Supernova nucleosynthesis and extremely metal-poor stars

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A Celebration of CEMP and a Gala of GALAH

Contents

- Metal enrichment by mass accretion from ISM
- Aspherical explosions as origins of EMP stars
- Origin of Carbon enhancement in CEMP-no stars

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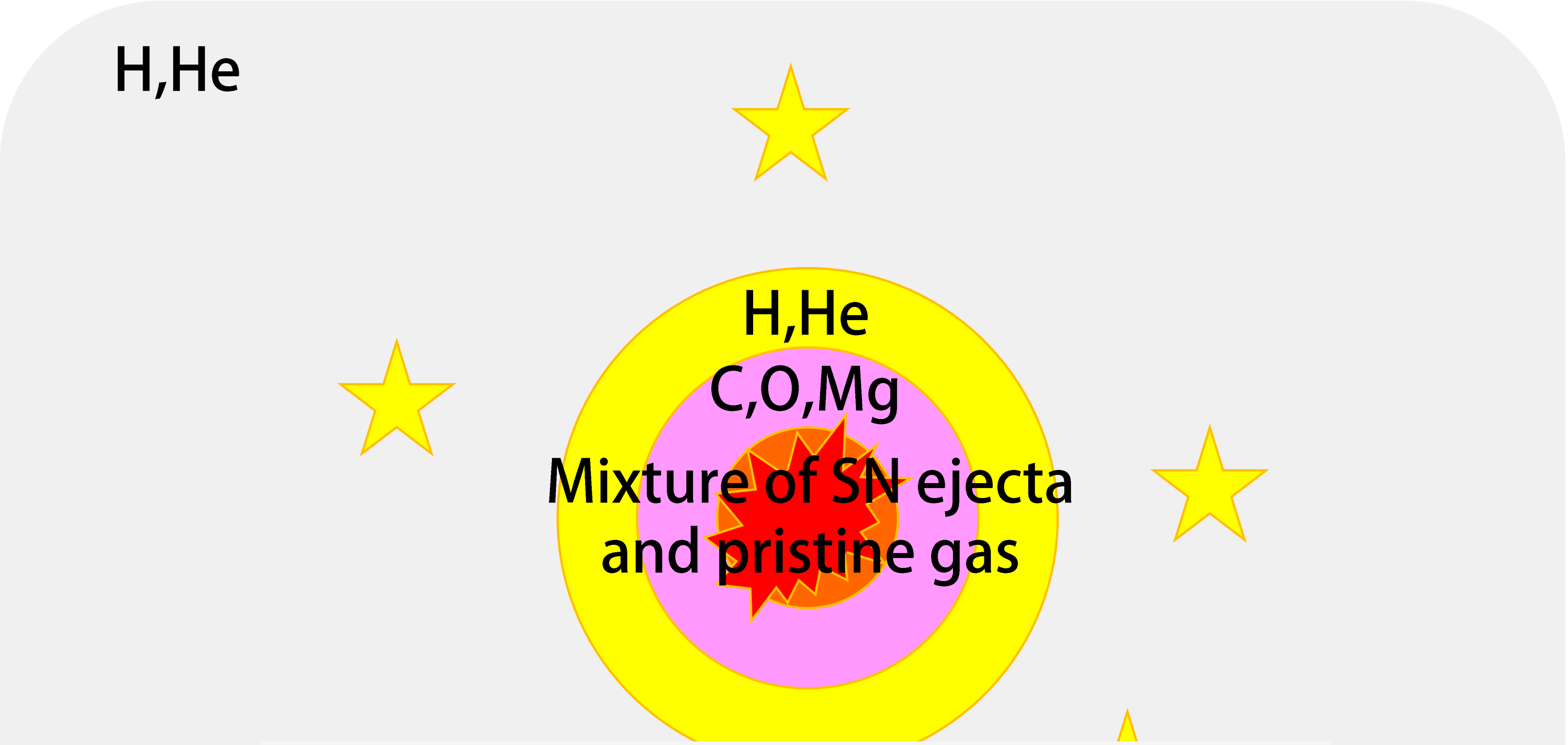
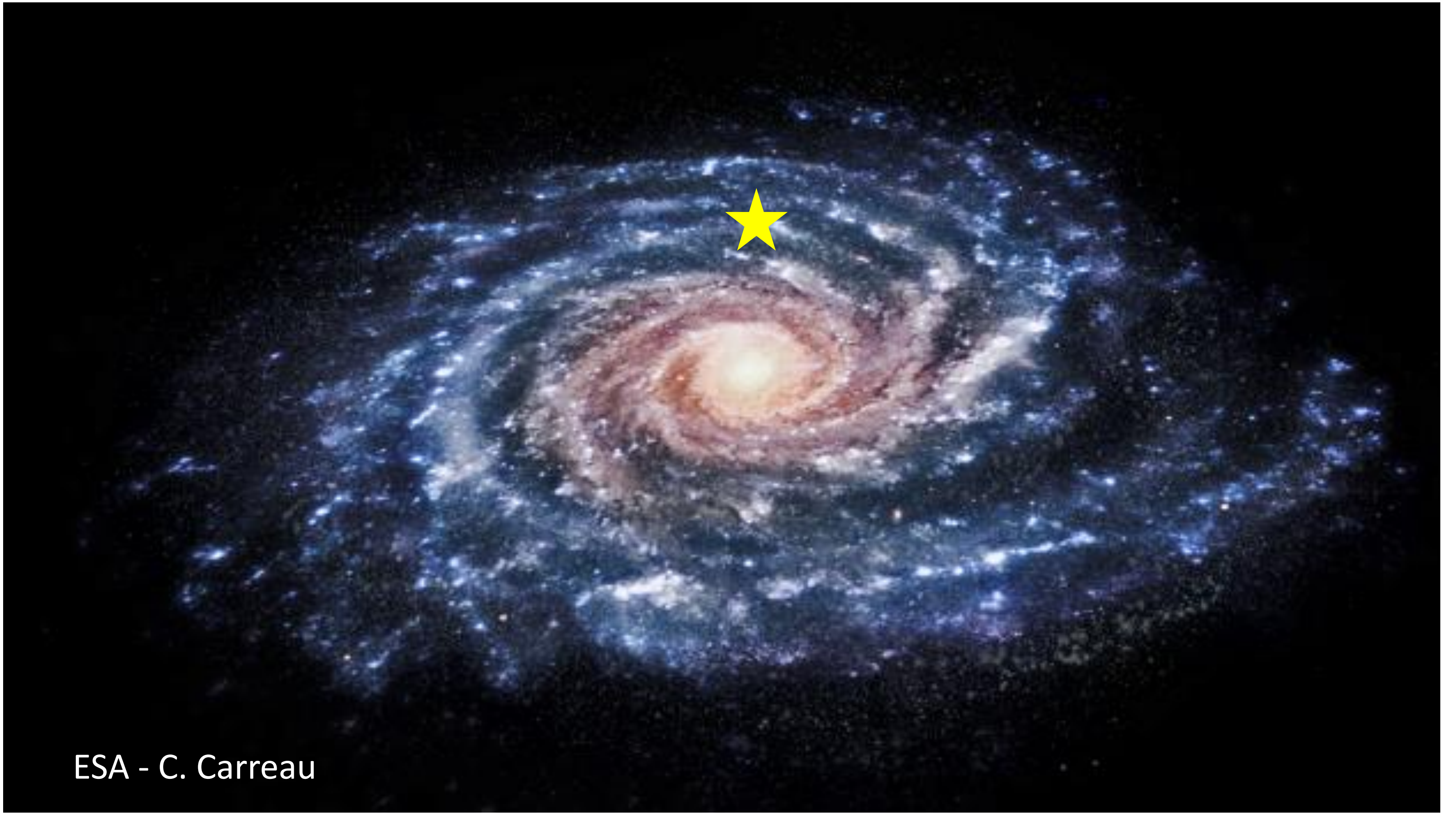
First chemical enrichment

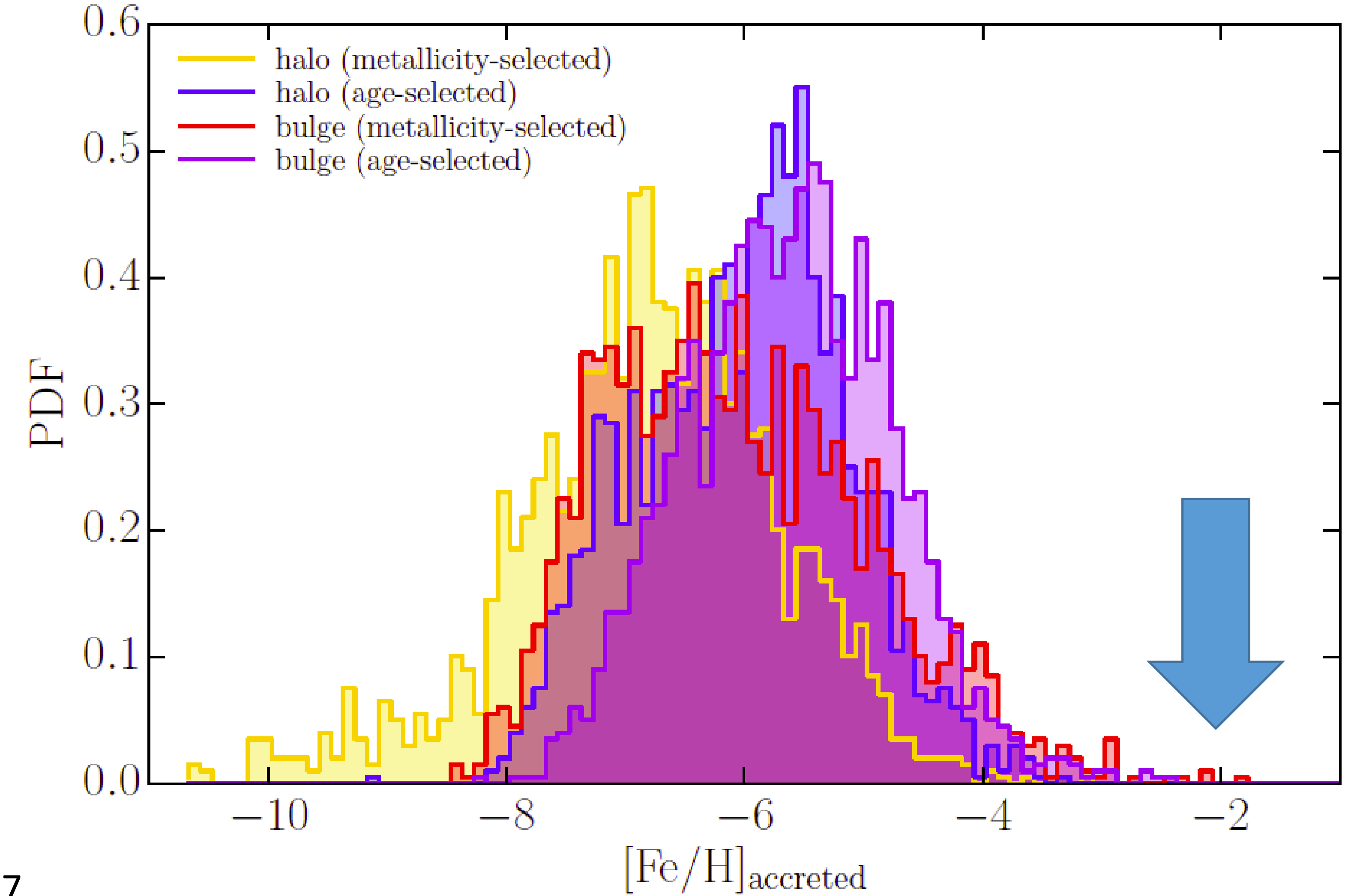


The abundance patterns of the EMP stars possess information on properties of Population III supernovae.

Metal-poor stars preserve their initial abundance patterns?



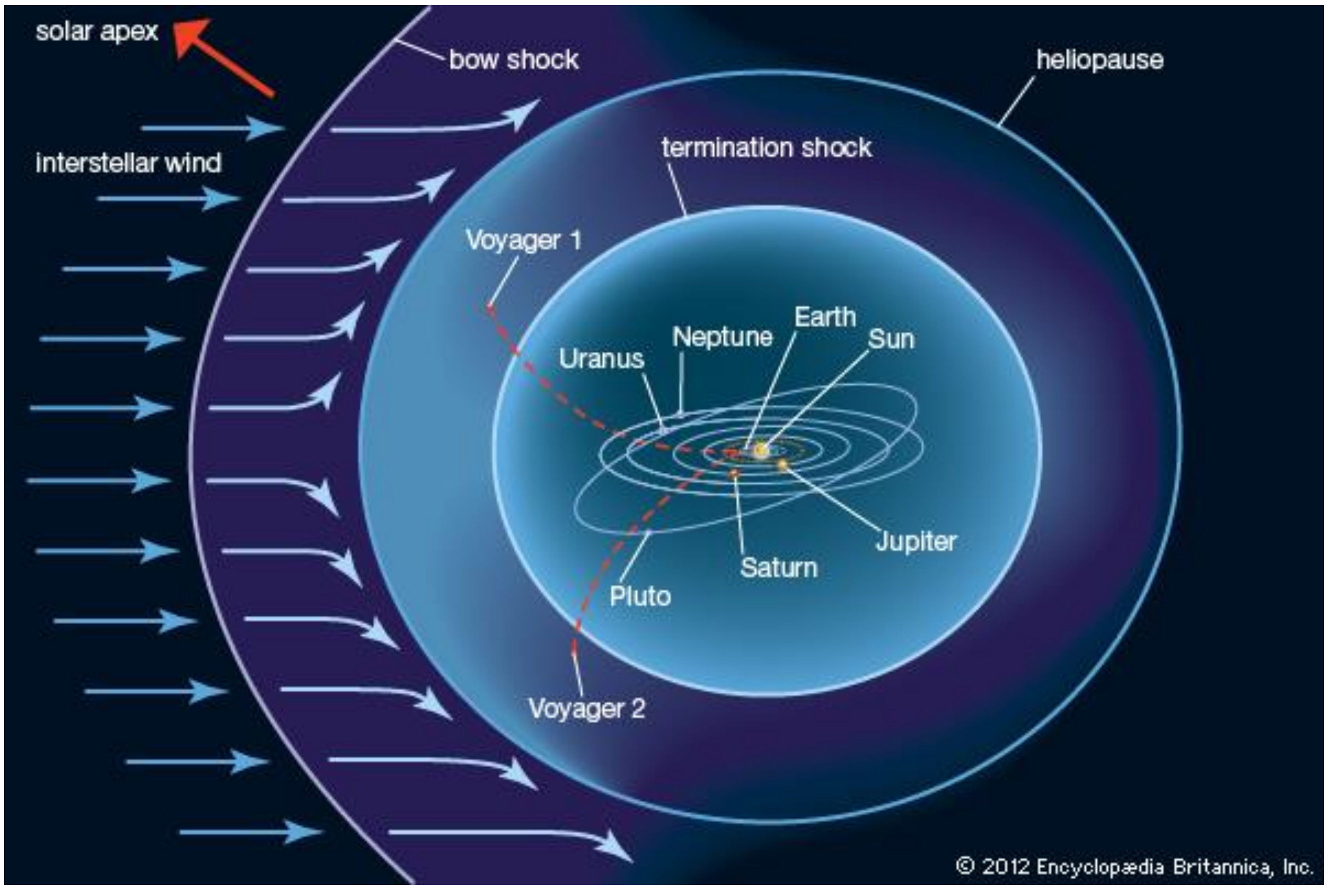
Bondi-Hoyle-Lyttleton accretion could enhance [Fe/H] up to -2



Shen+17

However, the estimate does not include stellar wind from EMP stars.

- Sun has a heliosphere blocking the ISM wind.



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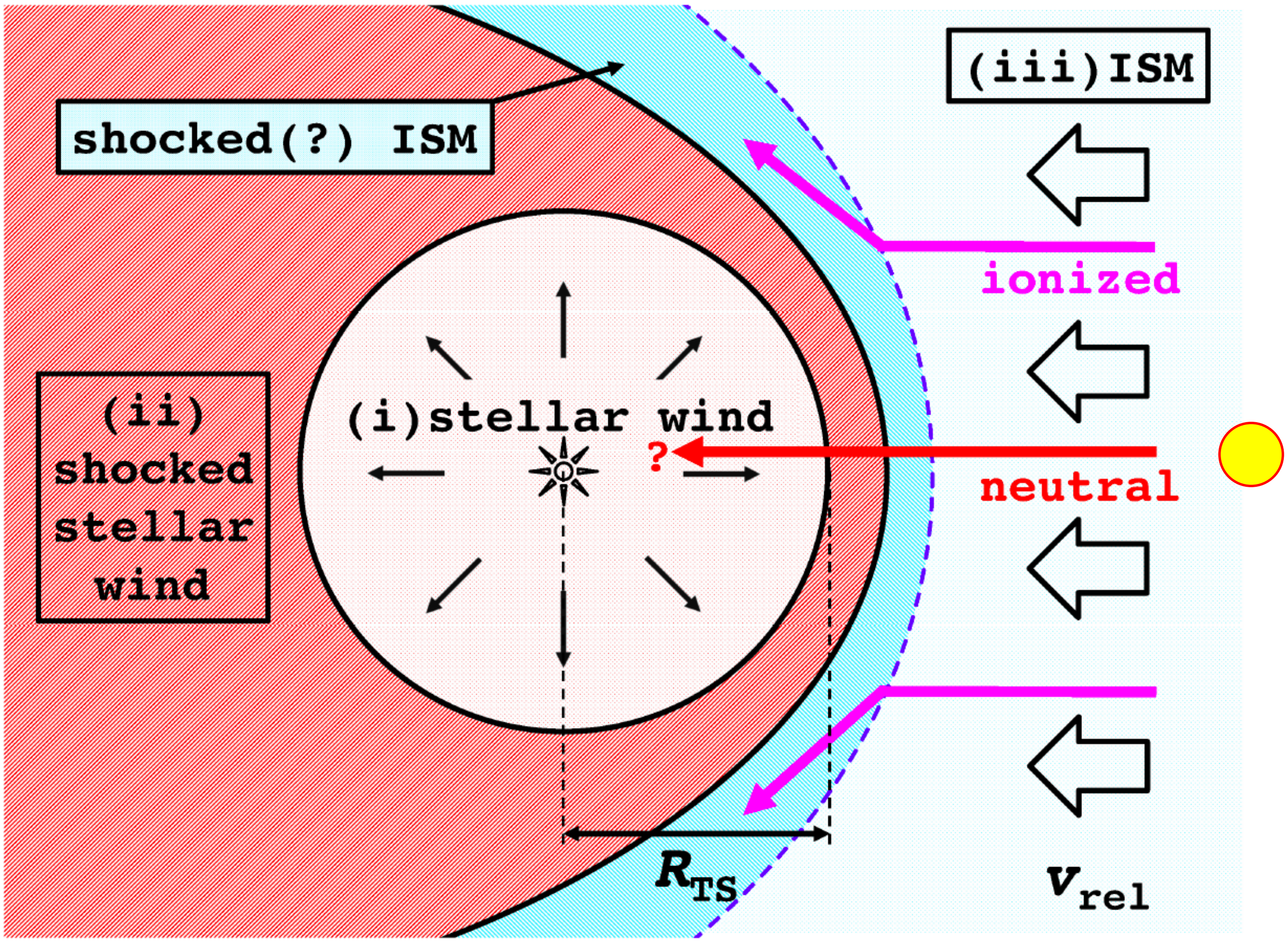
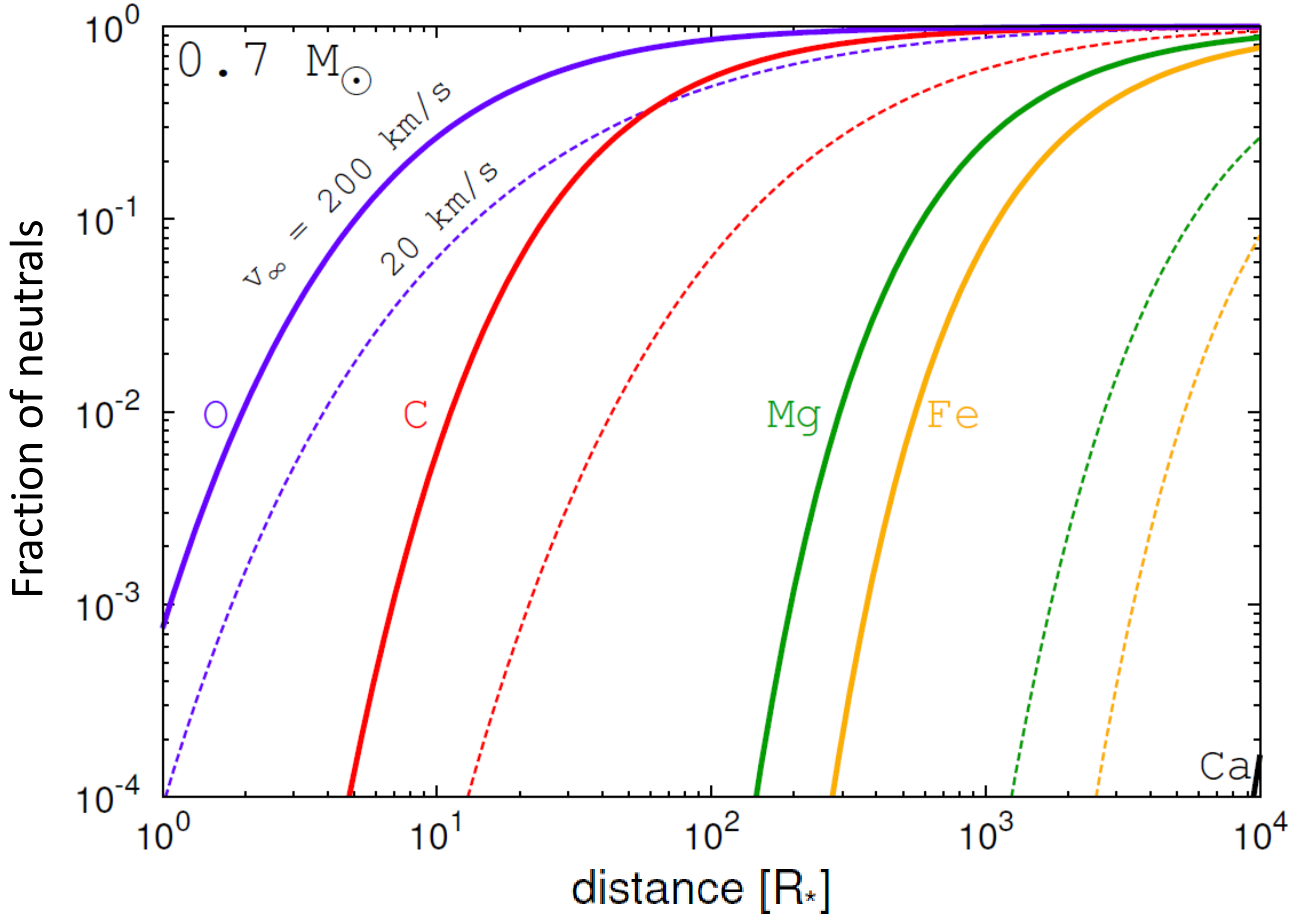


Tanaka, Chiaki, NT, & Susa 17

Photoionization considerably reduces the number of neutrals.



Most of metals cannot reach the stellar surface.

Surface pollution by ISM accretion is negligible.

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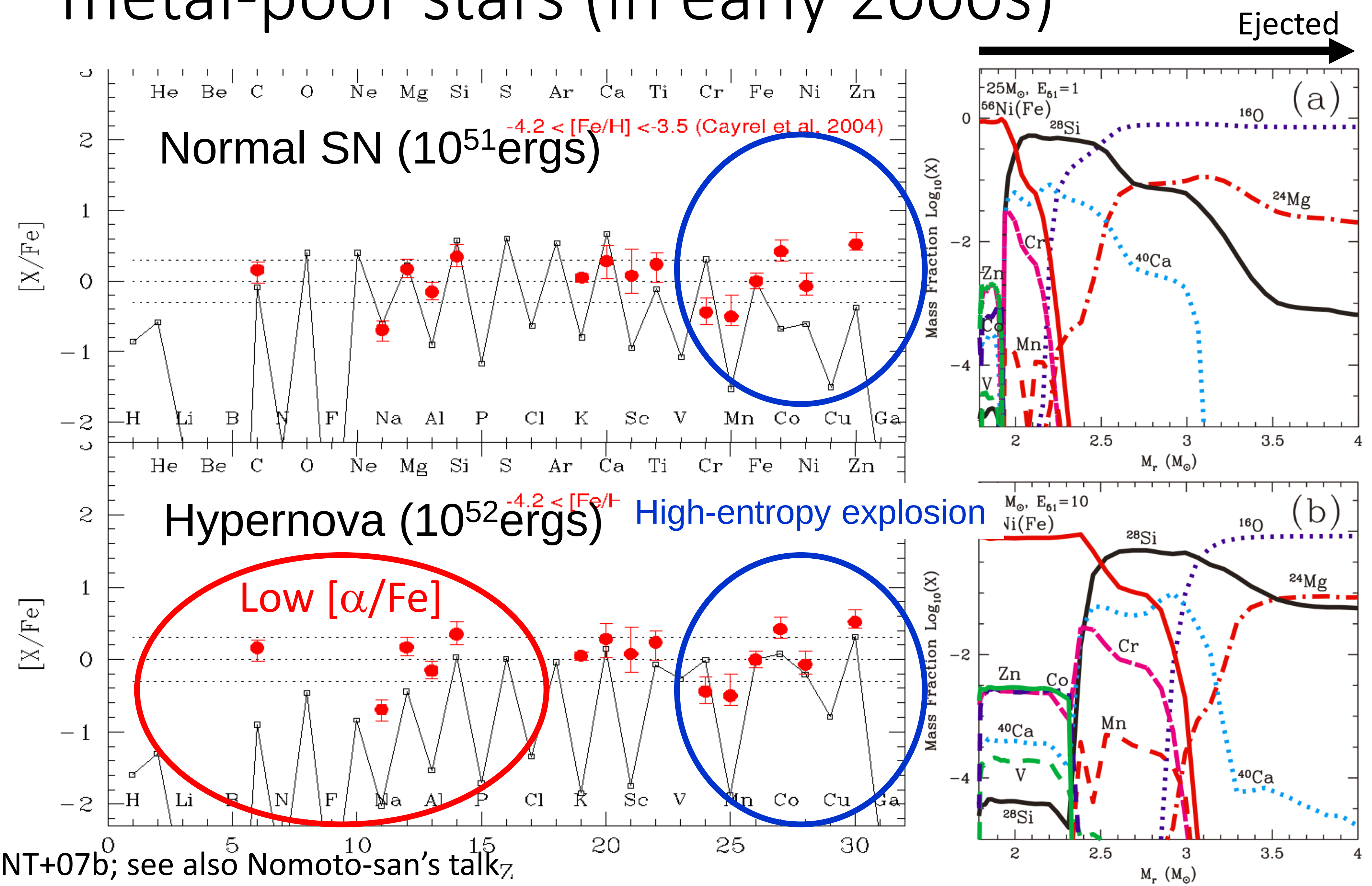
Spherical explosions cannot explain metal-poor stars (in early 2000s)

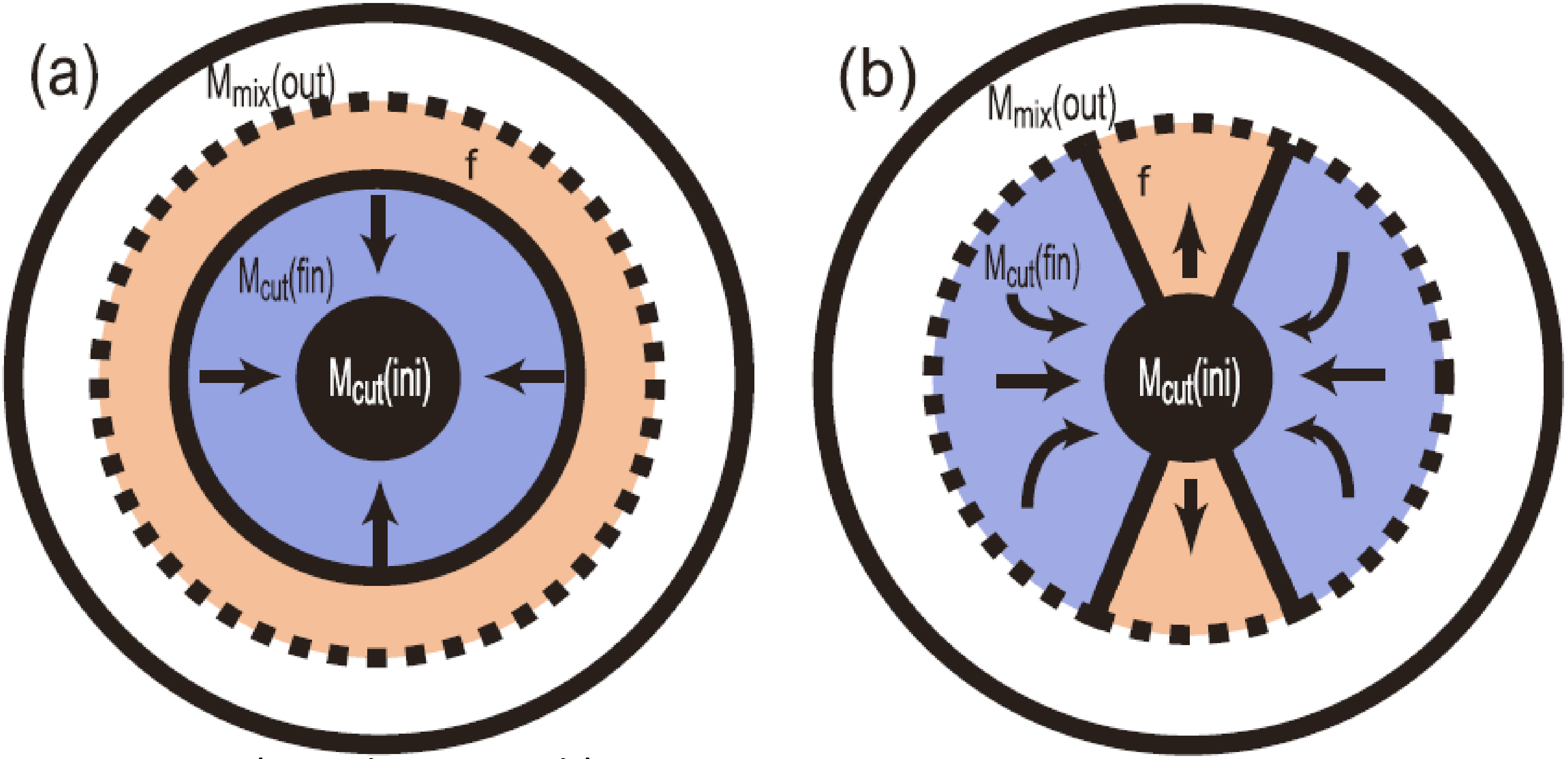


NT+07b; see also Nomoto-san's talk

Mixing-fallback model

- A parametric model mimics an aspherical explosion due to (a) the Rayleigh-Taylor mixing or (b) jet explosion.

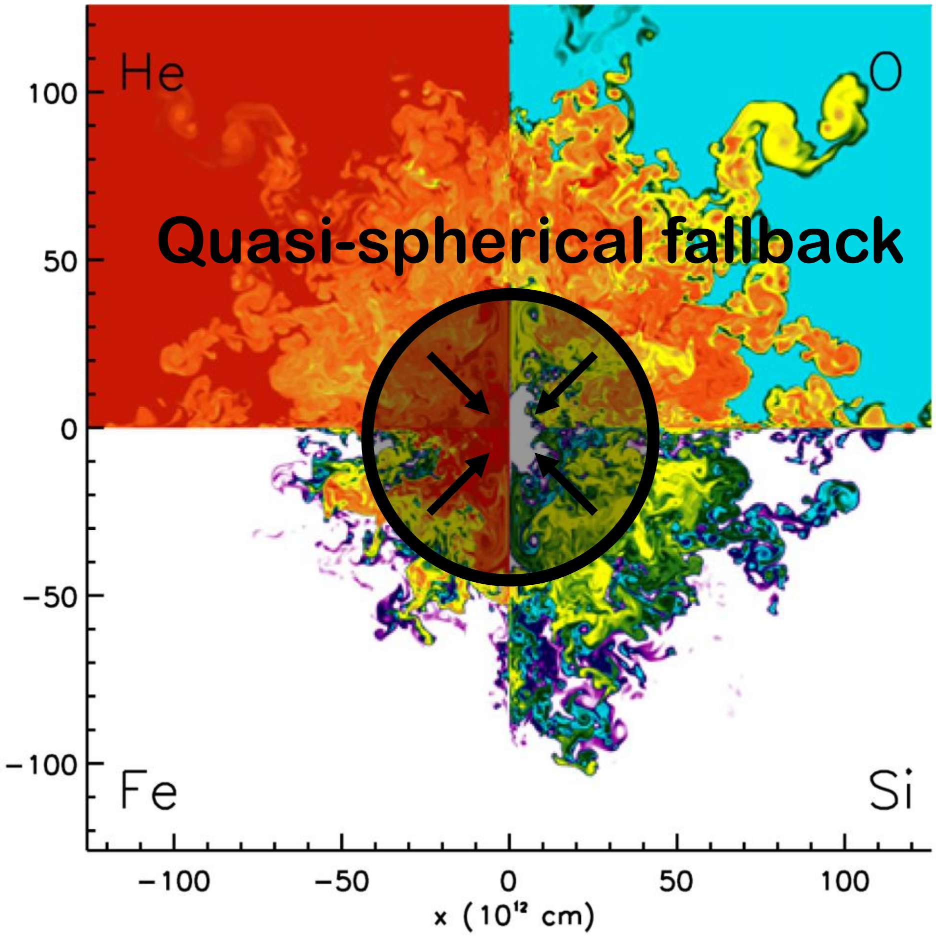
$$M_{\rm cut}({\rm fin}) = M_{\rm cut}({\rm ini}) + (1-f)[M_{\rm mix}({\rm out}) - M_{\rm cut}({\rm ini})]$$



Umeda & Nomoto 02 (see also NT+07b)

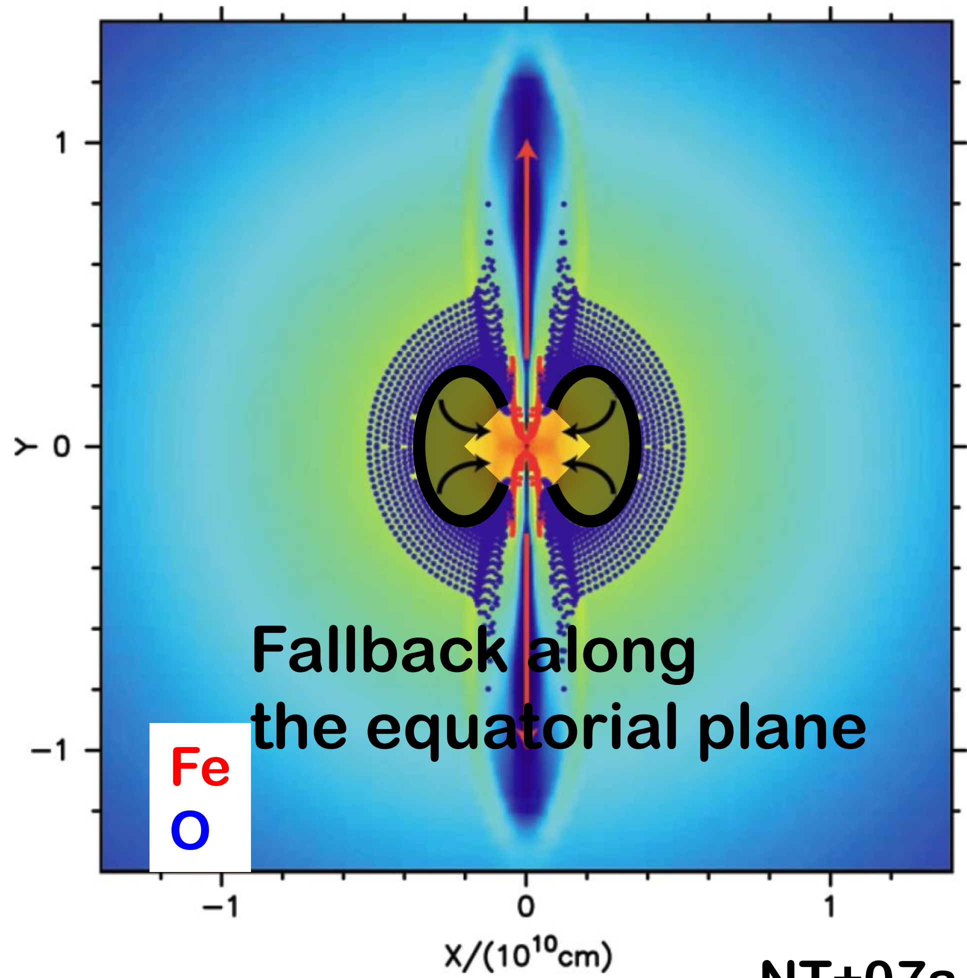
Simulation of mixing-fallback

Rayleigh-Taylor instability



Joggerst+10

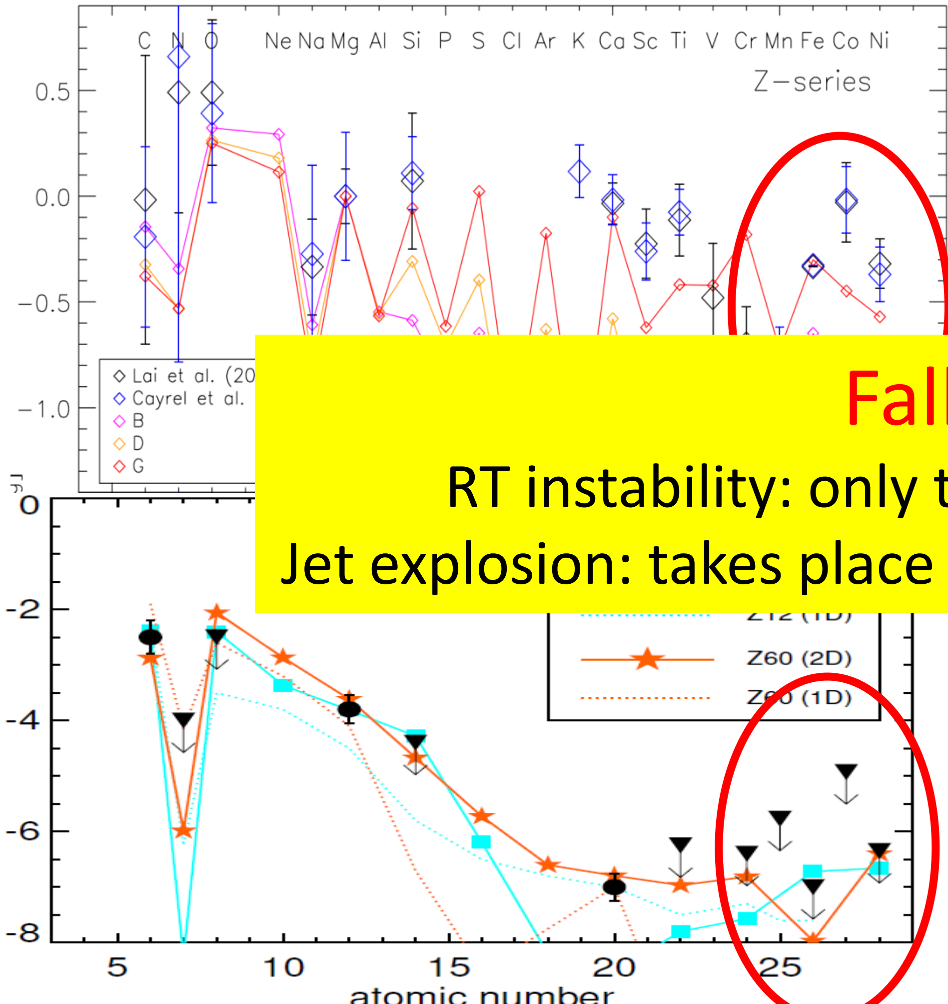
Jet-explosion



NT+07a

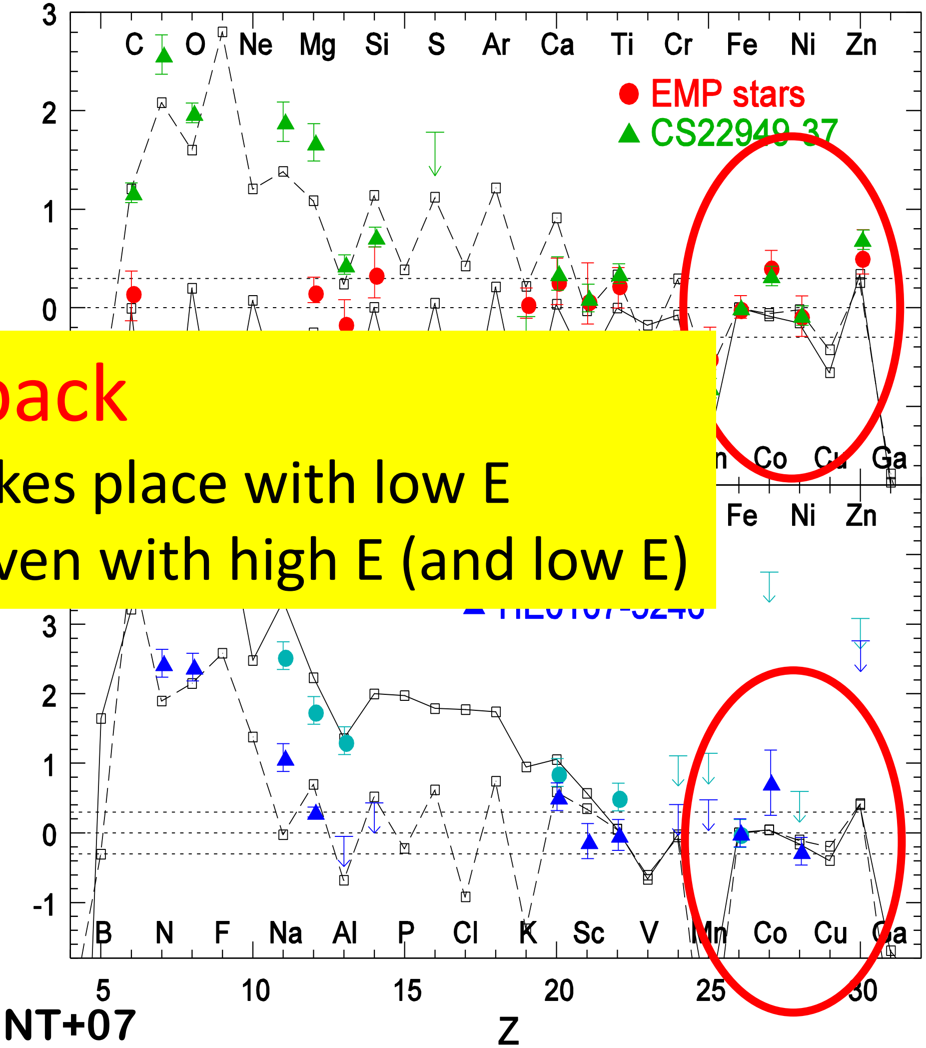
Nucleosynthesis yields

Rayleigh-Taylor instability



Joggerst+10; Chen+17

Jet explosion



NT+07

Fallback

RT instability: only takes place with low E

Jet explosion: takes place even with high E (and low E)

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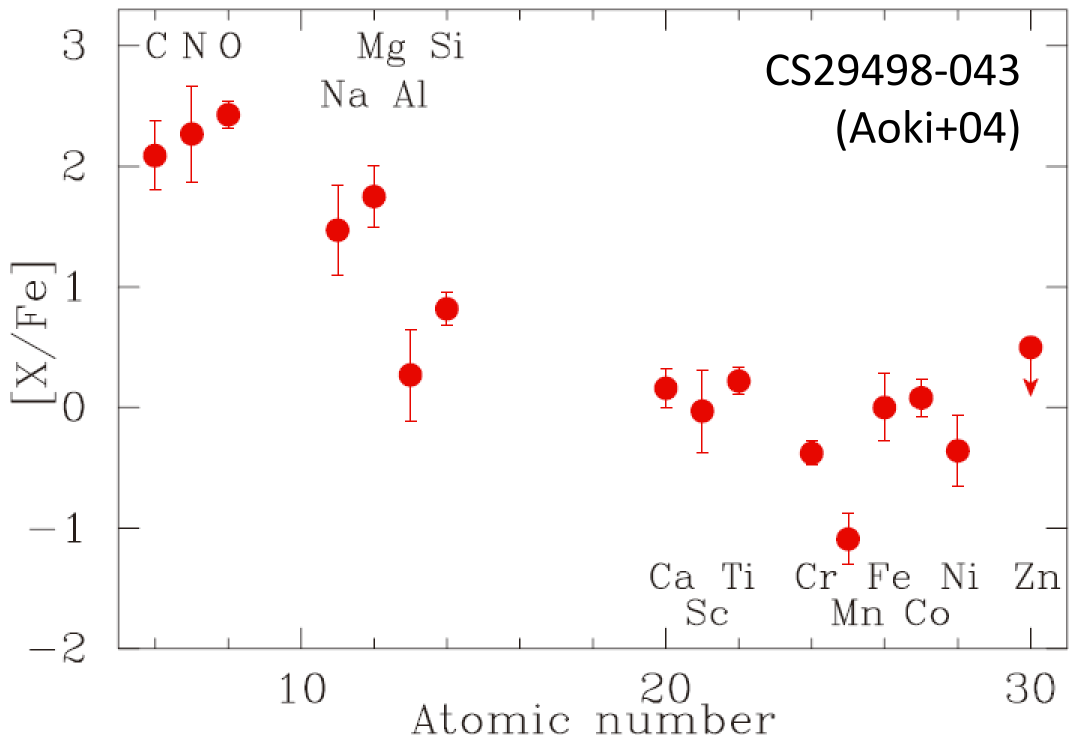
Origin of Carbon enhancement

- CEMP-s star
  - Binary: Mass transfer from AGB companion
  - Single star: Explosion of a massive rotator
- CEMP-no star
  - Faint SN (RT instability or jet explosion)
    (e.g., Joggerst+10; Chen+17; NT+07; NT09;)
  - Mass loss from massive rotator (spinstar) (e.g., Meynet+06)

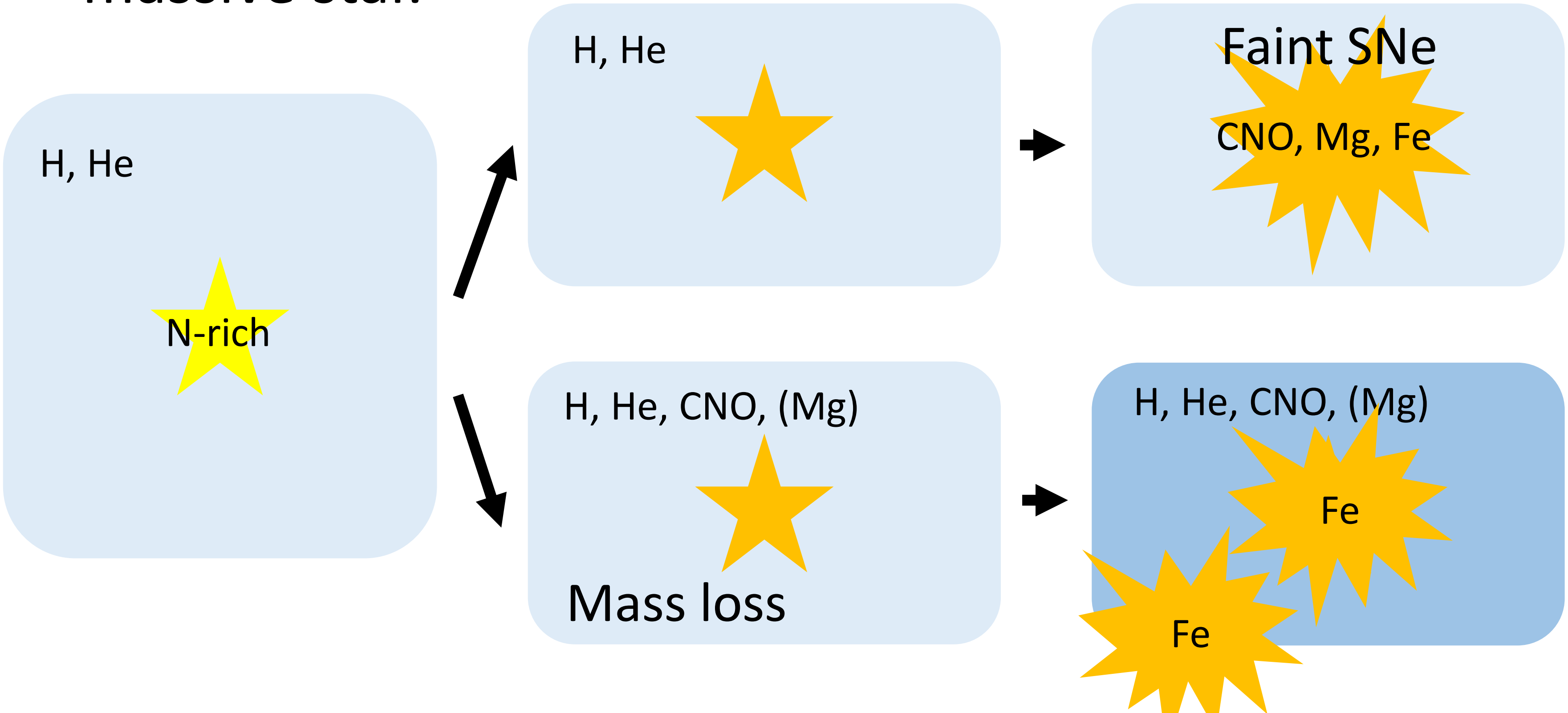
Faint SNe vs. Spinstars

- They are not exclusive and rather complimentary.
- CEMP-no star with [C/N] > 0 can be explained by the rotation in a massive star.



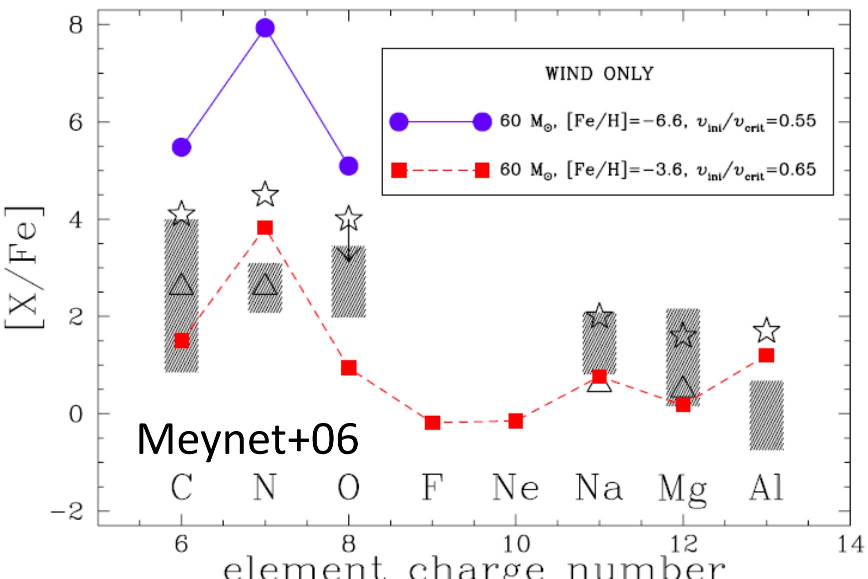
Faint SNe vs. Spinstars

- They are not exclusive and rather complimentary.
- CEMP-no star with [C/N] > 0 requires rotation in a massive star.



Faint SNe vs. Spinstars

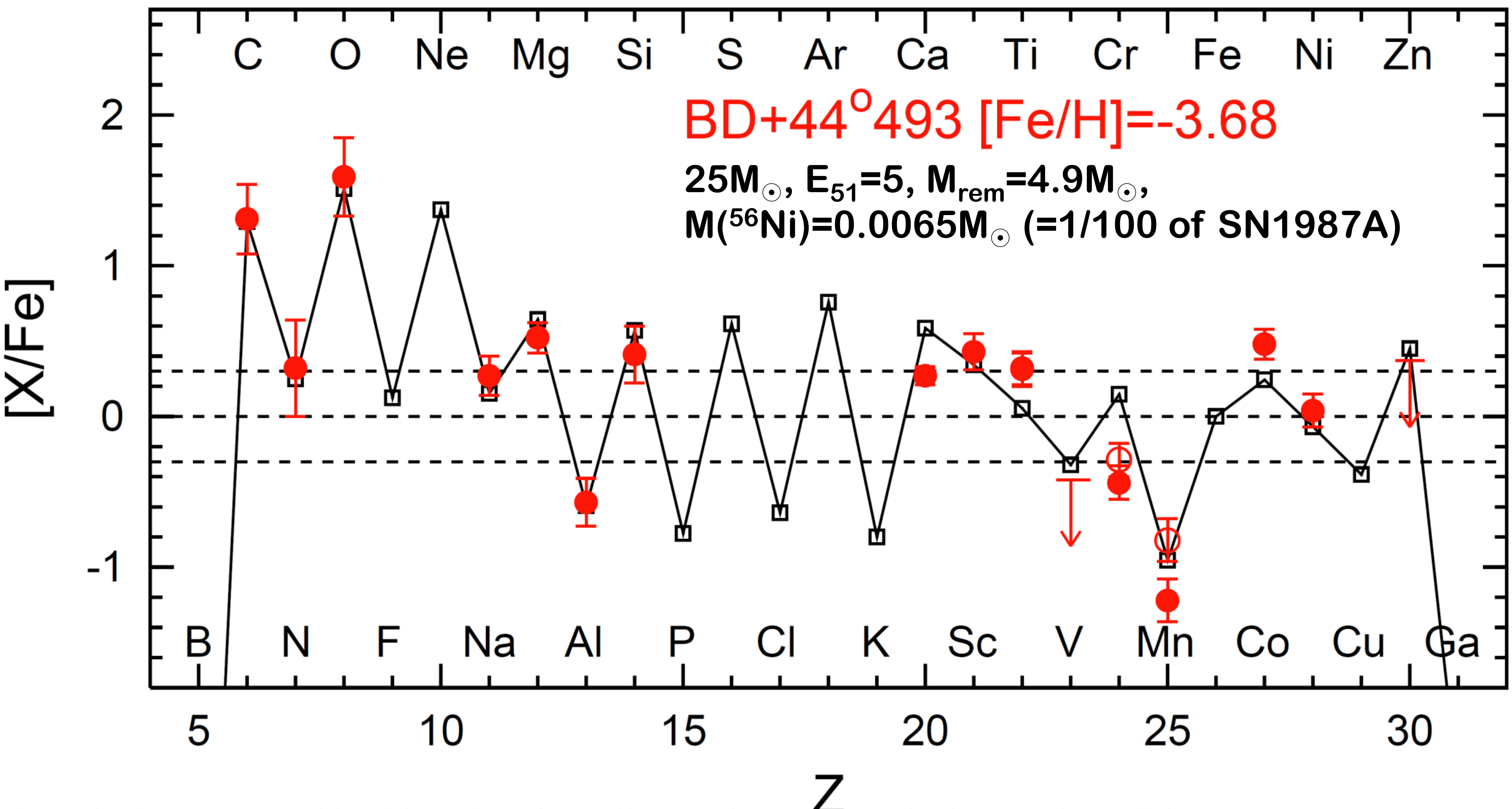
- They are not exclusive and rather complimentary.
- CEMP-no star with [C/N] > 0 requires rotation in a massive star.
- Spinstar has inevitably N-rich wind ejecta.



Faint SNe vs. Spinstars

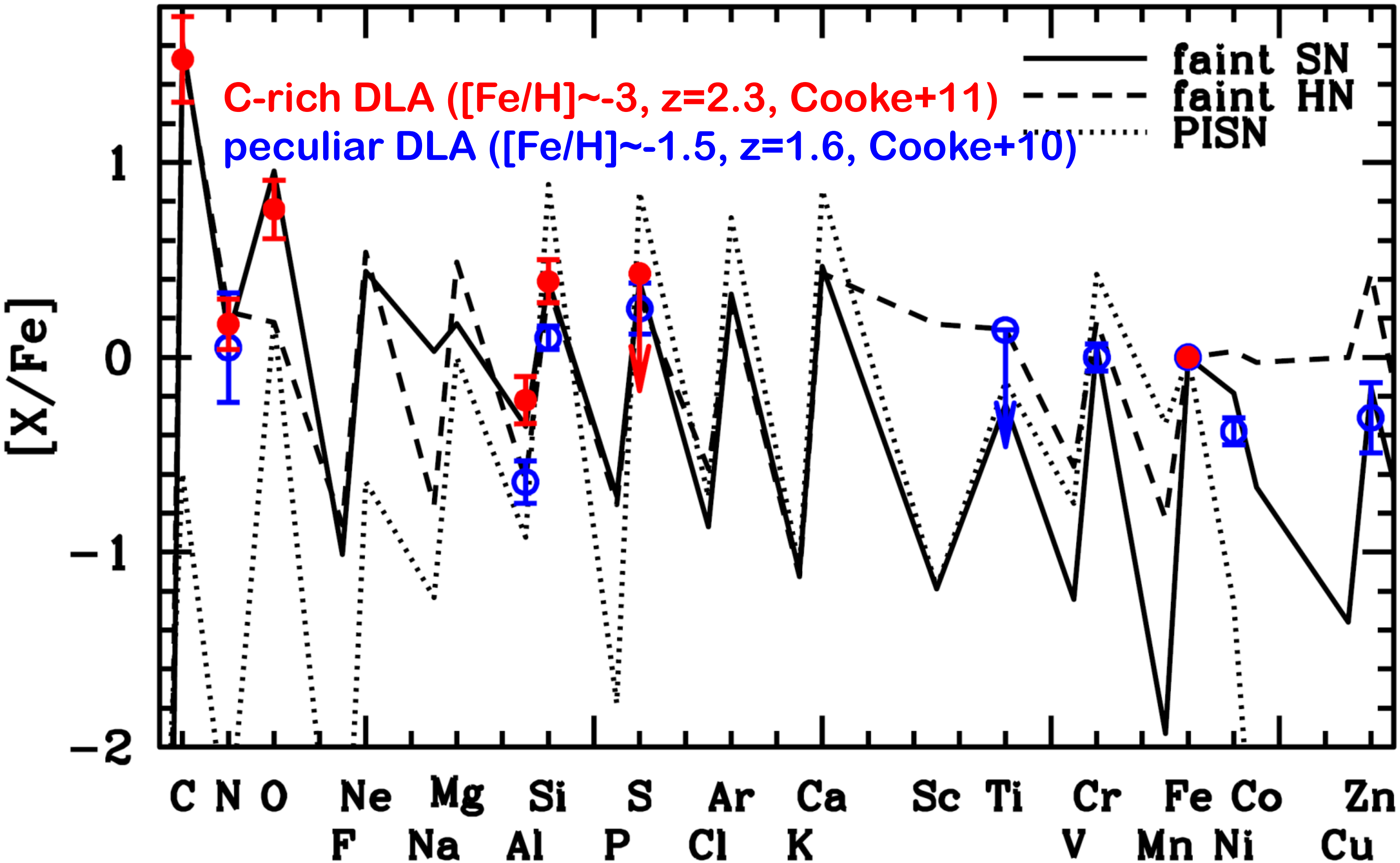
- They are not exclusive and rather complimentary.
- CEMP-no star with [C/N] ~ 0 requires rotation in a massive star.
- Spinstar has inevitably N-rich wind ejecta.
- Faint SN model does not need to be N-rich, if the rotation of progenitor is slow.

Evidence of faint SN of slow rotator
-metal-poor stars-



Ito, Aoki, Beers, NT, Honda, Carollo 13 (see also Aoki-san's talk)

Evidence of faint SN of slow rotator
-Low-[Fe/H] Damped Lyman α system-



Kobayashi, NT, Nomoto 11

Diagnostics of CEMP-no stars

My personal view

- Progenitor model
  - N-poor — Faint SN of slow rotator
  - [C/N]>0 — Faint SN of rapid rotator
    Spinstar w/ other SN for Fe
    (Mixed star, sometime NEMP stars)

- Mixing-fallback process in faint SNe
  - High E (e.g.,high [Zn/Fe]) — Jet explosion/collimated outflow
  - Low E — RT instability
    Jet explosion/collimated outflow

Summary

- Metal enrichment due to the mass accretion from the ISM is negligible.
- Aspherical explosion is required for all of the EMP stars (not only for the CEMP stars).
- Origins of CEMP-no stars
  - N-poor — Faint SN of slow rotator
  - [C/N]~0 — Faint SN of rapid rotator; Spinstar w/ other SN for Fe (Mixed star, sometime NEMP stars)
  - High E — Faint SN with jet/collimated outflow
  - Low E — Faint SN with RT instability; Faint SN with jet/collimated outflow