Signature of an aspherical SNe preserved in a hyper metal-poor star

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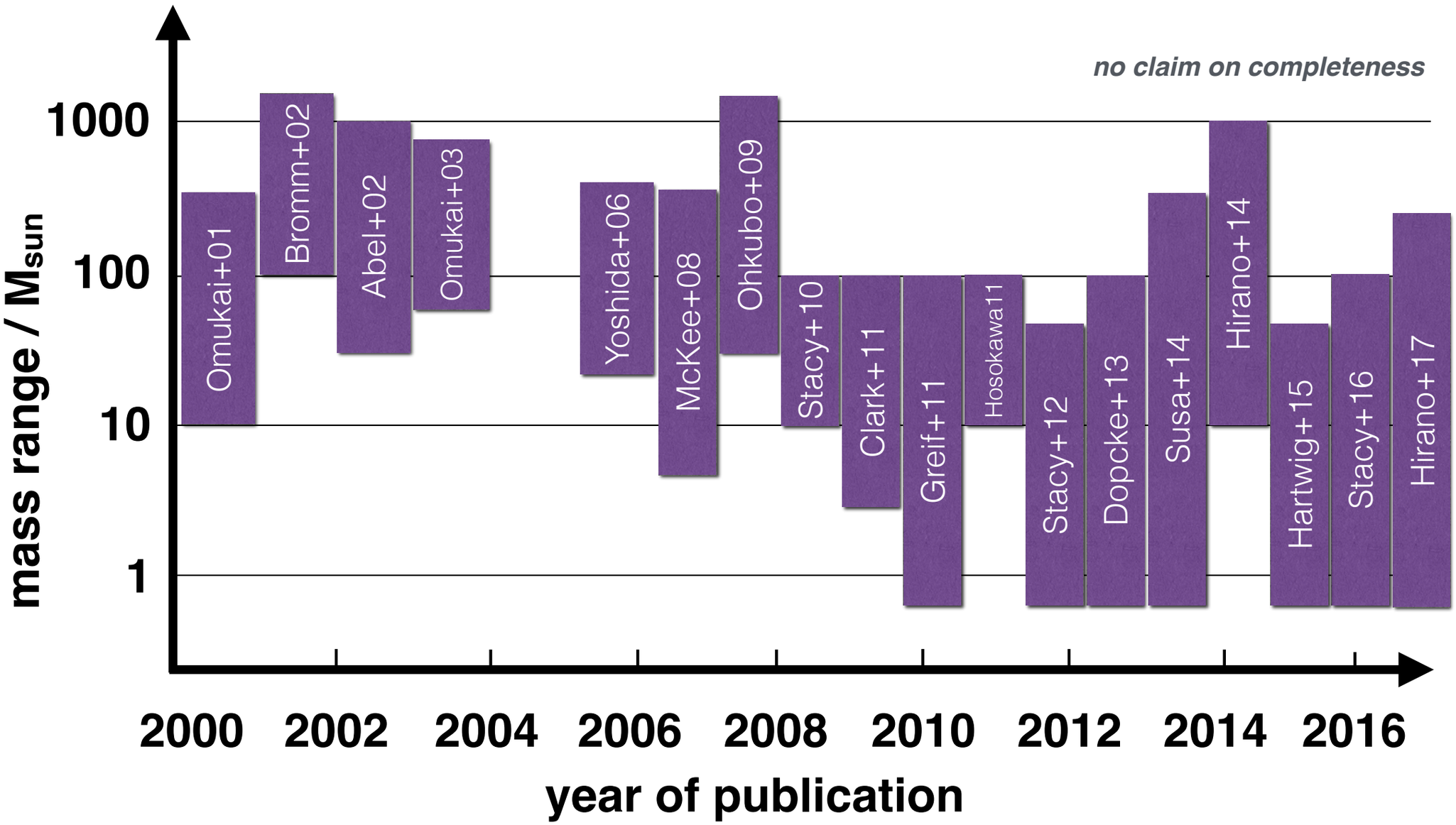
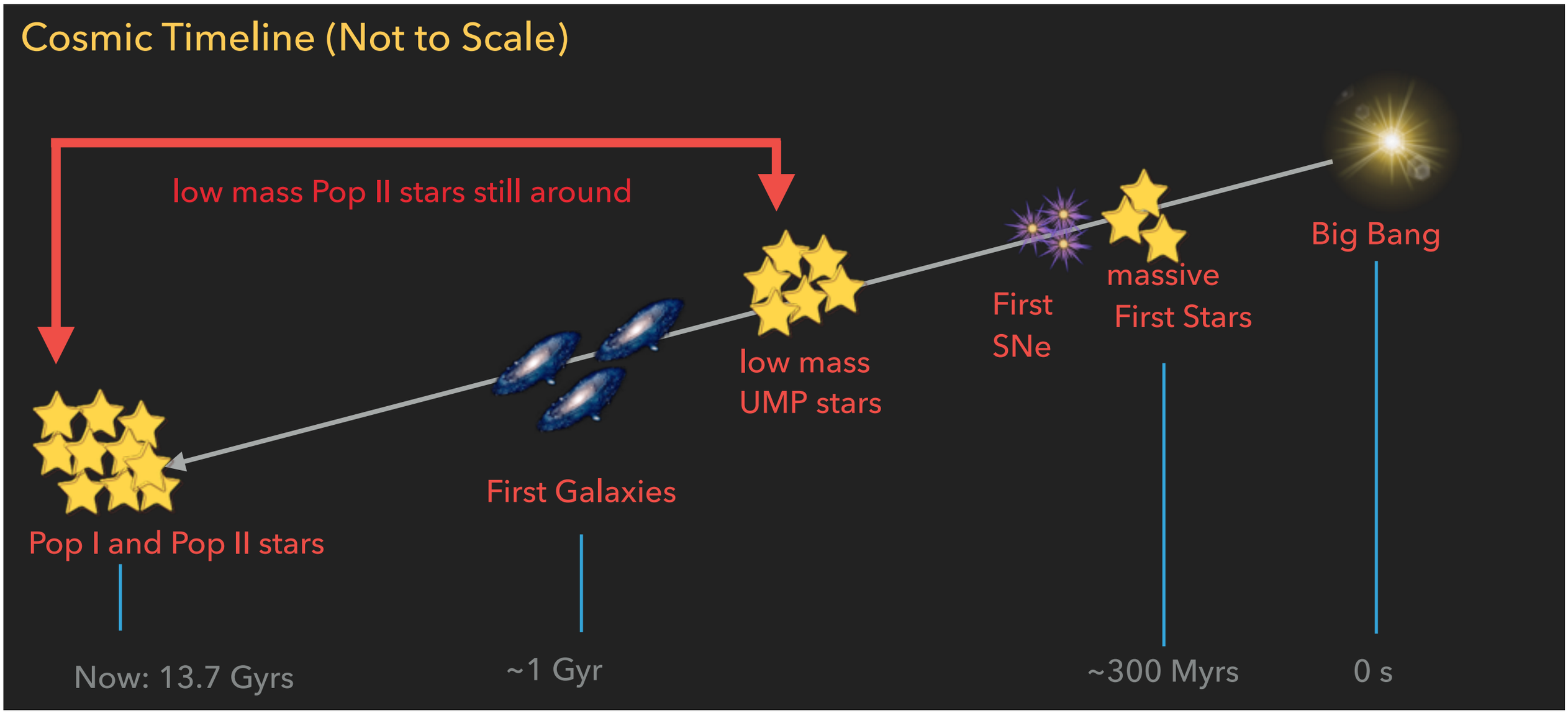
And again..



Adapted from T. Hartwig

UMP & HMP stars : Fossils of the Cosmic Dawn

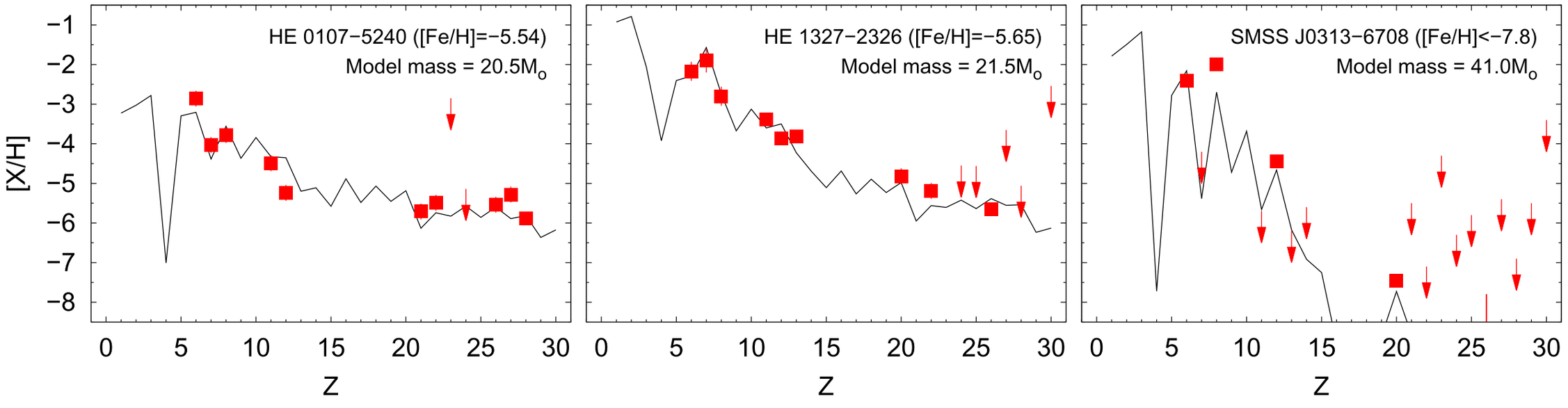
- They are rare stellar relics of the early universe.
- They have records of the “First” Population III stars recorded in their atmospheres



Can be used to infer First stars and SNe properties

- Comparing UMP & HMP stellar abundance patterns to First stars SNe nucleosynthesis yields to determine First stars progenitor properties: Mass, SNe energy, Mixing fractions,..
- Depends on derived elemental abundances : need complete and precise abundances

"Mixing and Fallback" models (Heger & Woosley 2010)

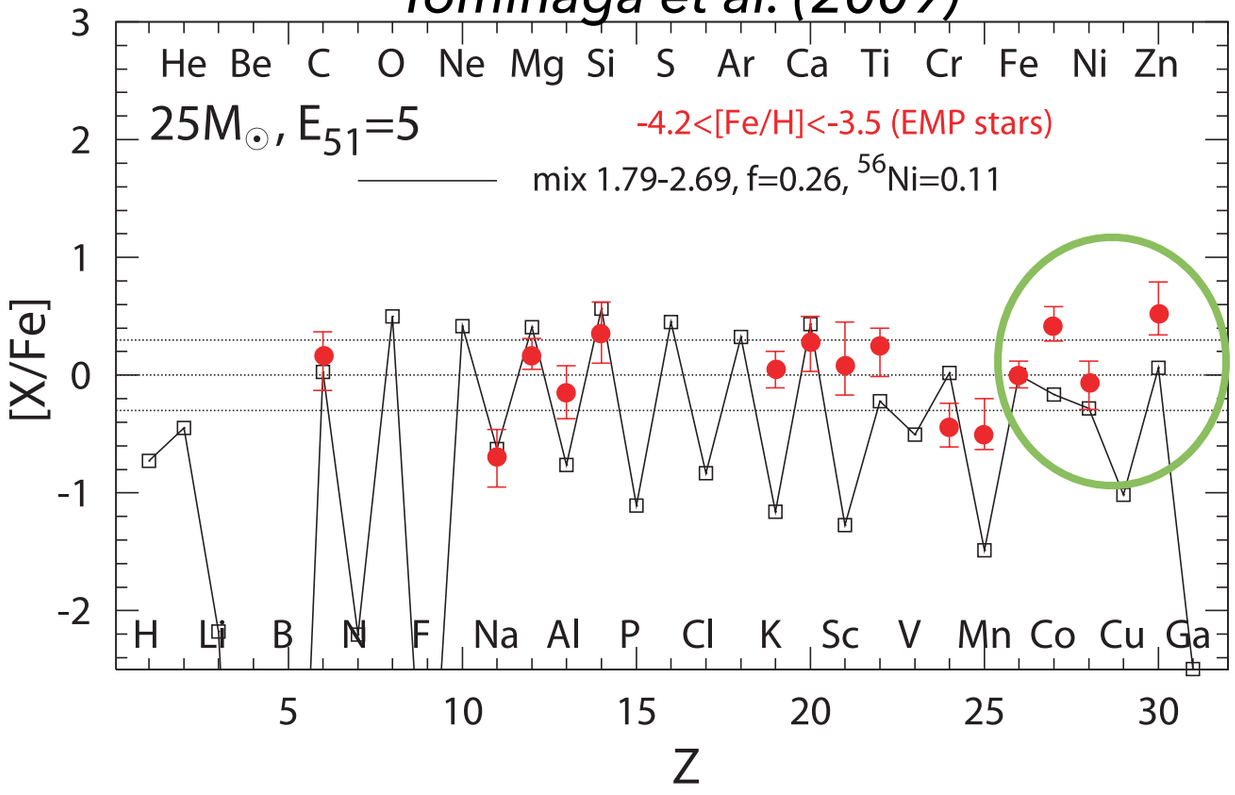


Placco et al. (2015)

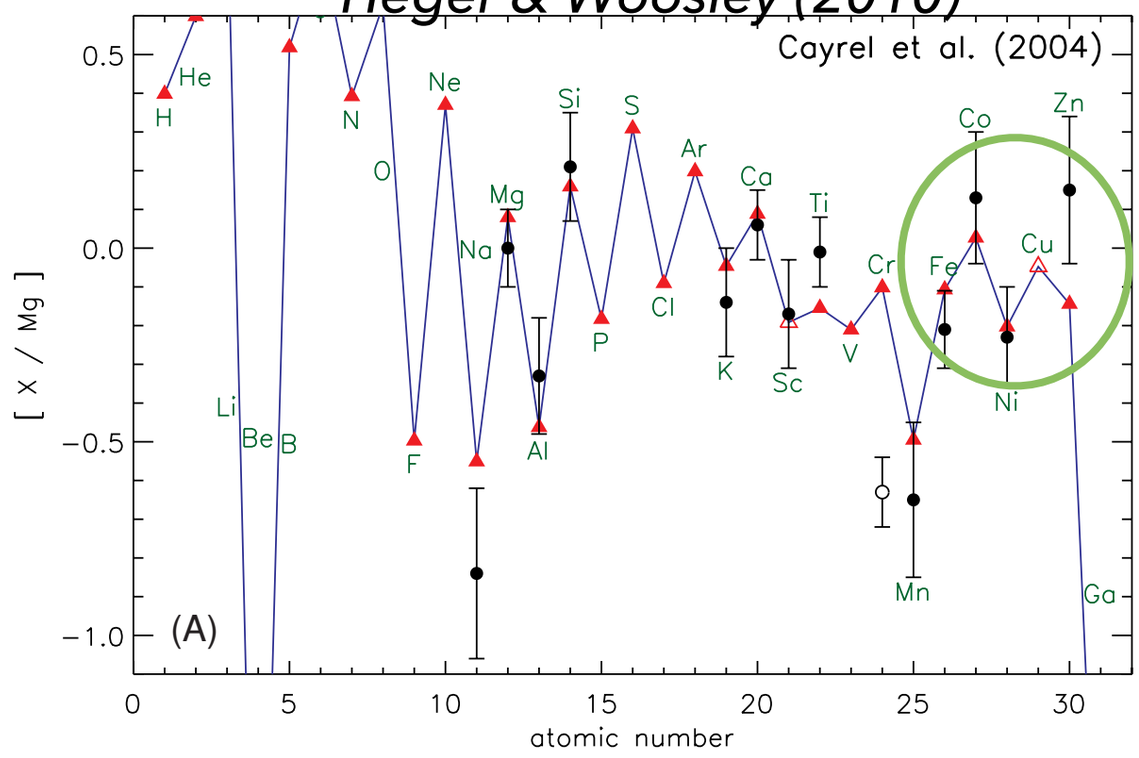
(Quasi) Spherical models are not able to produce Fe Peak elements

Umeda & Nomoto-San (2002)

Tominaga et al. (2009)

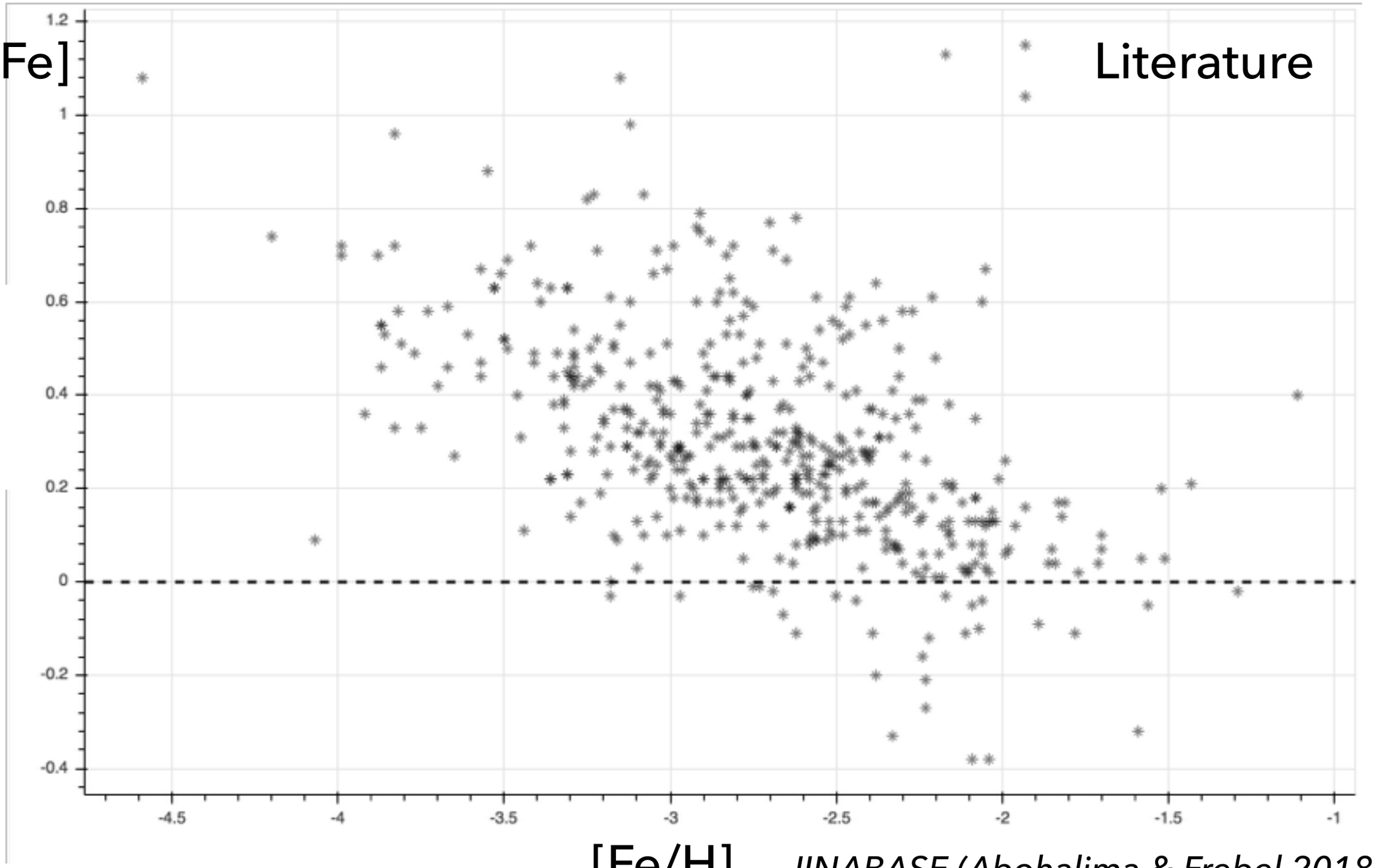


Heger & Woosley (2010)



Spherical and quasi-spherical (Mixing & Fallback) SNe models unable to produce Fe-peak elements (Co, Zn)

ZN IS ENHANCED RELATIVE TO FE IN METAL-POOR STARS



JINABASE (Abohalima & Frebel 2018)

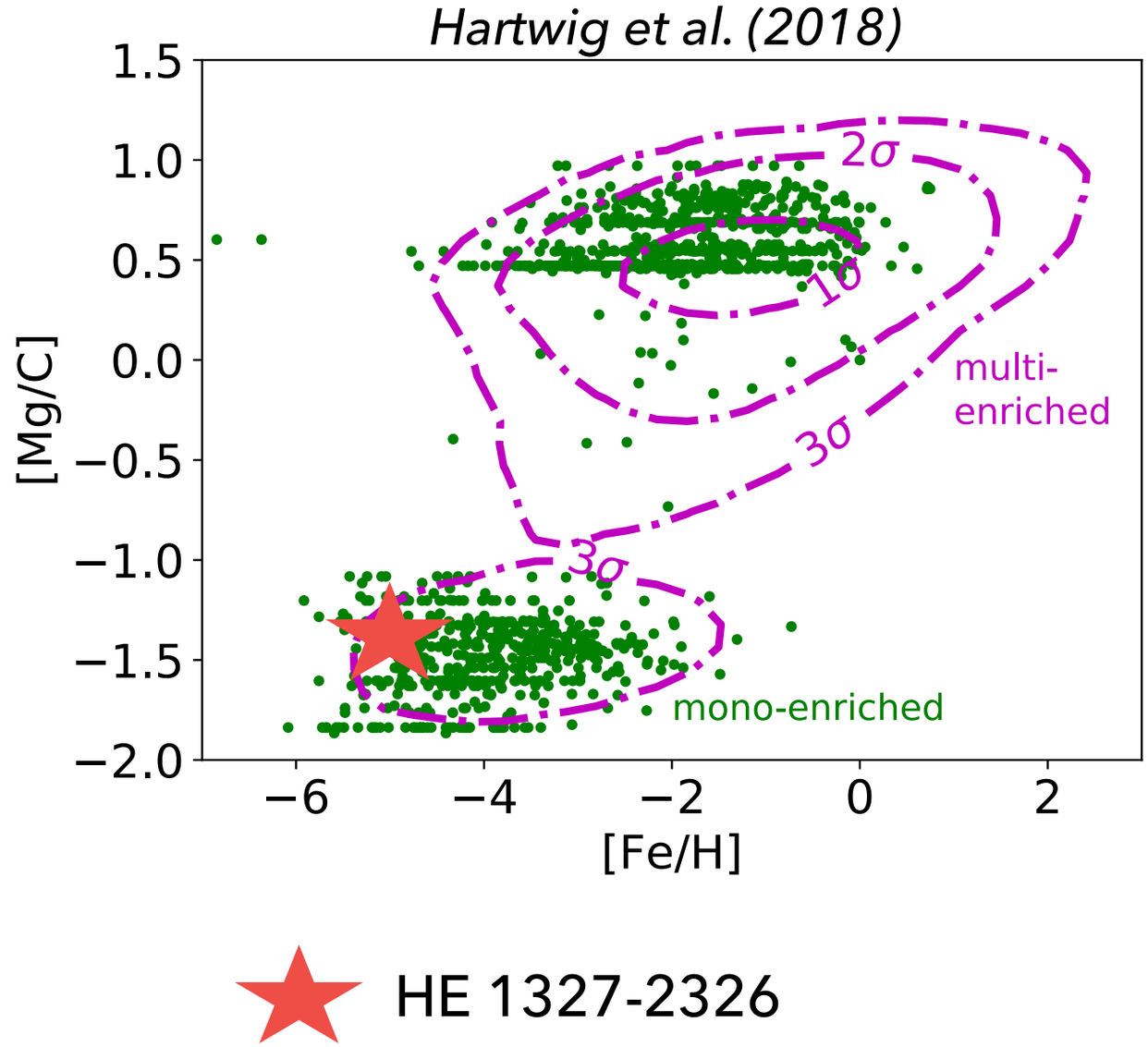
HE 1327-2326 : Mono-Enriched star by single SNe event

- V=13.5 (Frebel et al. 2005)
- Low [Fe/H] (Non-LTE) = -5.20

  (Ezzeddine et al. 2017)
- [Mg/C] = -1.49
  - [Mg/H](Non-LTE) = -3.71

    (Sitnova et al. submitted)
  - [C/H](3D) = -2.22

    (Frebel et al. 2008)



- Well studied in the Optical region

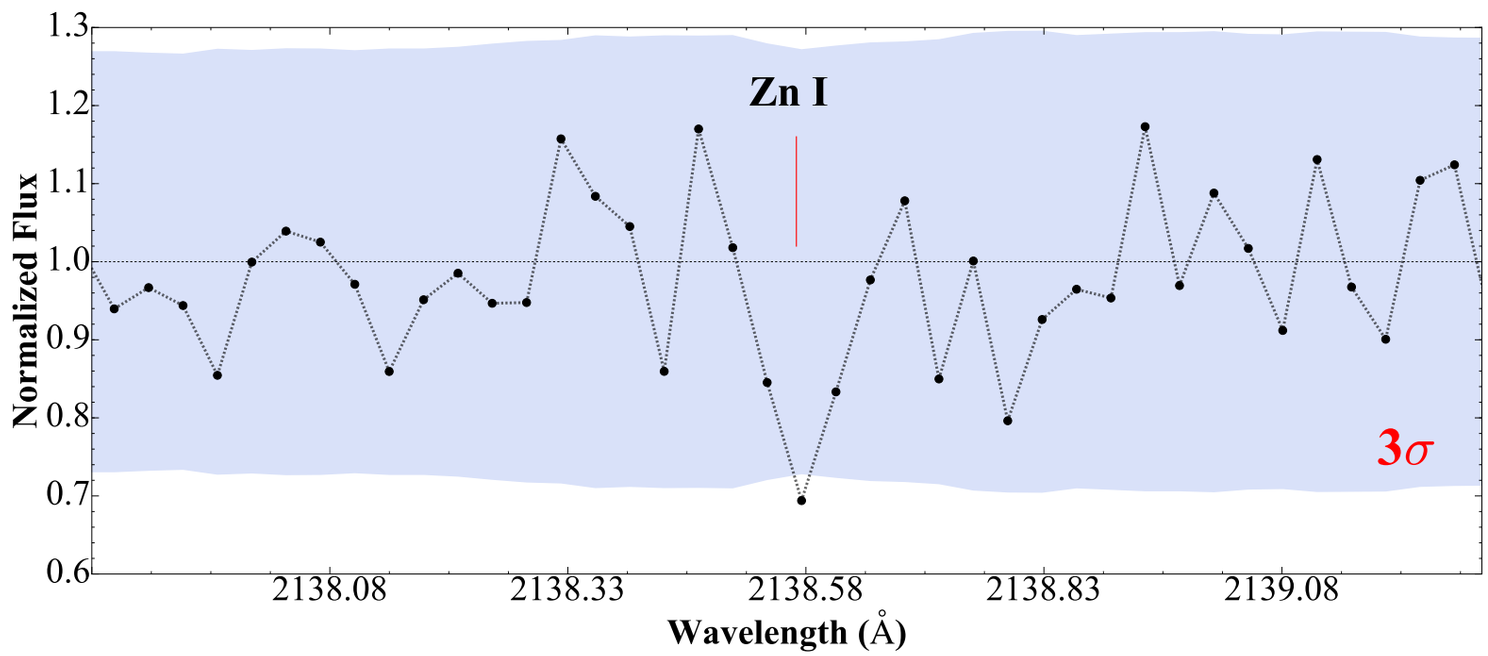
  (e.g., Frebel et al. 2005, 2008;

  Aoki et al. 2006; Korn et al. 2009,…)

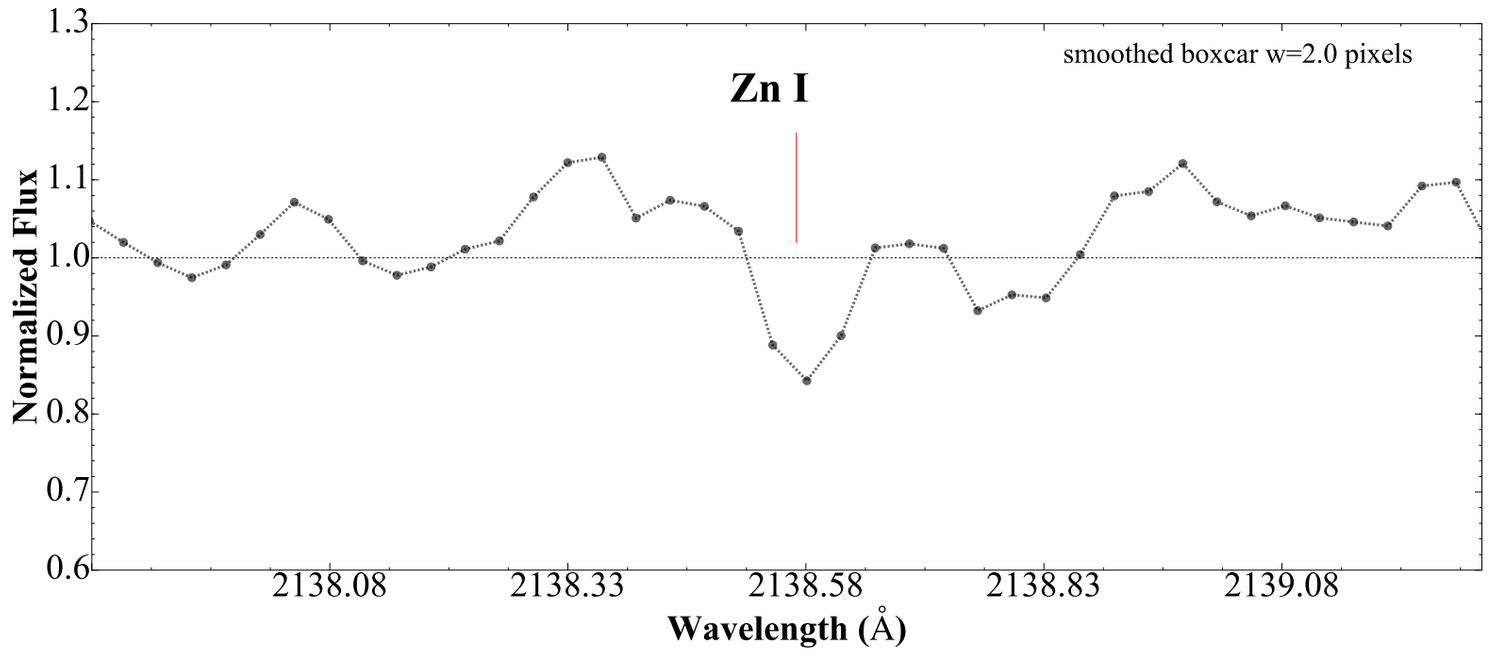
First detection of Zn in HMP star in UV HST/COS spectrum

- UV *HST*/COS spectrum
- ZnI detection at 2138.58 Angstroms
- First Zn abundance measurement in an HMP star ([Fe/H]<-5)

Ezzeddine et al. submitted



- [Zn/Fe] = 0.80 ± 0.25
- Enhanced abundance relative to Fe
- What about NLTE?



[Fe/H] -> YES

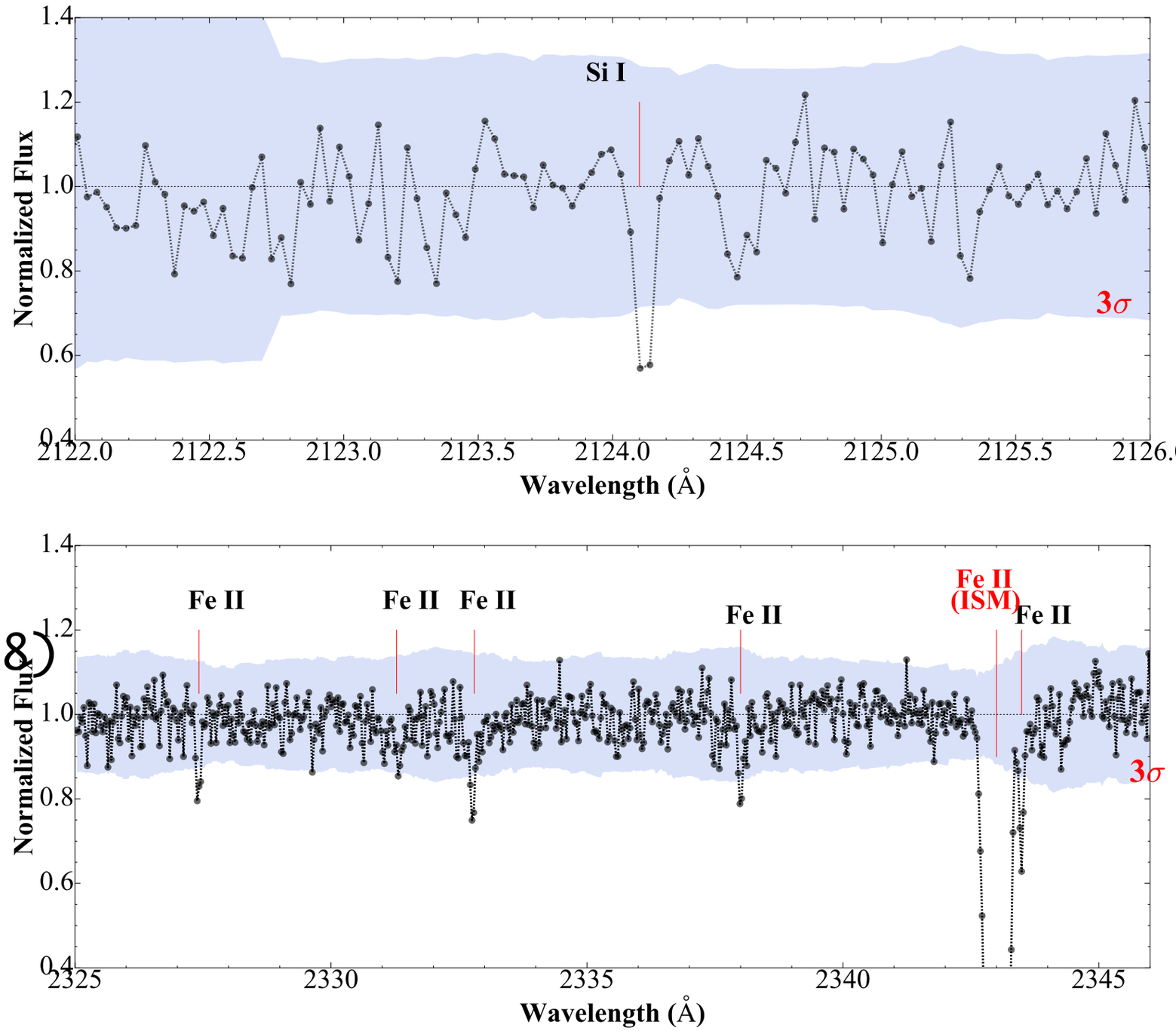
[Zn/H] -> no, BUT any “small” correction would only increase [Zn/H]

(Takeda et al. 2016)

Also FeII and SiI detected for the first time

- UV/Optical abundance shift detected for FeII
- Negligible NLTE effects for Fe II
- Possible 3D effects (Amarsi et al. 2016)
- Missing UV opacities?
- Roederer & Barklem (2018) found no ZnI & ZnII abundance discrepancies b/w optical and UV.

Ezzeddine & Frebel (2018)



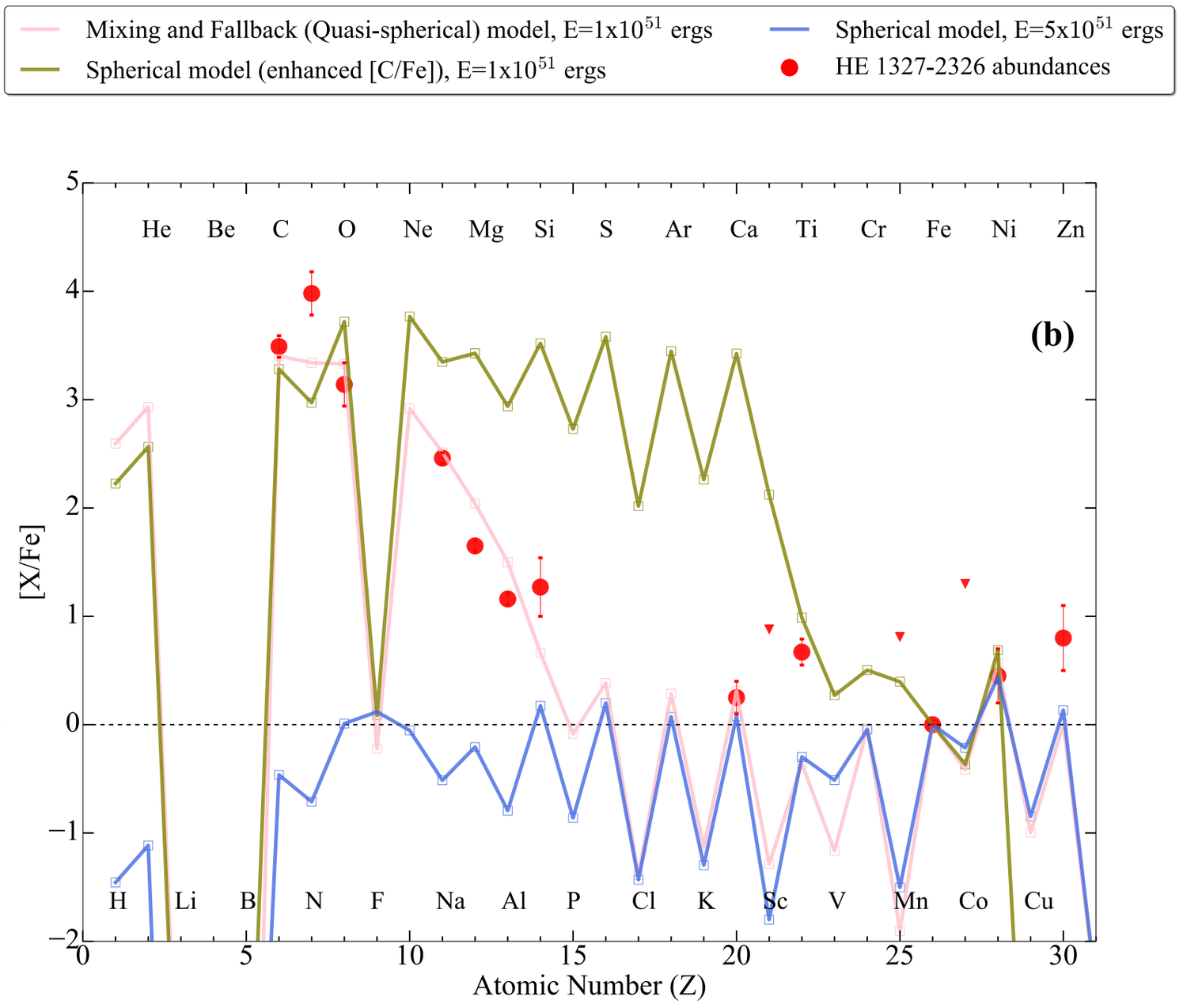
Comparison to spherical SNe models

Ezzeddine et al (submitted)

Enhanced Zn requires high entropy environment.

Cannot be reproduced with spherical or (quasi) explosions.

(Tominaga 2007; Grimmett & Heger 2018)

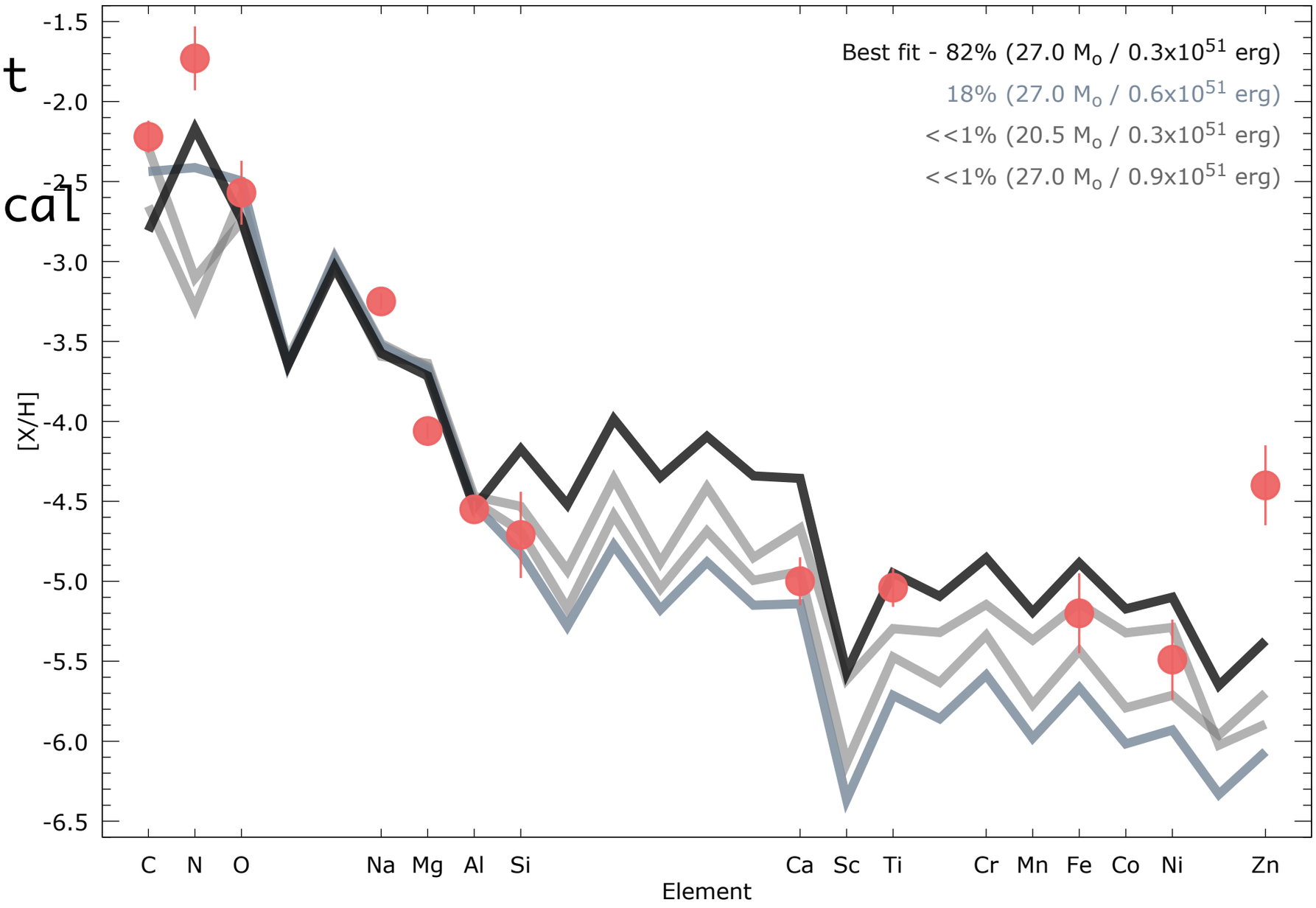


Comparison to (quasi) spherical SNe models

Statistical fit to 10,000 re-sampled chemical abundance patterns of HE1327-2326

(Placco et al 2016)

Placco et al. (2016)



starfit.net *(Heger & Woosley 2010)*

Comparison to aspherical SNe models

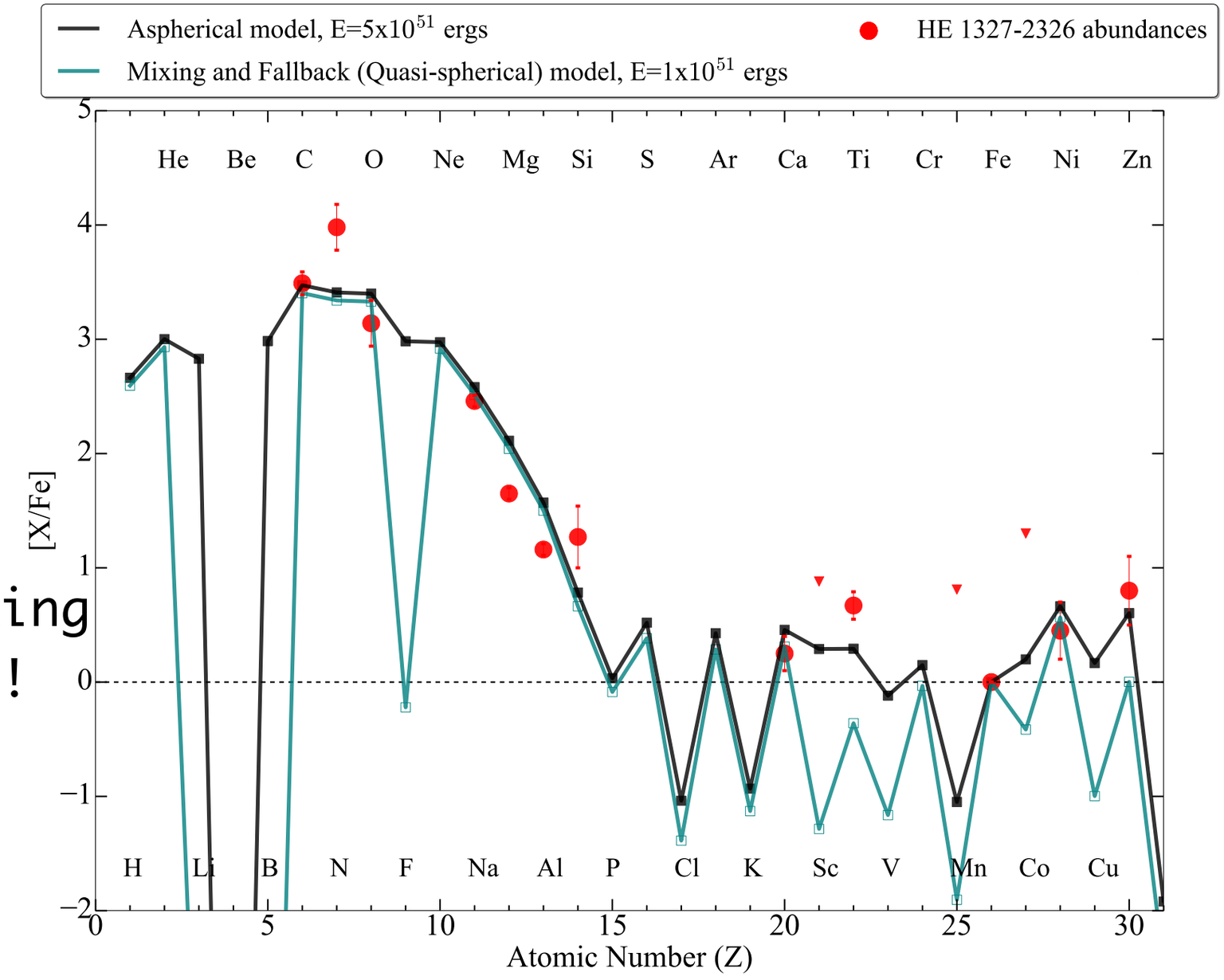
Ezzeddine et al (submitted)

Aspherical explosion with bipolar-outflows can reproduce the Zn in HE1327-2326

Tominaga (2007)

First direct evidence of Aspherical explosions taking place in the First stars!!

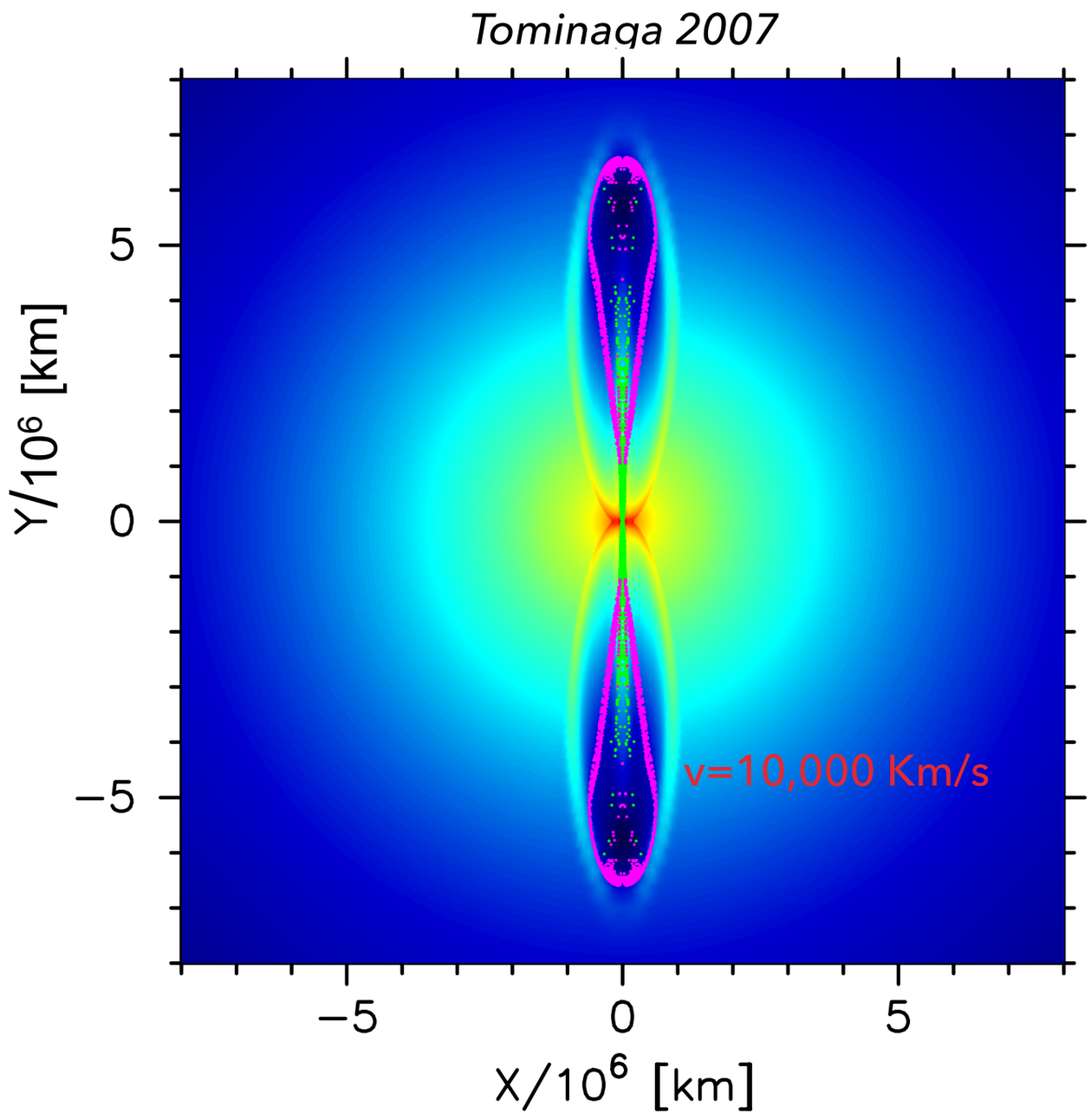
Confirming predictions by Tominaga-San (2007), Grimmett & Heger (2018)



Aspherical SNe with bipolar-outflows

Jet-like supernova exploding in an asymmetric fashion at t = 50s.

Colors represent densities of dominant ejected elements: Fe and Zn, C and O



Evidence from Rotation

Aspherical SNe driven by fast rotation of PopIII stars

(Maeda & Nomoto 2003; Meynet et al. 2006; Ekstrom et al. 2008; Tsujimoto & Nishimura 2018)

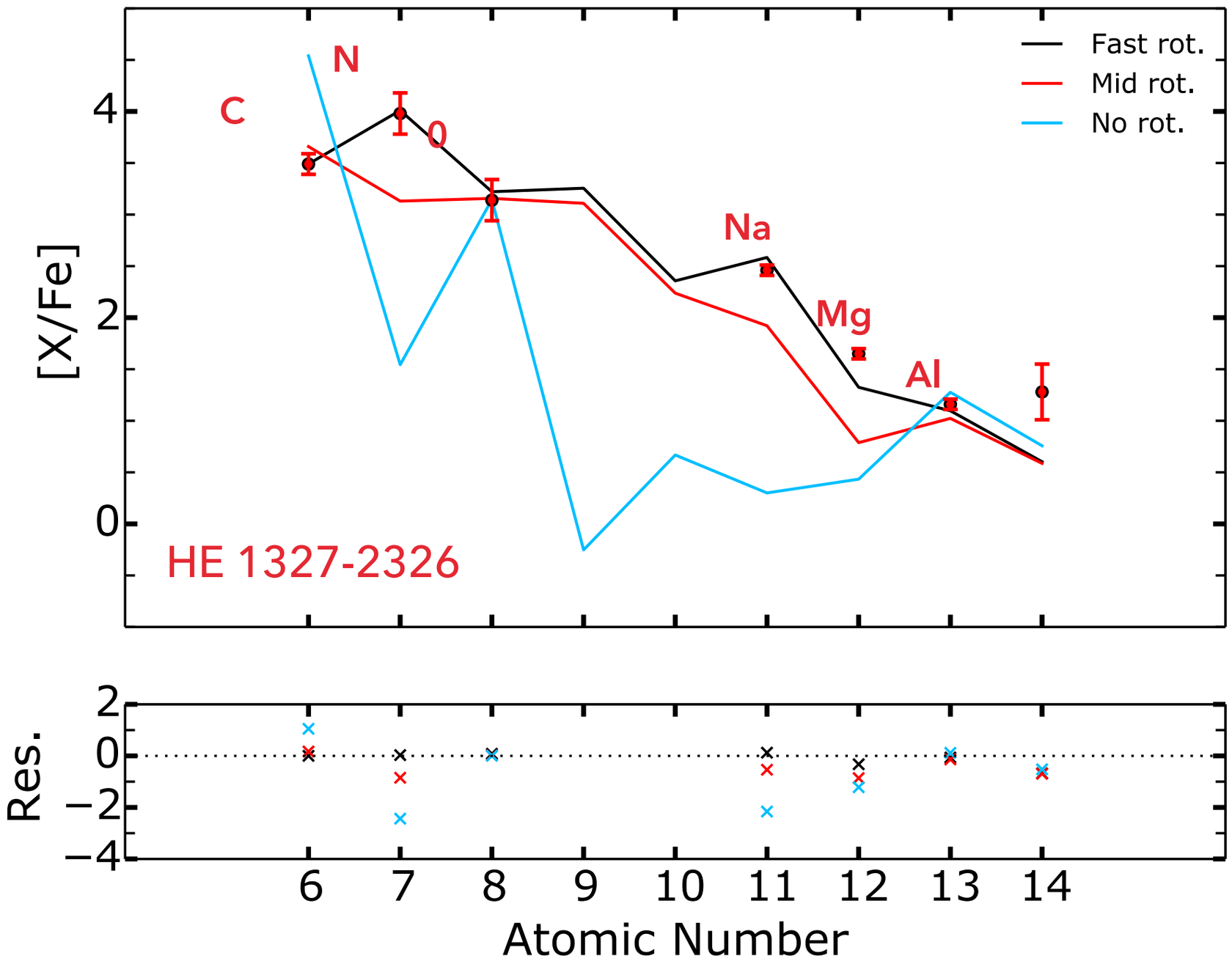
Explains CNO enhancements:

HE 1327-2326
[N/Fe] = 3.98

HE 0107−5240
[N/Fe] = 2.57

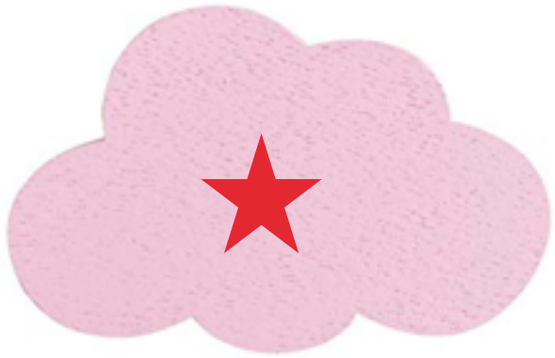
SD 1313−0019
[N/Fe] = 3.46

Arthur Choplin (priv comm)



Implications on chemical enrichment

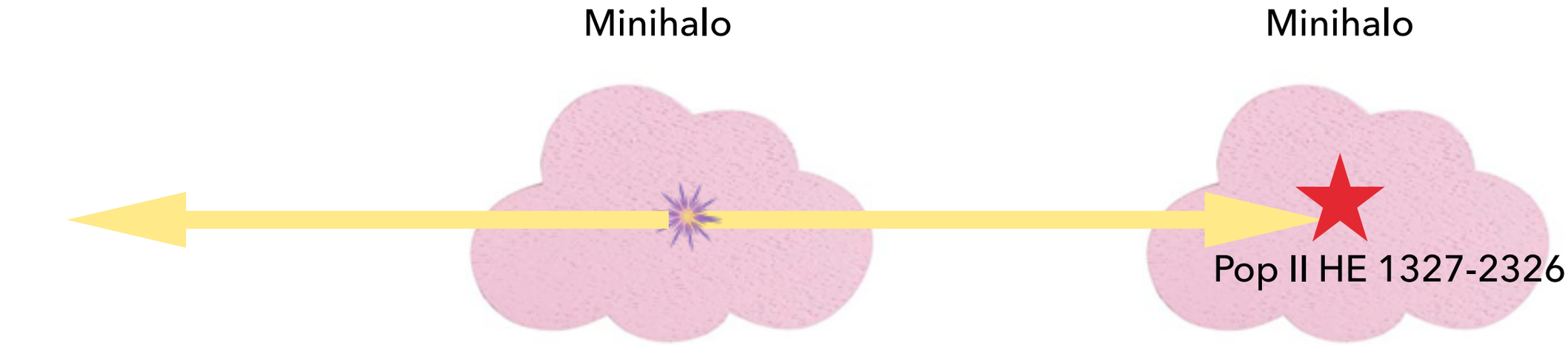
Minihalo



Minihalo

Minihalo

Implications on chemical enrichment



Stars like HE 1327-2326 could have formed from ex-situ enrichment!(Smith et al. 2015, Jeon et al. 2017)

Could explain inhomogeneities found in stars with [Fe/H]<-4.5 relative to higher [Fe/H] (Aoki 2013)

Outer halo (possibly accreted) nature of HE1327-2326 confirmed by *Gaia* DR2

Takeaway points

- First detection and measurement of Zn abundance in HMP star: HE 1327-2326!
- Enhanced [Zn/Fe] ratio could be produced by aspherical SNe with bipolar jets
- Direct evidence that aspherical explosions could take place in the First stars, driven by fast rotations (+magnetic fields)!
- Implications on subsequent chemical enrichment -> ejecta could enrich neighboring minihalo -> stars like HE 1327-2326 could formed in ex-situ -> supported by outer halo nature (*Gaia* DR2)
- This scenario could explain the abundance inhomogeneities found in UMP stars [Fe/H]<-4.0 -> Presence of different enrichment channels in the early Universe