Supernova Nucleosynthesis

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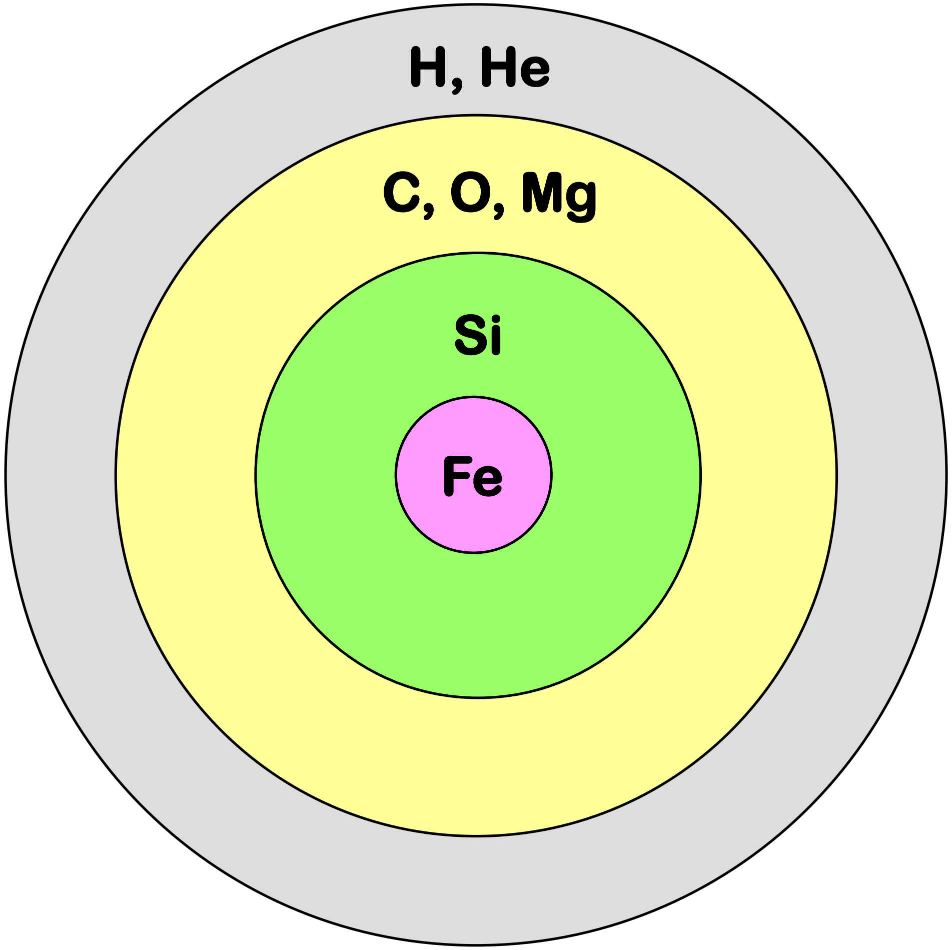
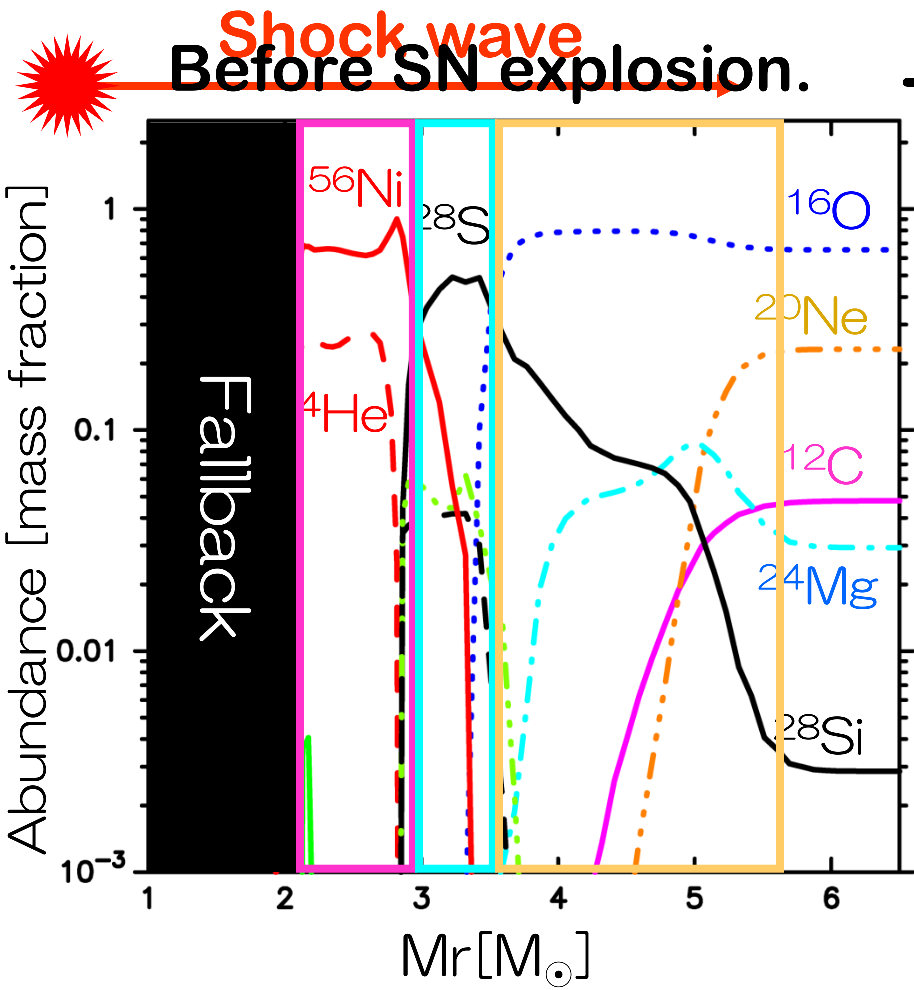
Final stage of massive stars

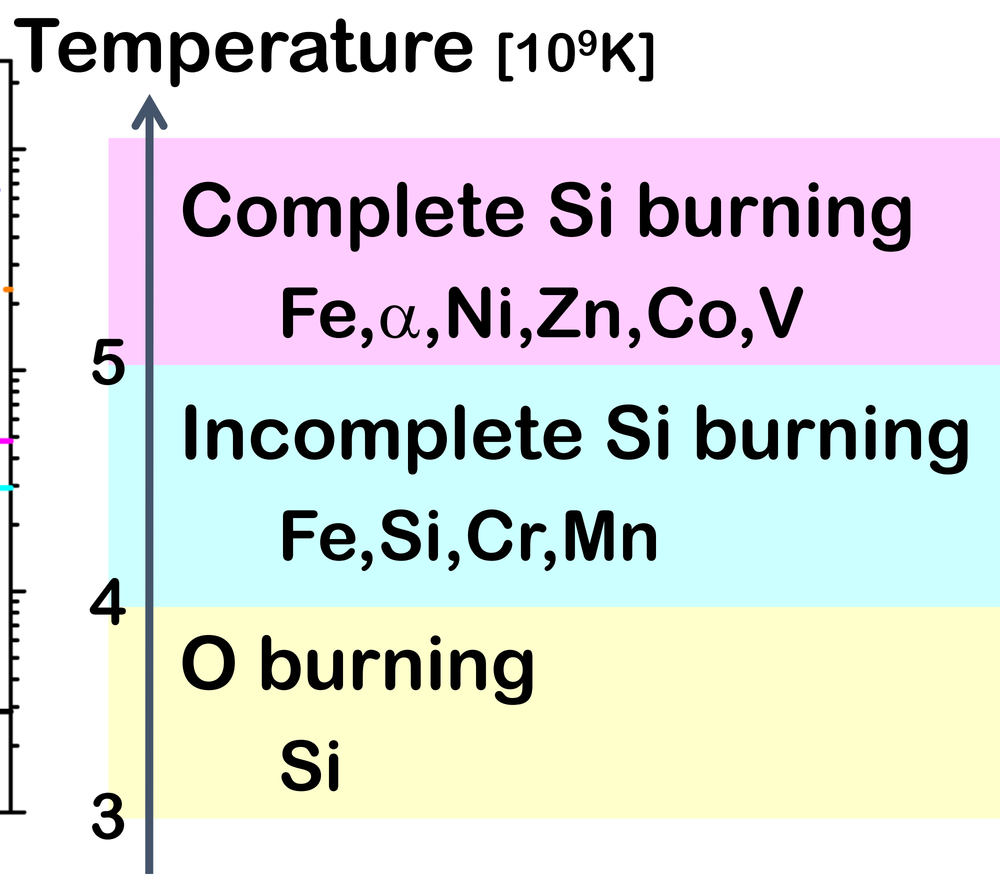


Hirschi-san's, Yoon-san's, and Yusof-san's talks

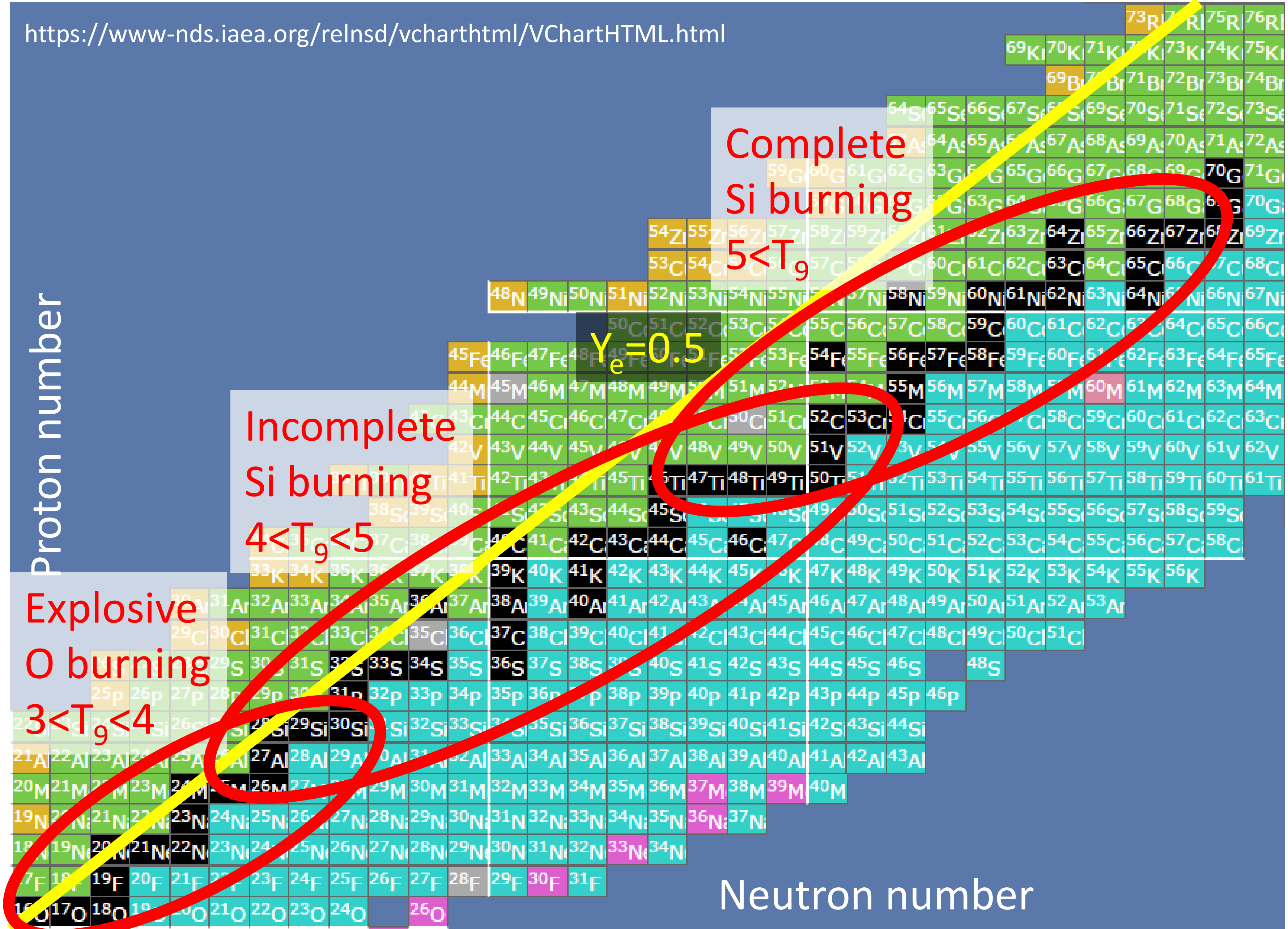
Explosive nucleosynthesis

Heavier elements are synthesized at higher T layer (i.e., in the inner layer).

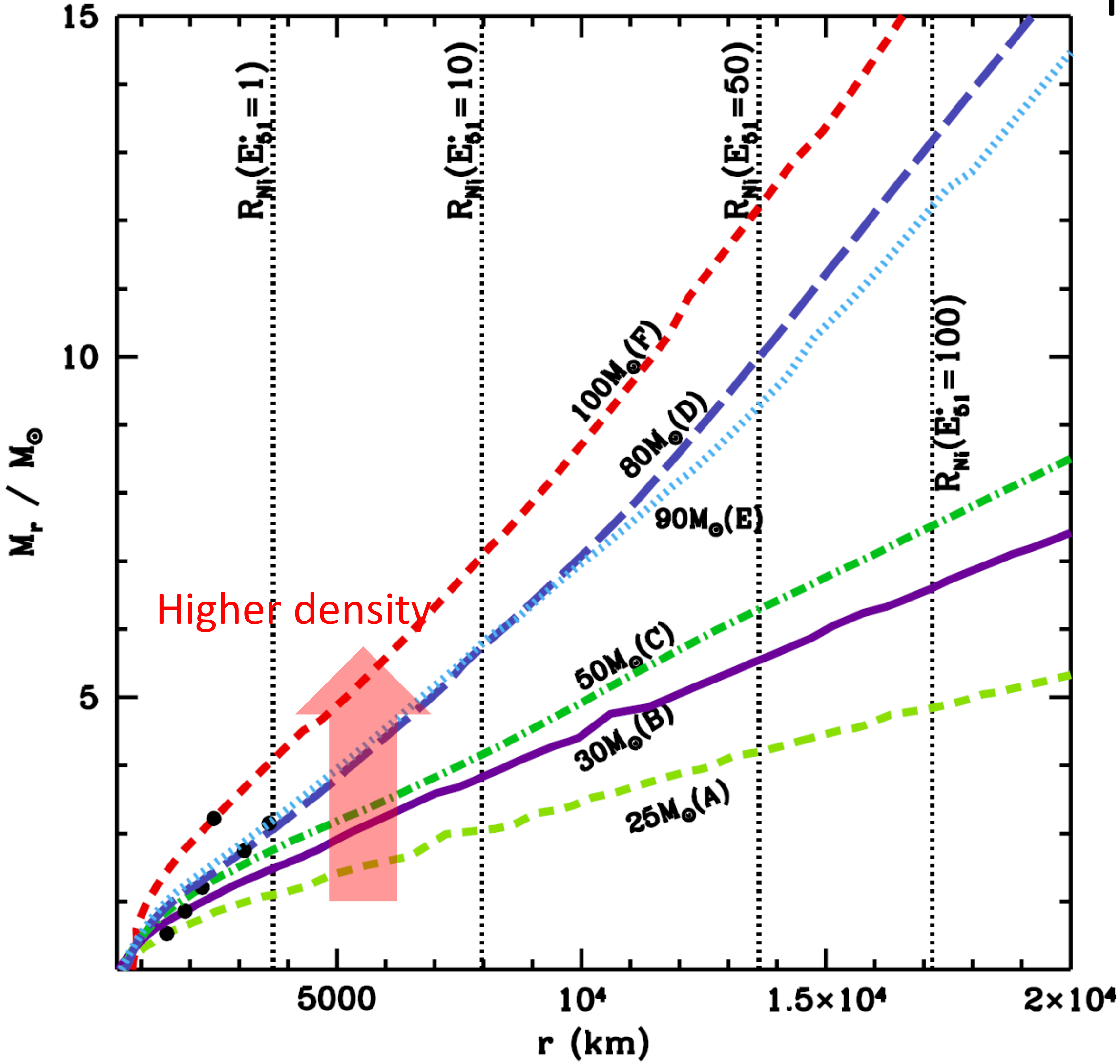




Nuclear chart -explosive burning-



Where explosive nucleosynthesis takes place?



Radiation dominated shock

$$E = E_K + E_B \sim 4\pi R^3 aT^4/3$$

E: explosion energy

E_K: final kinetic energy

E_B: binding energy

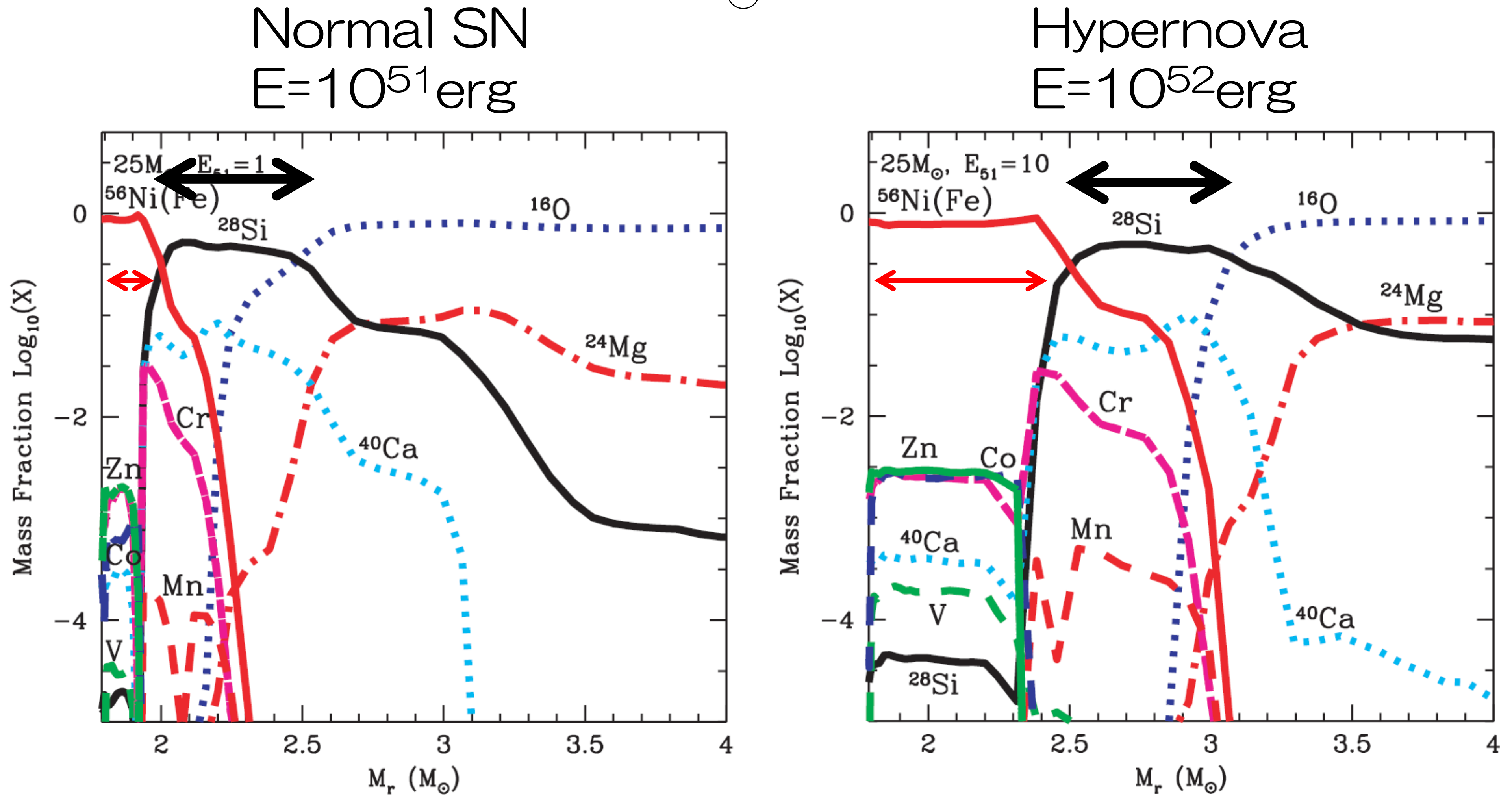
R: shock radius

$$R_{Ni} < 3700\text{km} \, (E/10^{51}\text{erg})^{1/3} \, (T/5\text{x}10^9\text{K})^{-4/3}$$

Umeda & Nomoto 2008

Difference due to explosion energy

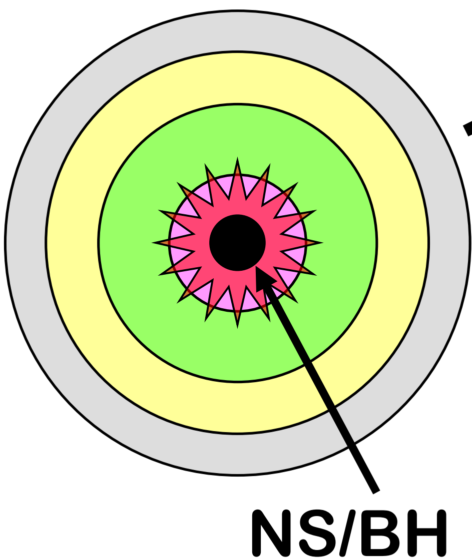
$25M_\odot$ model



Observational constraints

Core collapse

$(8M_\odot < M < 130M_\odot)$

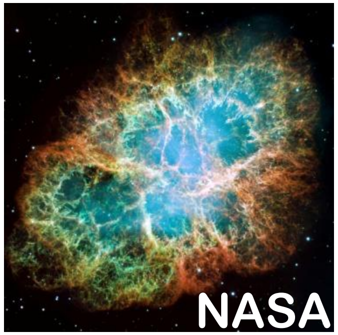


Supernovae

Light curve

Spectra

Polarization



SNR

Abundance

Central remnant

Next star

Abundance

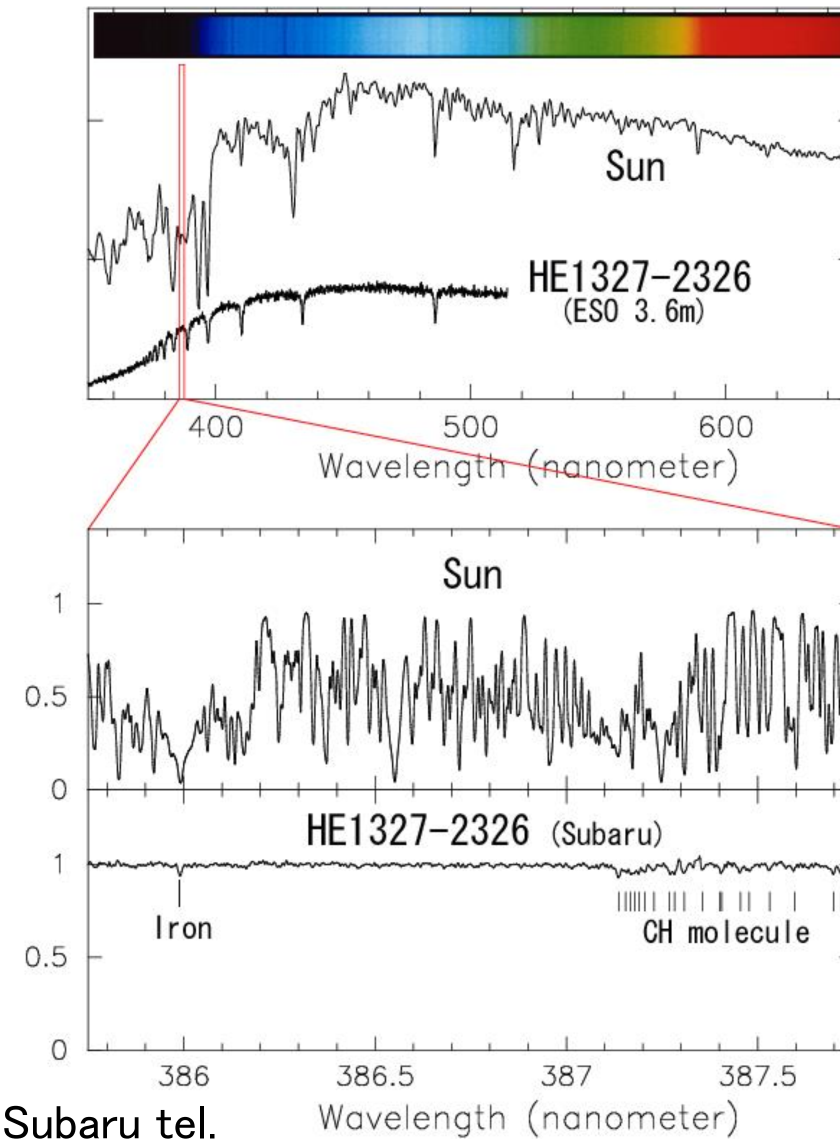
Velocity

Jerkstrand-san's talk

Next generation stars

In order to derive supernova properties, a star with small number of parent SNe is needed because features of each SN are diluted by other SNe.

Such stars are metal-poor stars formed in the early Universe.



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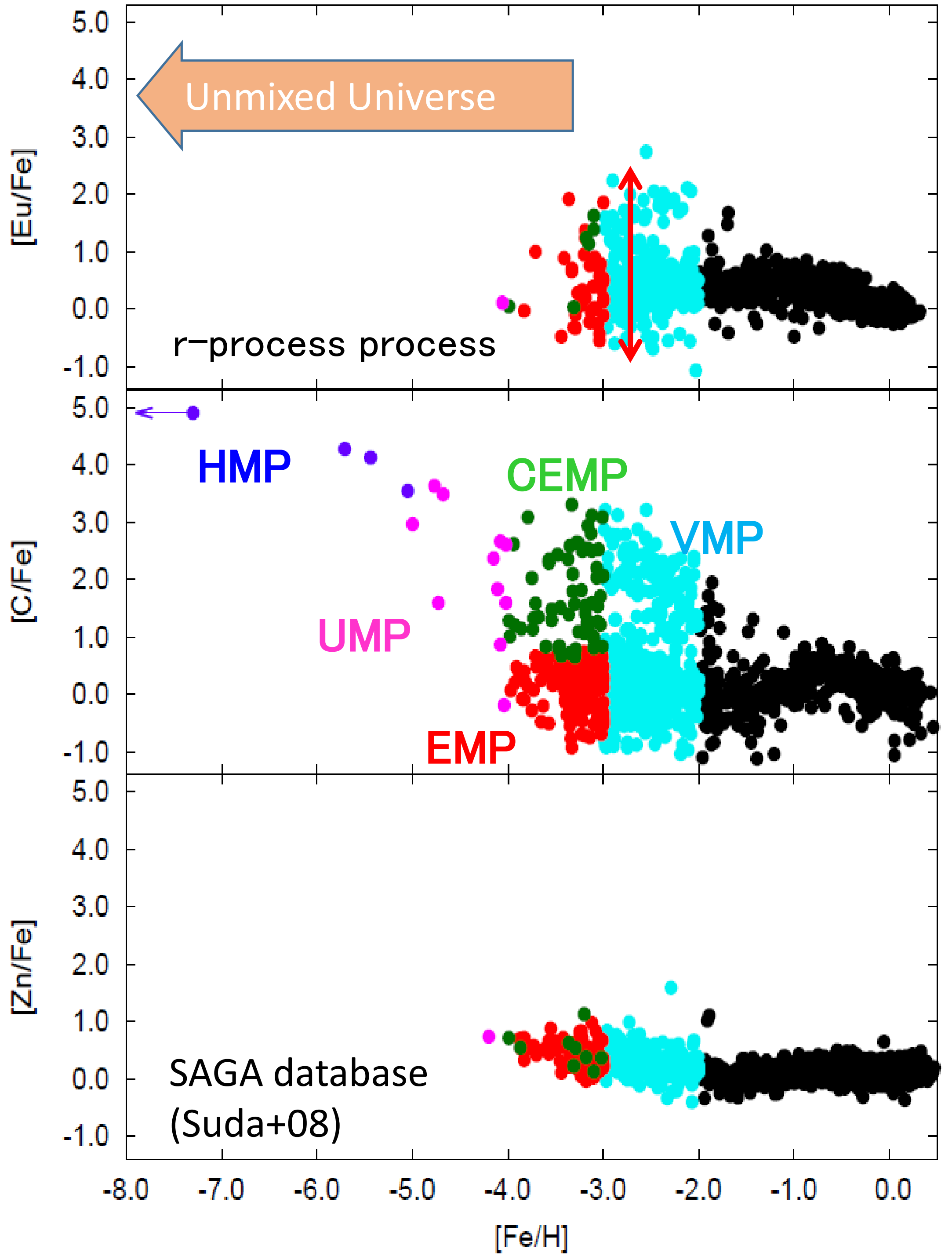
Beers-san's and Aoki-san's talks

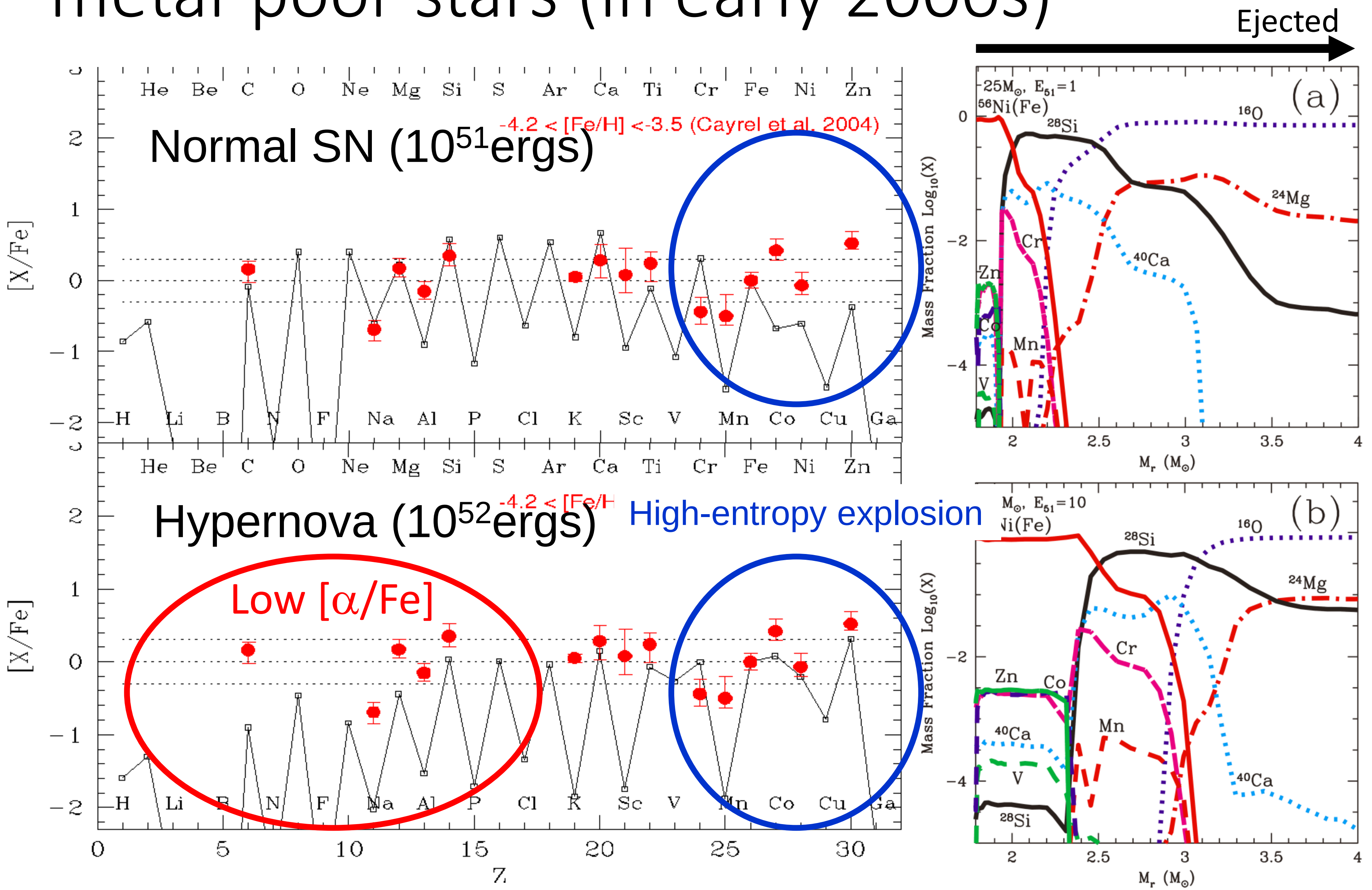
Metal-poor stars

[Fe/H]<−5
Hyper Metal−Poor (HMP)
[Fe/H]<−4
Ultra Metal−Poor (UMP)
[Fe/H]<−3
Extremely Metal−Poor (EMP)
[Fe/H]<−2
Very Metal−poor (VMP)
(Beers & Christlieb 05)



Single/a few SNe contributed to the EMP stars (e.g., Tumlinson 06)

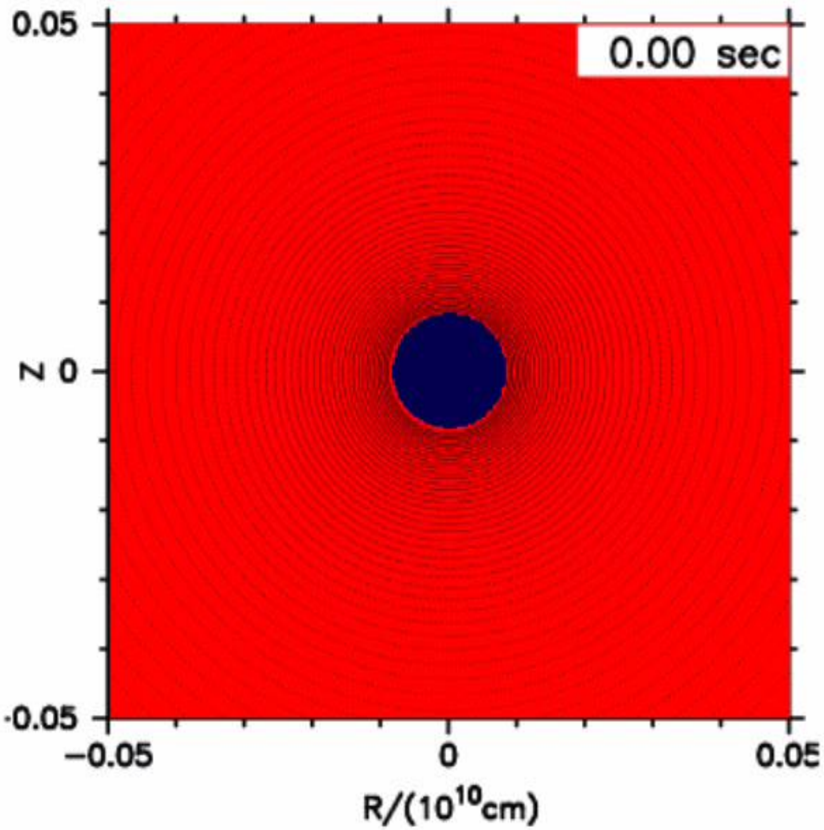
Spherical explosions cannot explain metal-poor stars (in early 2000s)

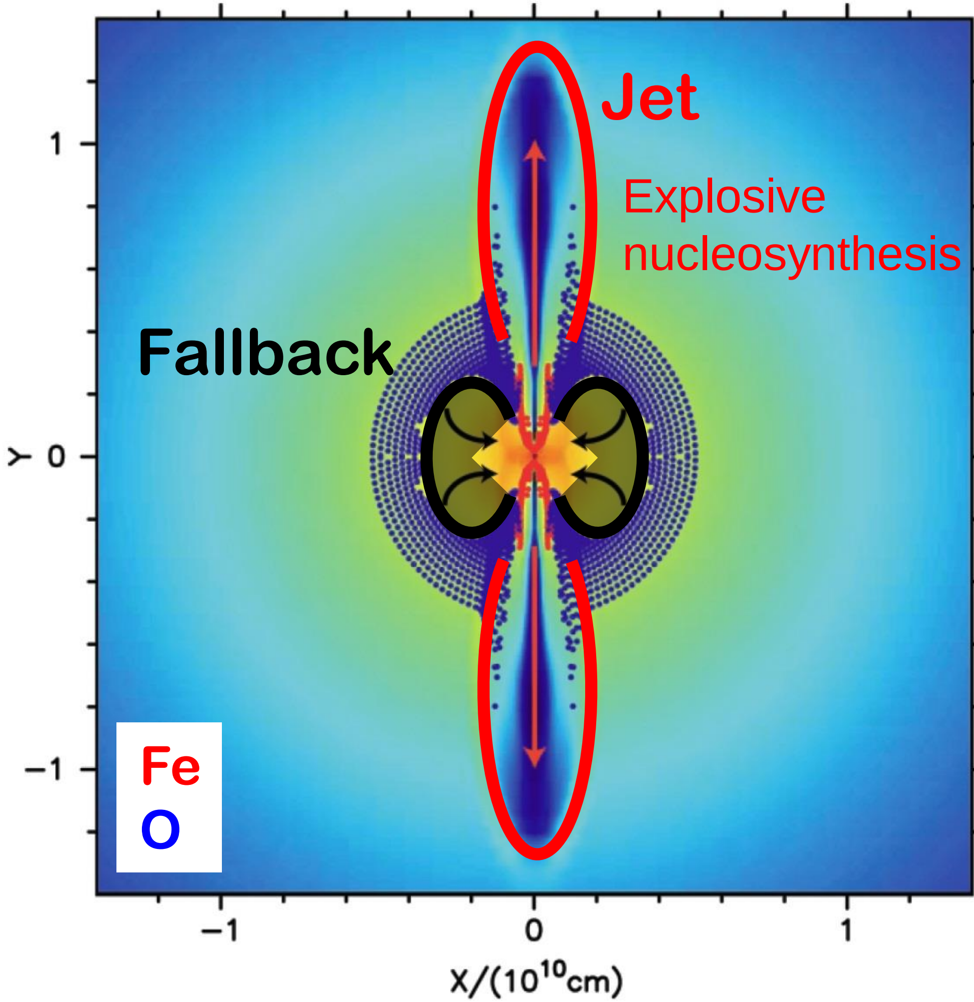


Explosive nucleosynthesis in aspherical explosions

M_{ms}=40$M_\odot$, Z=0

E=1.5x10^{52}erg





NT+07;NT09

Abundance patterns are well reproduced.

EMP stars

$\dot{E}_{dep}$=30x10[51]erg/s

M([56]Ni)~0.1$M_\odot$

CEMP stars

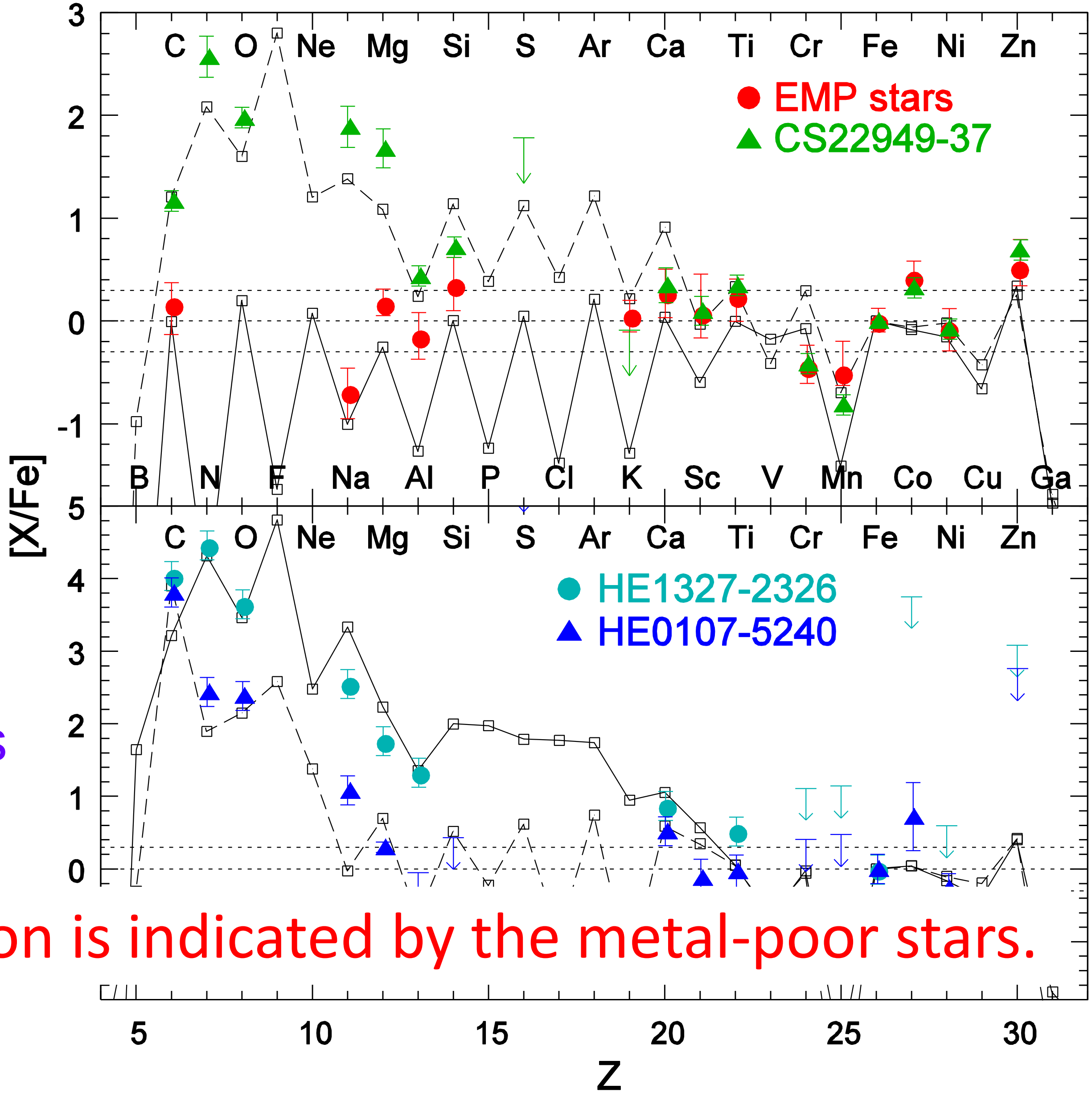
$\dot{E}_{dep}$=3x10[51]erg/s

M([56]Ni)~8x10[-4]$M_\odot$

HMP stars

$\dot{E}_{dep}$=0.5-1.5x10[51]erg/s

M([56]Ni)~3-4x10[-6]$M_\odot$

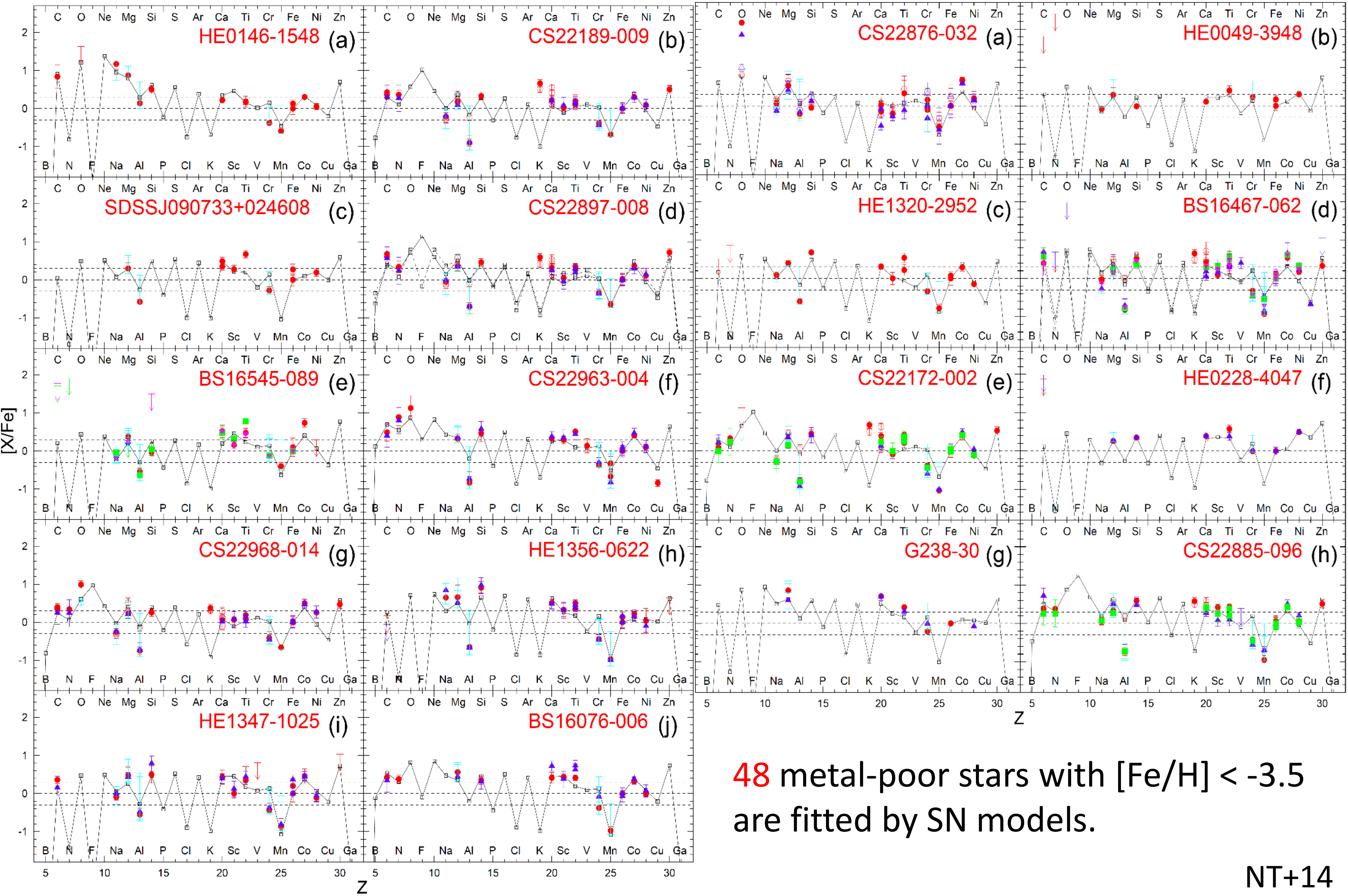


Aspherical explosion is indicated by the metal-poor stars.

NT+07

Application as a clue of the early Universe

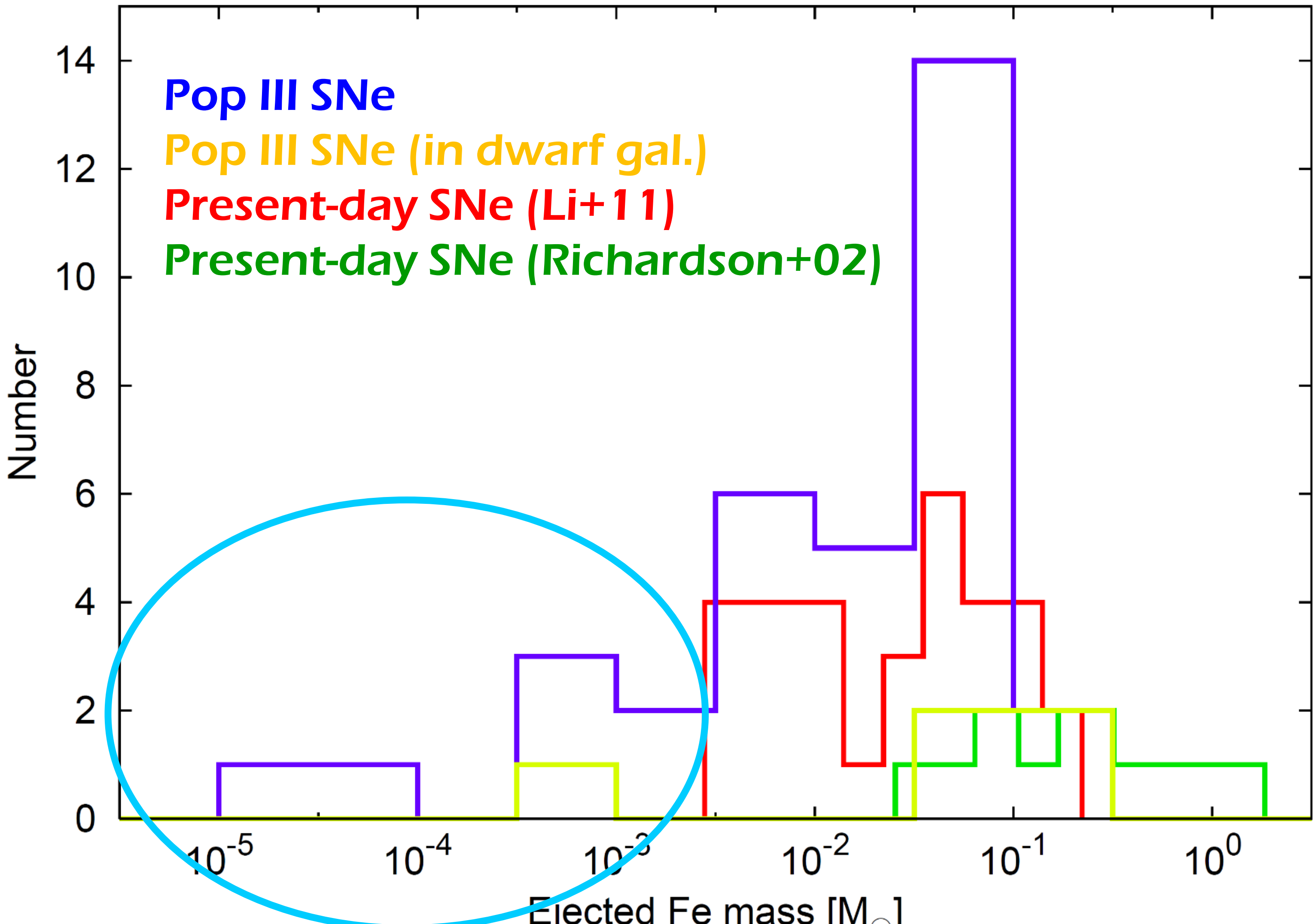
Metal-poor stars tell us SNe in the early Universe



48 metal-poor stars with [Fe/H] < -3.5 are fitted by SN models.

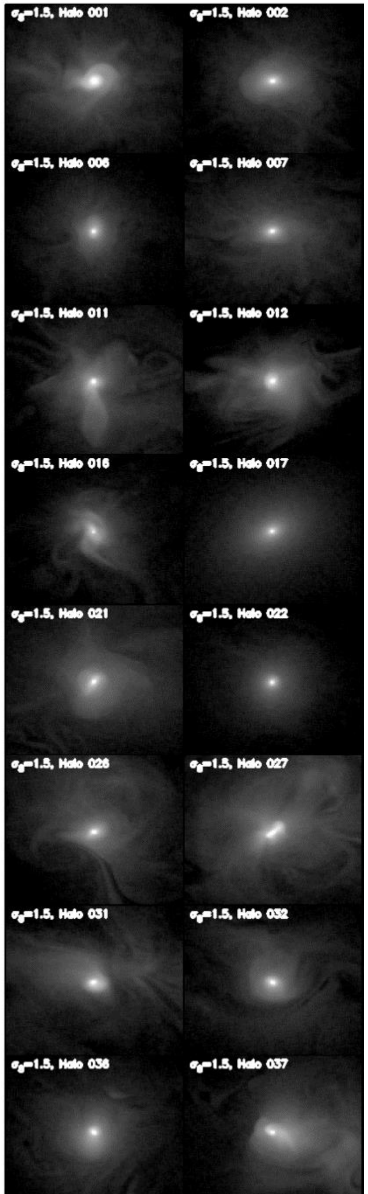
NT+14

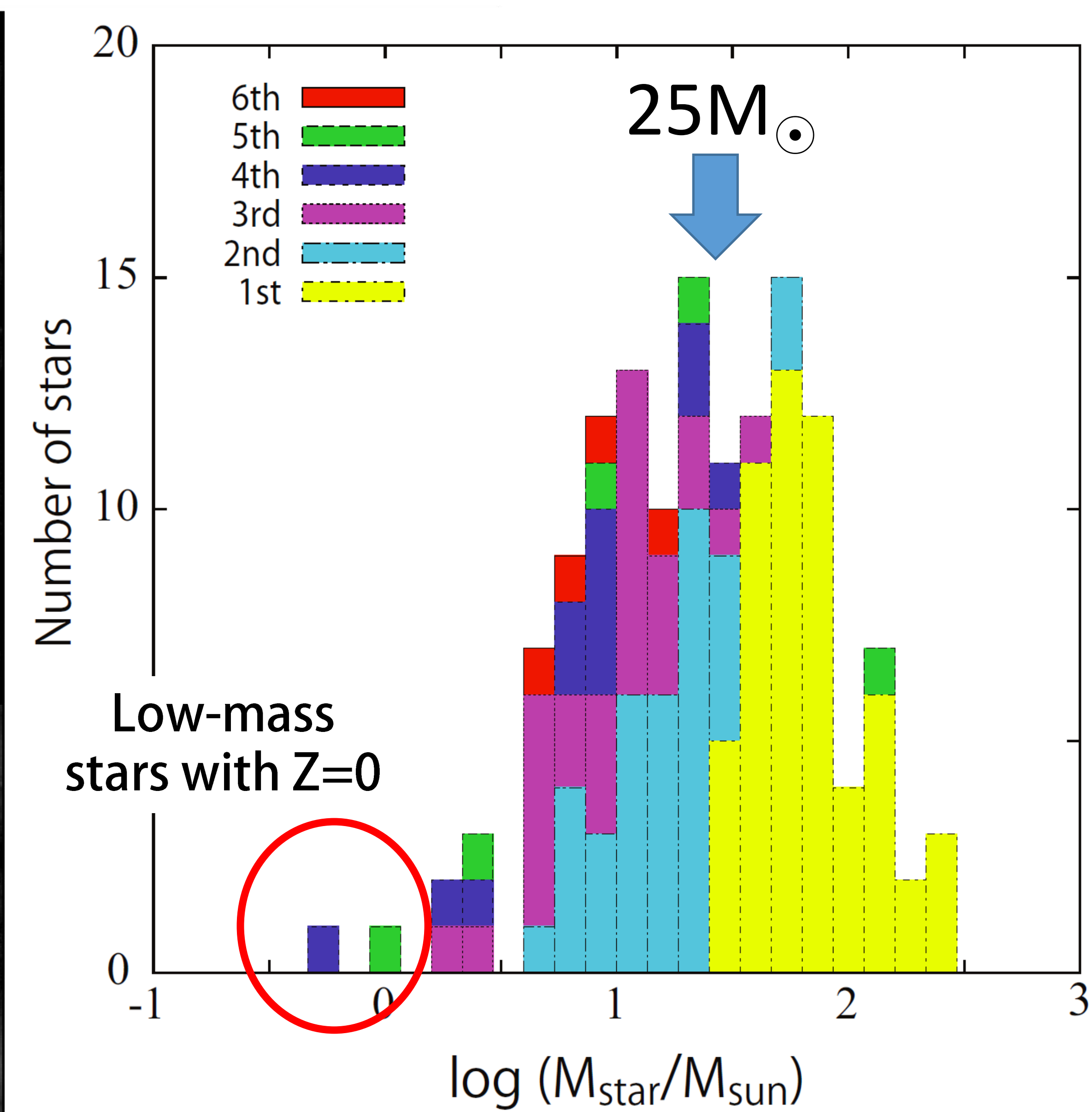
Ejected Fe mass
- Pop III SNe vs. present-day SNe -



NT+14

IMF from cosmological and local simulations





Summary

- Explosive nucleosynthesis produces Fe-peak elements.
- Nucleosynthetic signatures are clue to constrain properties of supernovae by comparing with observations.
- Aspherical explosions are indicated by EMP stars.
- Initial mass function of Pop III stars and properties of Pop III SNe are constrained.