Supernova nucleosynthesis

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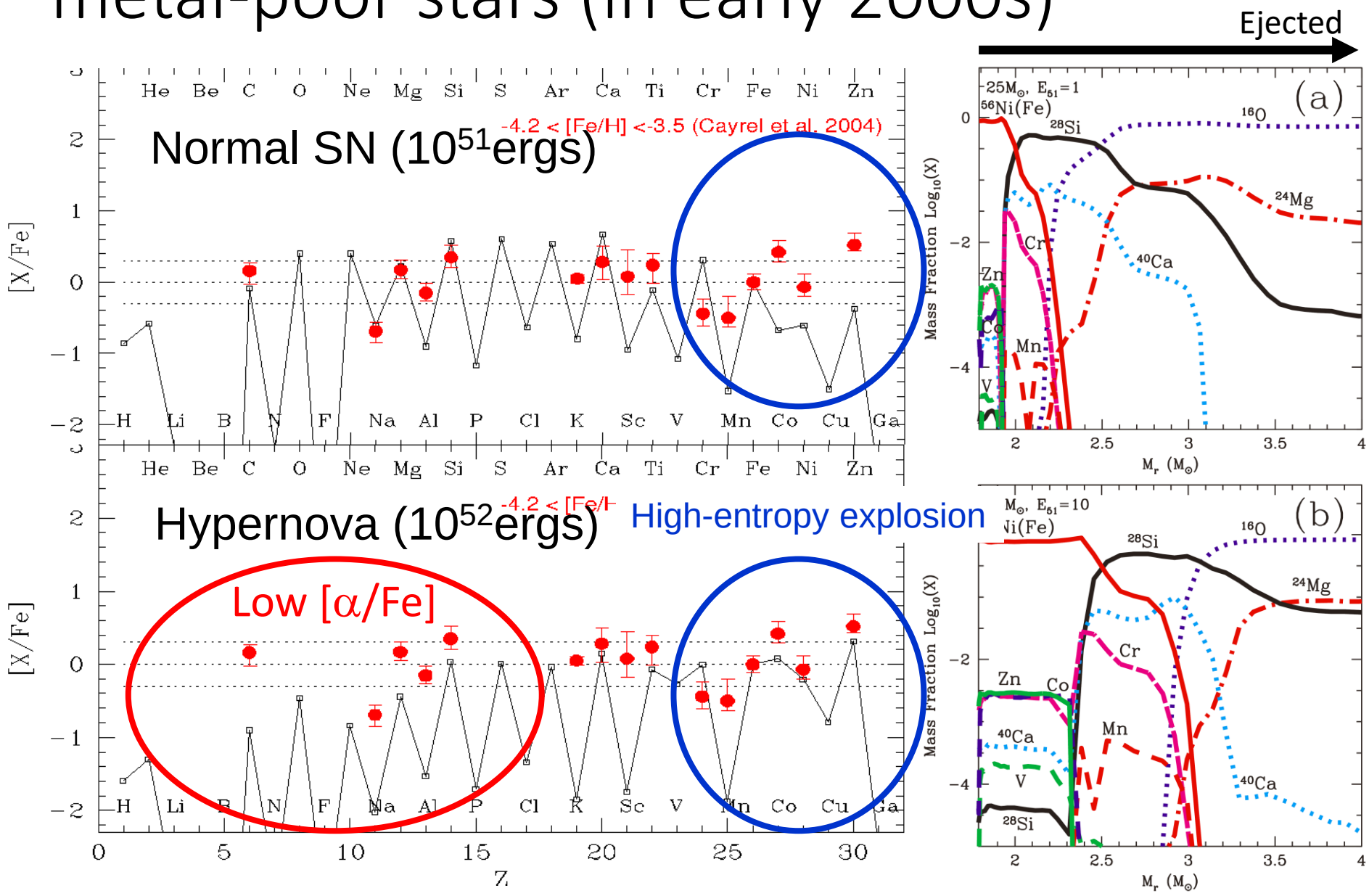
Stellar Archaeology as a Time Machine to the First Stars

Contents

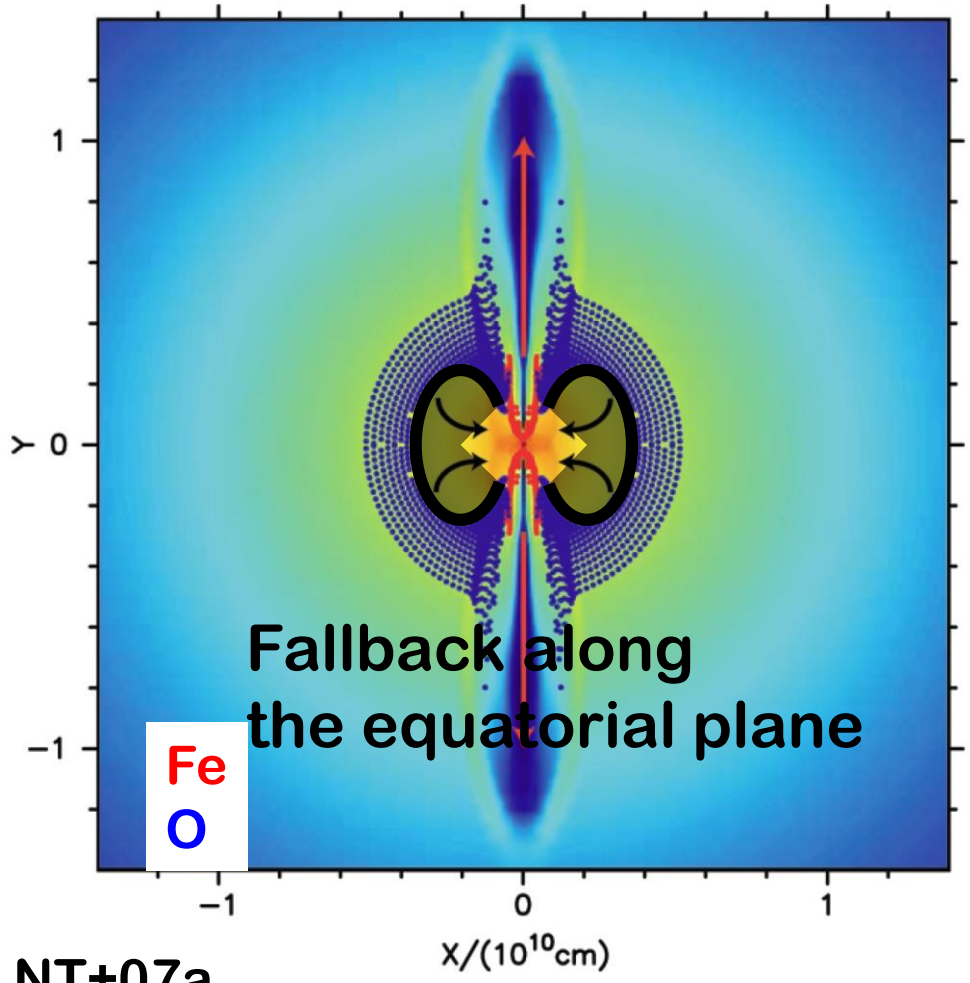
- Aspherical supernova explosions for metal-poor stars
- Aspherical supernova explosions in the present day
- Jet and elliptical explosions compared with metal-poor stars

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



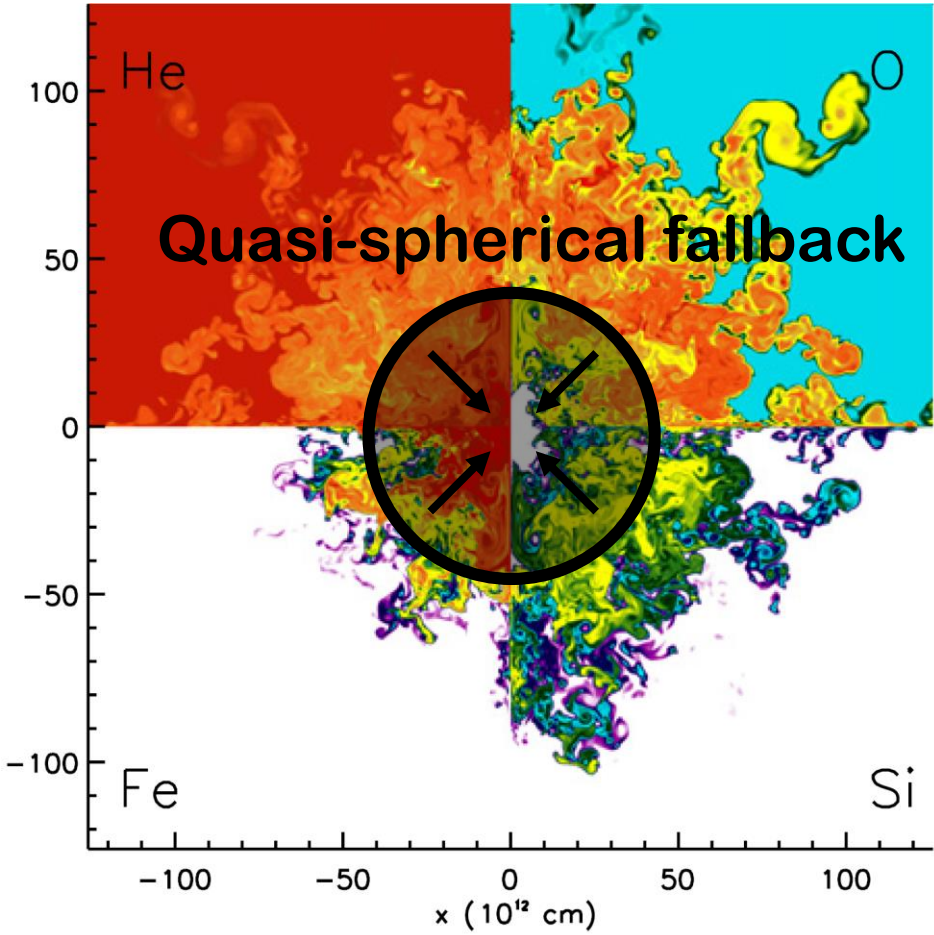
Simulation of mixing-fallback

Jet explosion



NT+07a

Rayleigh-Taylor instability



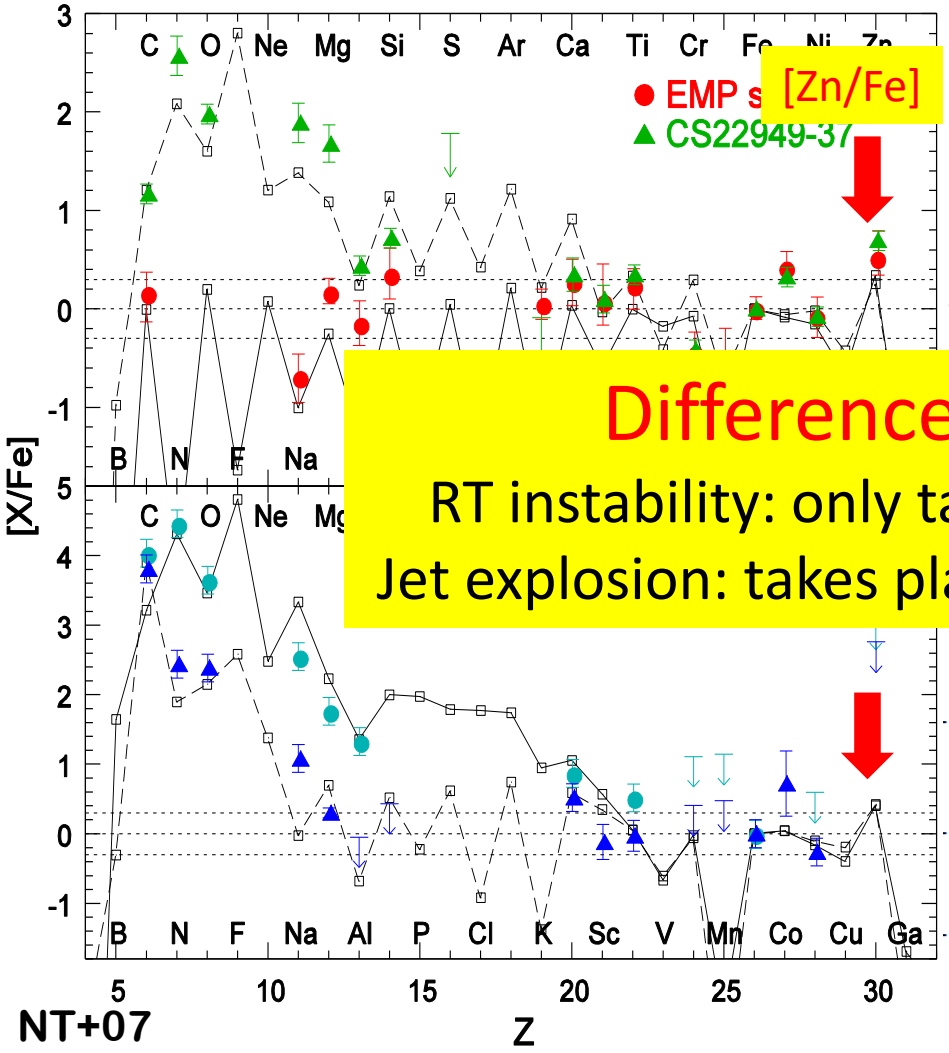
Joggerst+10

Nucleosynthesis yields

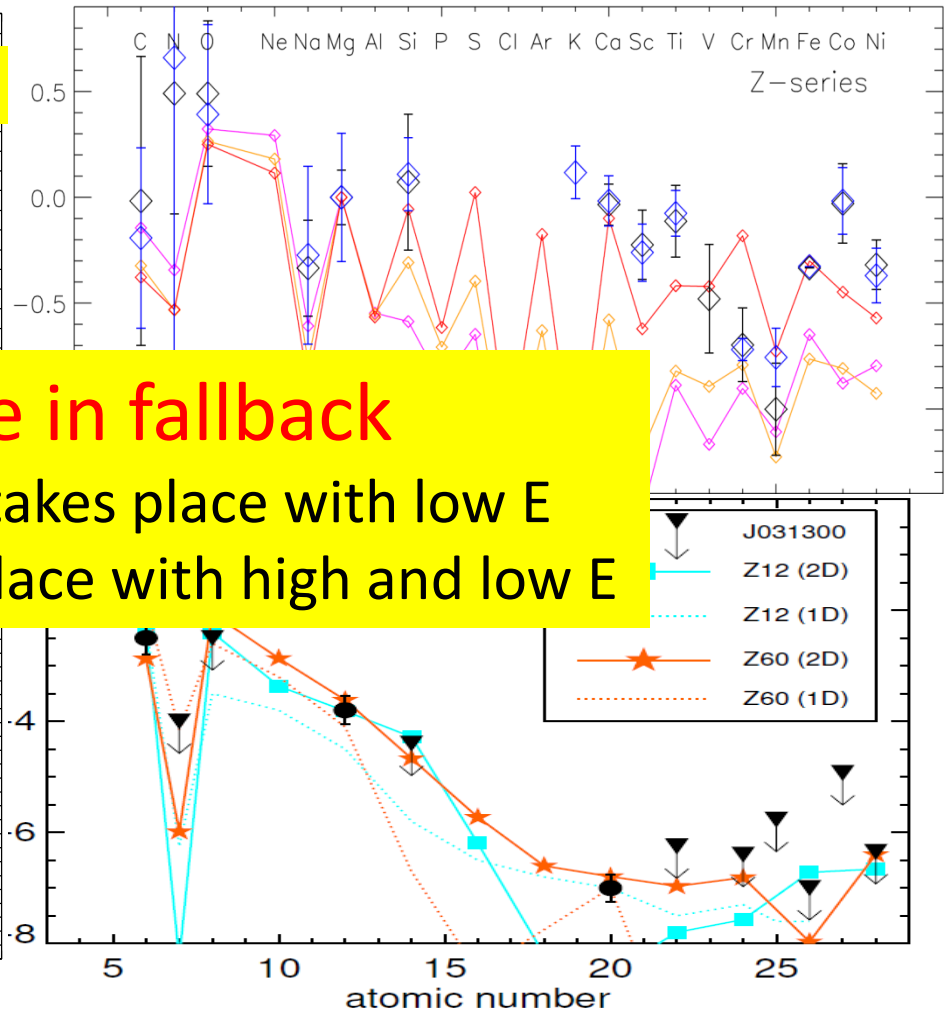
These mechanisms reproduce the abundance patterns of EMP stars.

Jet explosion

-> Ezzeddine-san's talk



Rayleigh-Taylor instability



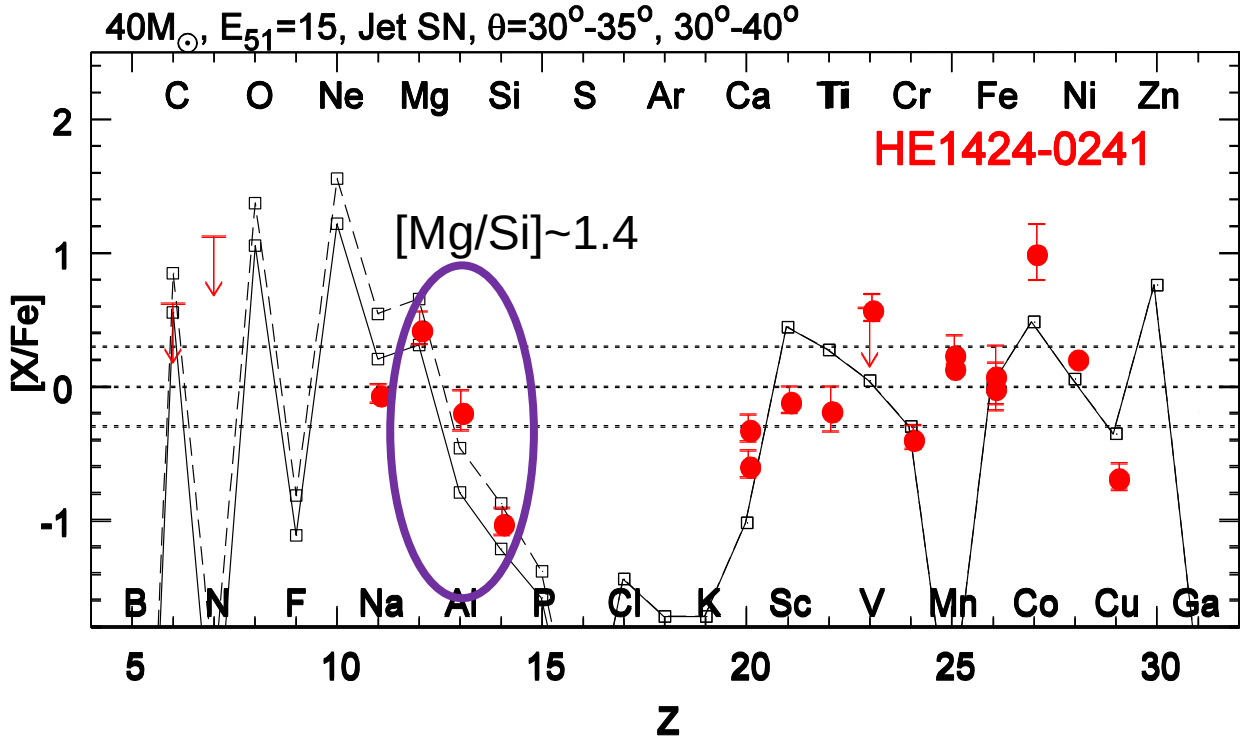
Difference in fallback

RT instability: only takes place with low E

Jet explosion: takes place with high and low E

An evidence of aspherical explosion

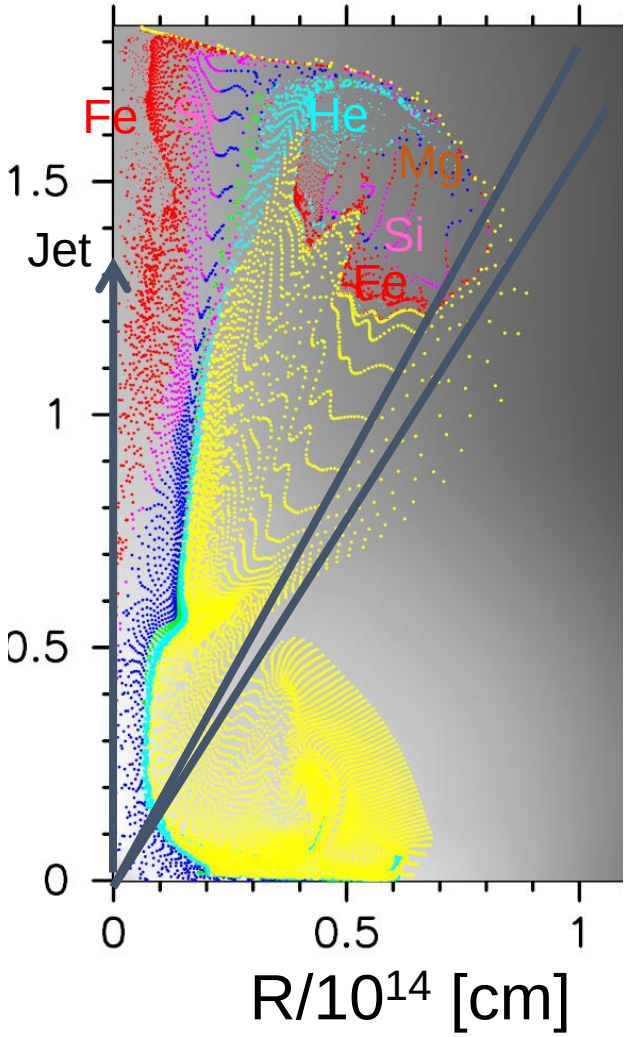
- A peculiar Si-deficient star: HE1424-0241 (Cohen + 07)



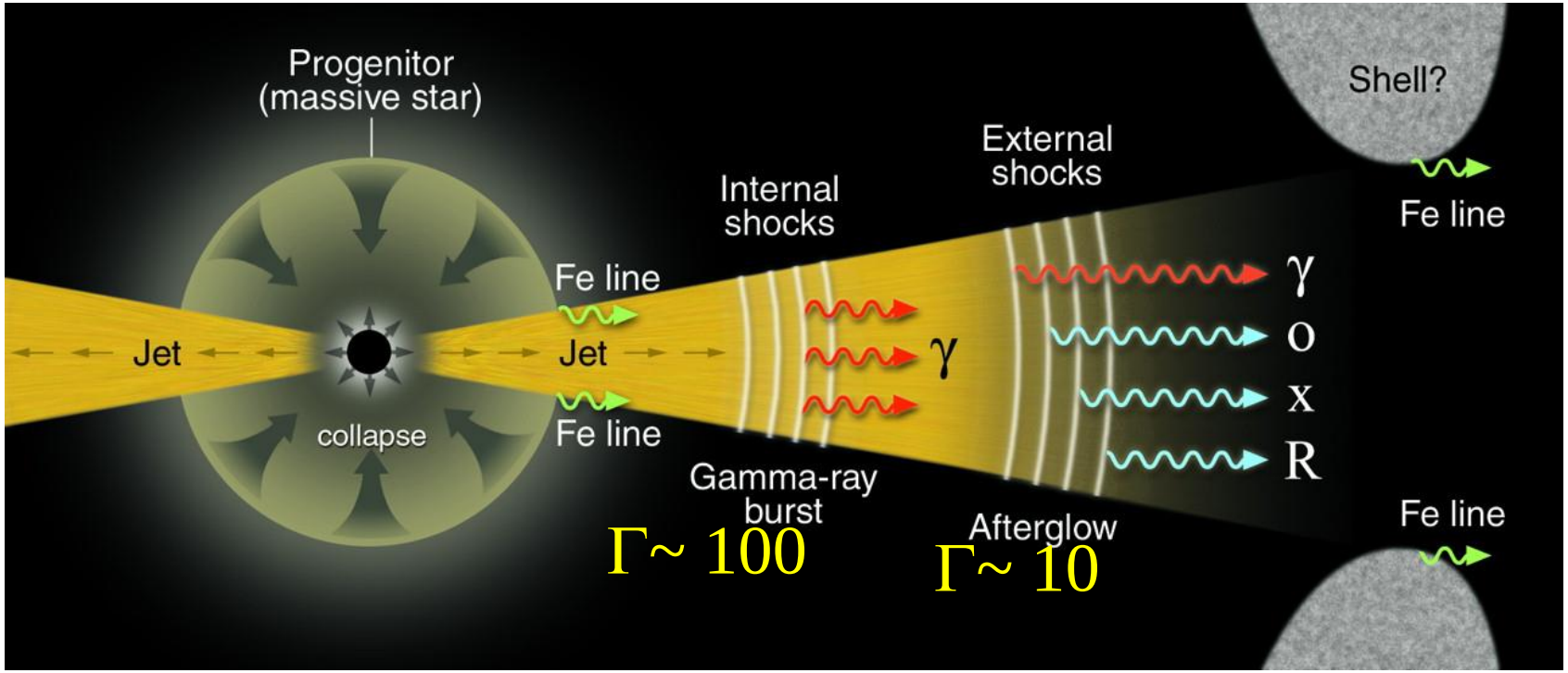
A possible explanation

Angule-dependent yield

(NT 09)



GRB-SNe

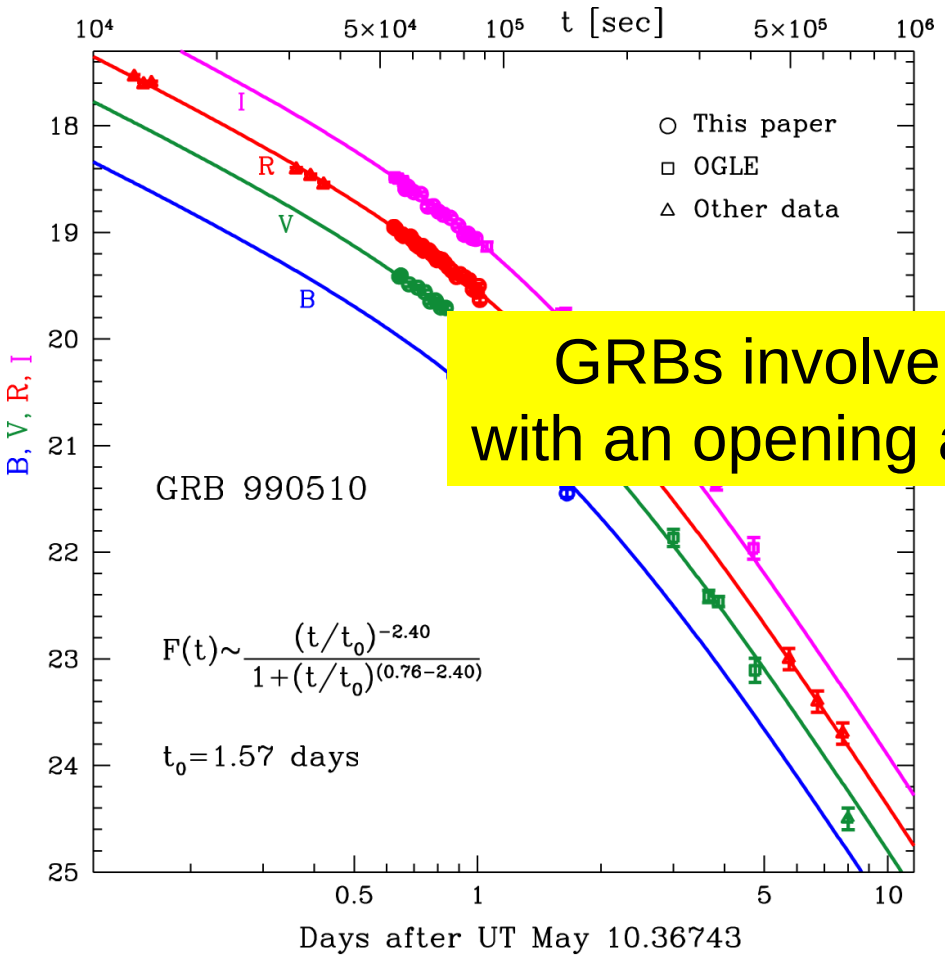


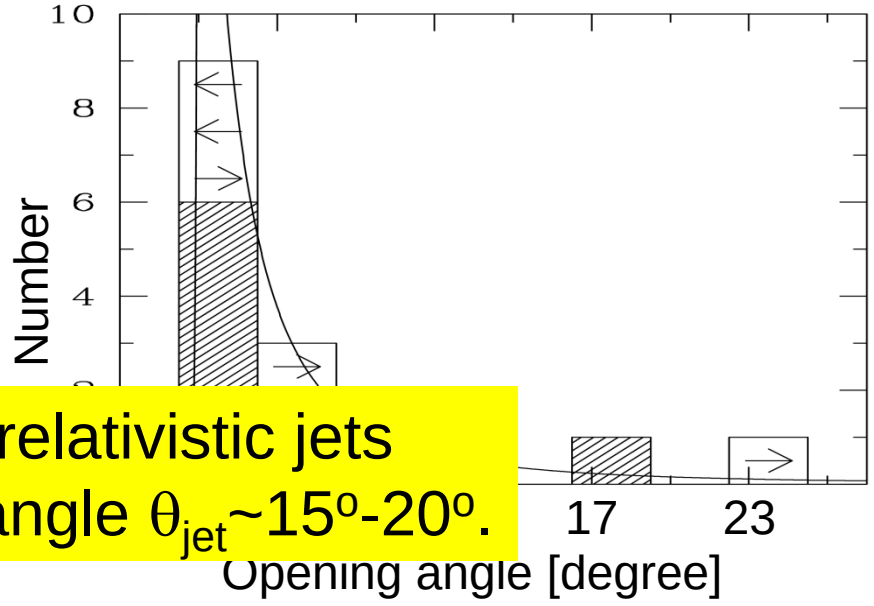
A GRB associated with energetic SN (GRB-SN) is an aspherical explosion of a massive star.

Aspherisity of GRBs

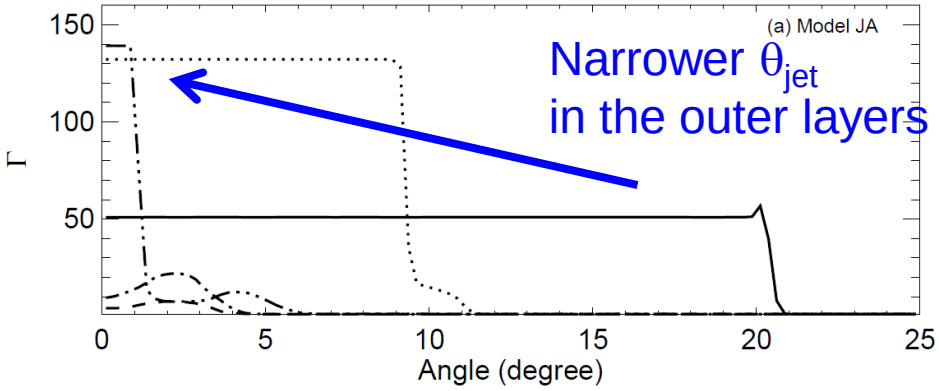
(e.g., Stanek et al. 99; Frail et al. 01; Zhang et al. 03)

- Jet break





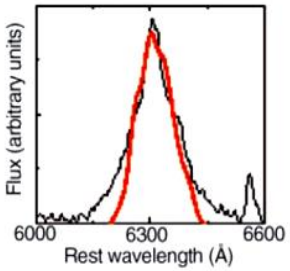
GRBs involve relativistic jets with an opening angle θ_{jet}~15º-20º.

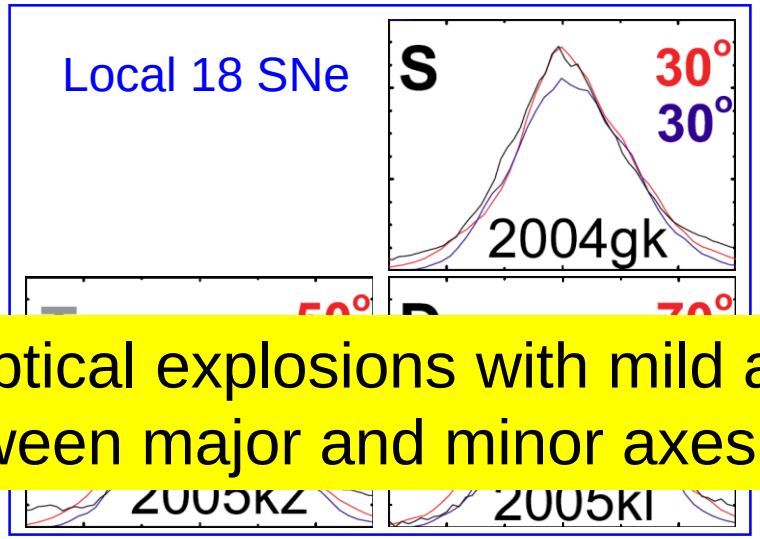


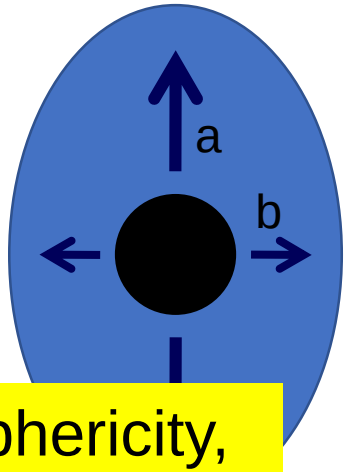
Aspherisity of SNe

- Nebular observation

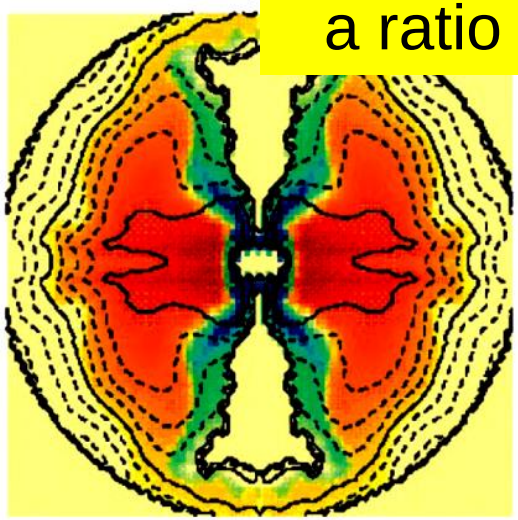
(Maeda et al. 06;08)







SNe are elliptical explosions with mild asphericity, a ratio between major and minor axes (BP~2-8).



2003jd

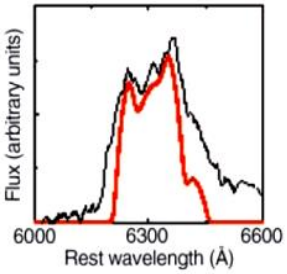
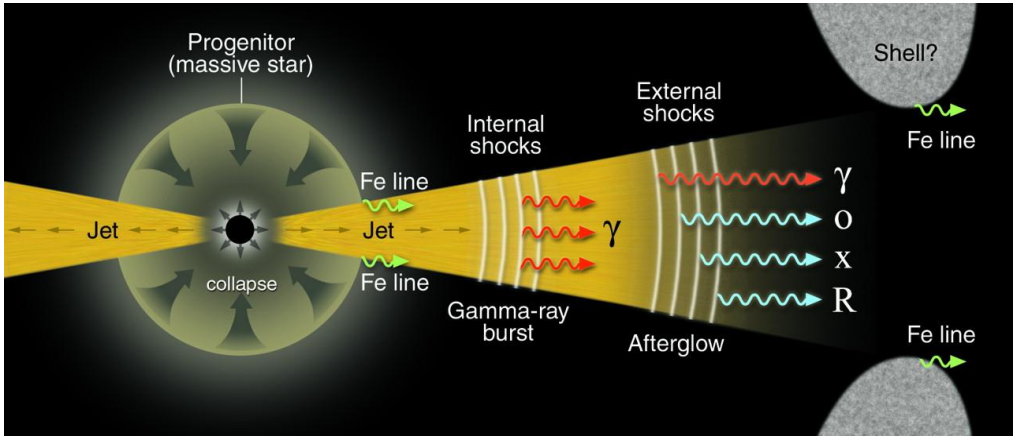


Table 1. Fraction of double-peaked [O I] SNe.

Model	Dividing angle*	Fraction†
Spherical	–	0%
BP2 Local SNe	~70°	~34%
BP8 1998bw	~50°	~64%
Observed	–	39 ± 11%

GRB-SNe should have two components

- GRB980425/SN1998bw
  - Relativistic jets and elliptical explosion coexist.

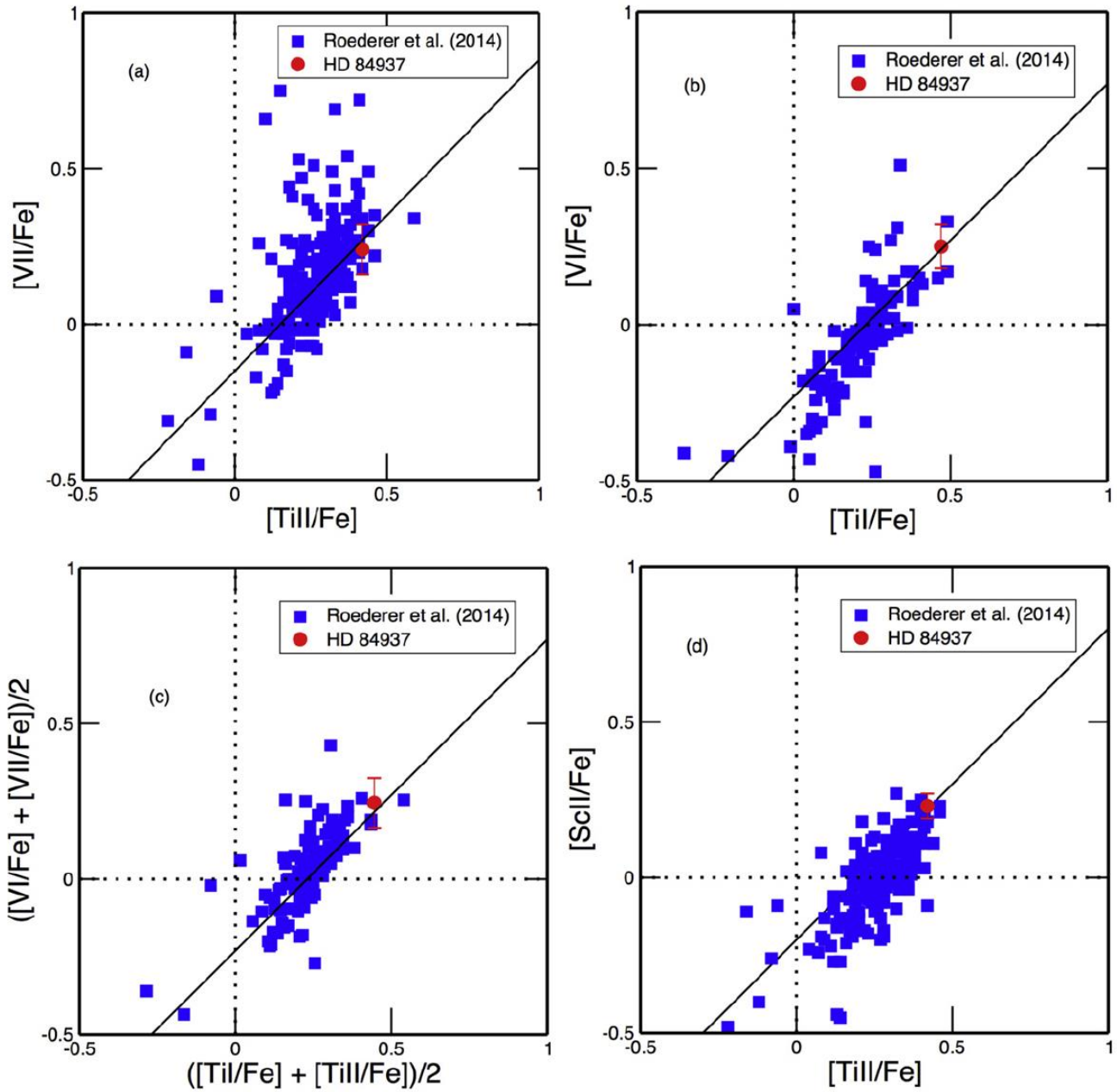


Jet explosions with θ_{jet}~15°

Elliptical explosions with BP~2-8

How does it affect the supernova nucleosynthesis?

Correlation among Sc-Ti-V



Sneden+16

Summary

- Aspherical supernova explosions are required to explain the abundance patterns of metal-poor stars.
- The calculations of jet and elliptical explosions, inspired by GRB-SNe, are performed with neutrino emission.
- The slope of [Ti/Fe] vs. [V/Fe] is reproduced with jet and elliptical explosions and even better with the neutrino emission.
- However, the slope for [Sc/Fe] is still difficult and the ratios [Sc/Fe], [Ti/Fe], and [V/Fe] are underproduced.
- We are still on the way to explain these ratios.