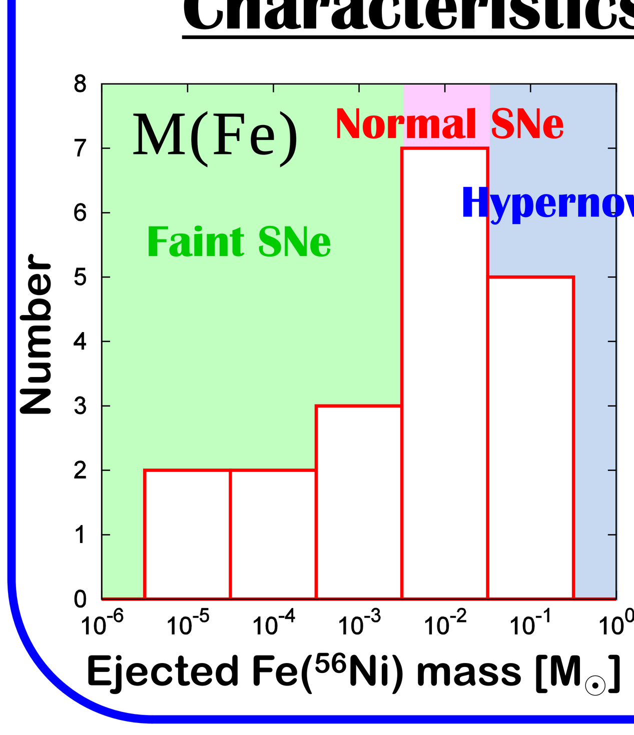


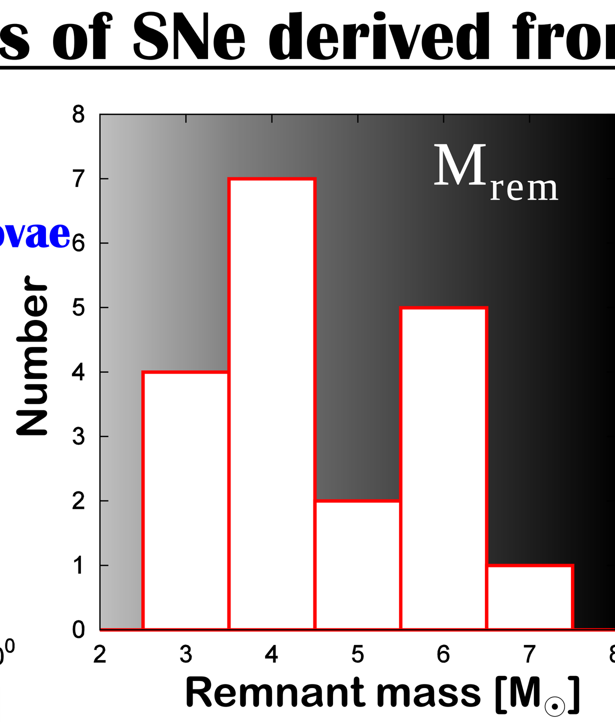
3. 17 EMP stars with [Fe/H]<-3.5

The abundance patterns of EMP stars are well reproduced by SN models with different M(Fe) and M_{rem}.



Characteristics of SNe derived from 17 EMP stars





EMP star surveys
SEGUE and Skymapper etc.

Large samples and SN modeling

Distributions of SN properties in the early universe