Core-collapse supernovae: PUSH method and Nucleosynthesis

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What can spherical approximations do for us?

- Want to address questions such as
  - What are conditions for explosive nucleosynthesis?
  - Connection between progenitor and remnant?
  - How are they related to explosion dynamics and energetics?
  - Nucleosynthesis predictions from many models (eg for GCE)

Induced explosions

- Traditionally used: piston or thermal bomb
  - No neutrinos and no PNS
  - → What happens t electron fraction Ye?
  - Ejecta mass? Especially Ni and Fe-group abundances

- Mimic effects of multi-D simulations in 1D ("absorption" method)
  - Increase neutrino absorption and emission rates in heating region
  - Limitations: large factors change system beyond additional energy deposition

Liebendoerfer (2004)
Frohlich+(2006a)
Fischer+(2010)

The PUSH method

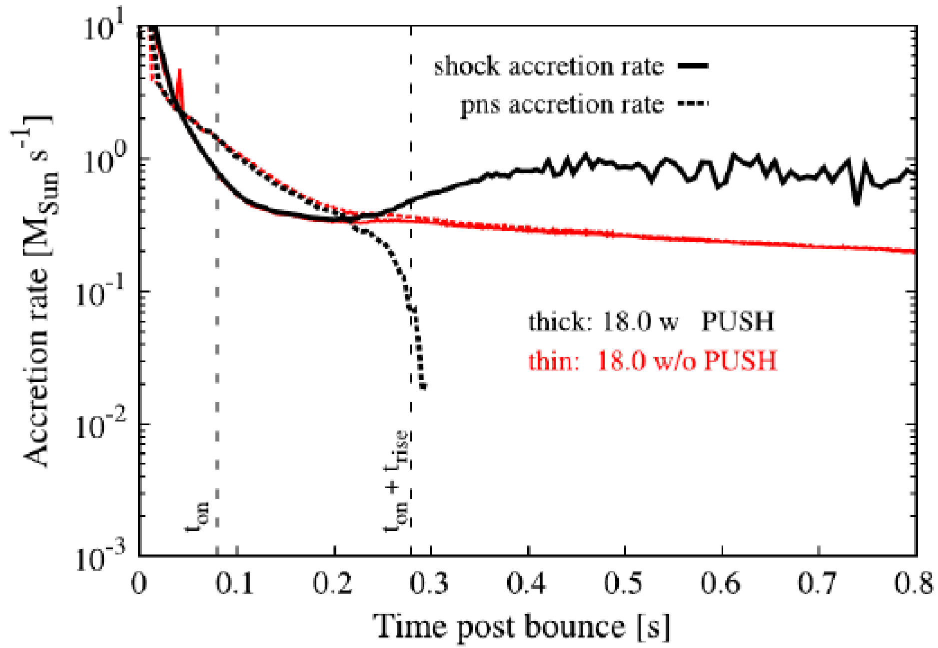
- Based on neutrino-driven mechanism:
  - Increased heating and residence time in multi-D
- Only charged-current reactions link neutrons to protons (nucleosynthesis!)
- Provide additional heating by tapping the mu and tau (anti)neutrinos in otherwise consistent spherically symmetric simulations
- Advantages: robust and general description, preserves properties of electron-type neutrinos, consistent PNS evolution

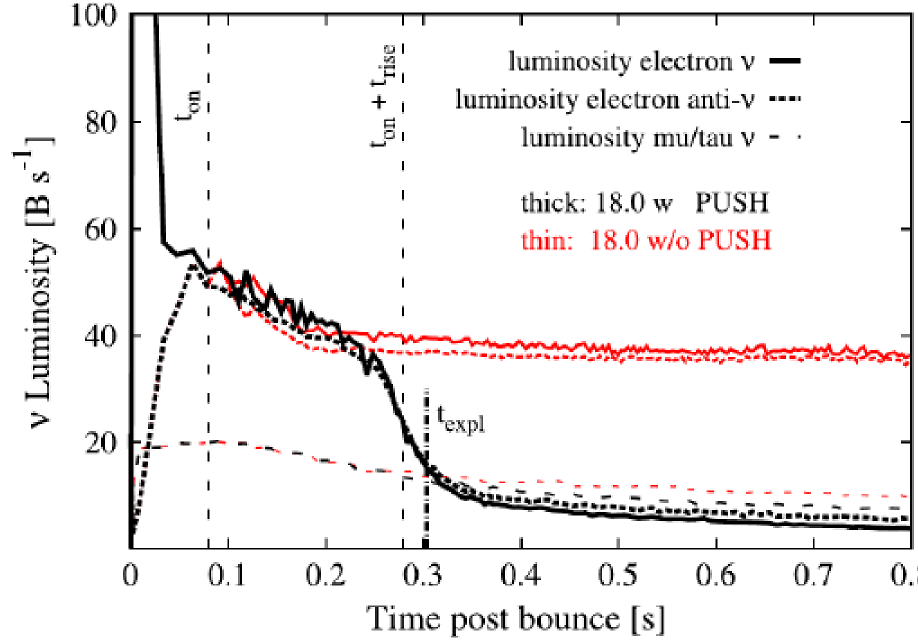
→ Bridges gap between nucleosynthesis needs and still very expensive multi-D models

Perego, et al (2015)

The PUSH method

- PUSH method

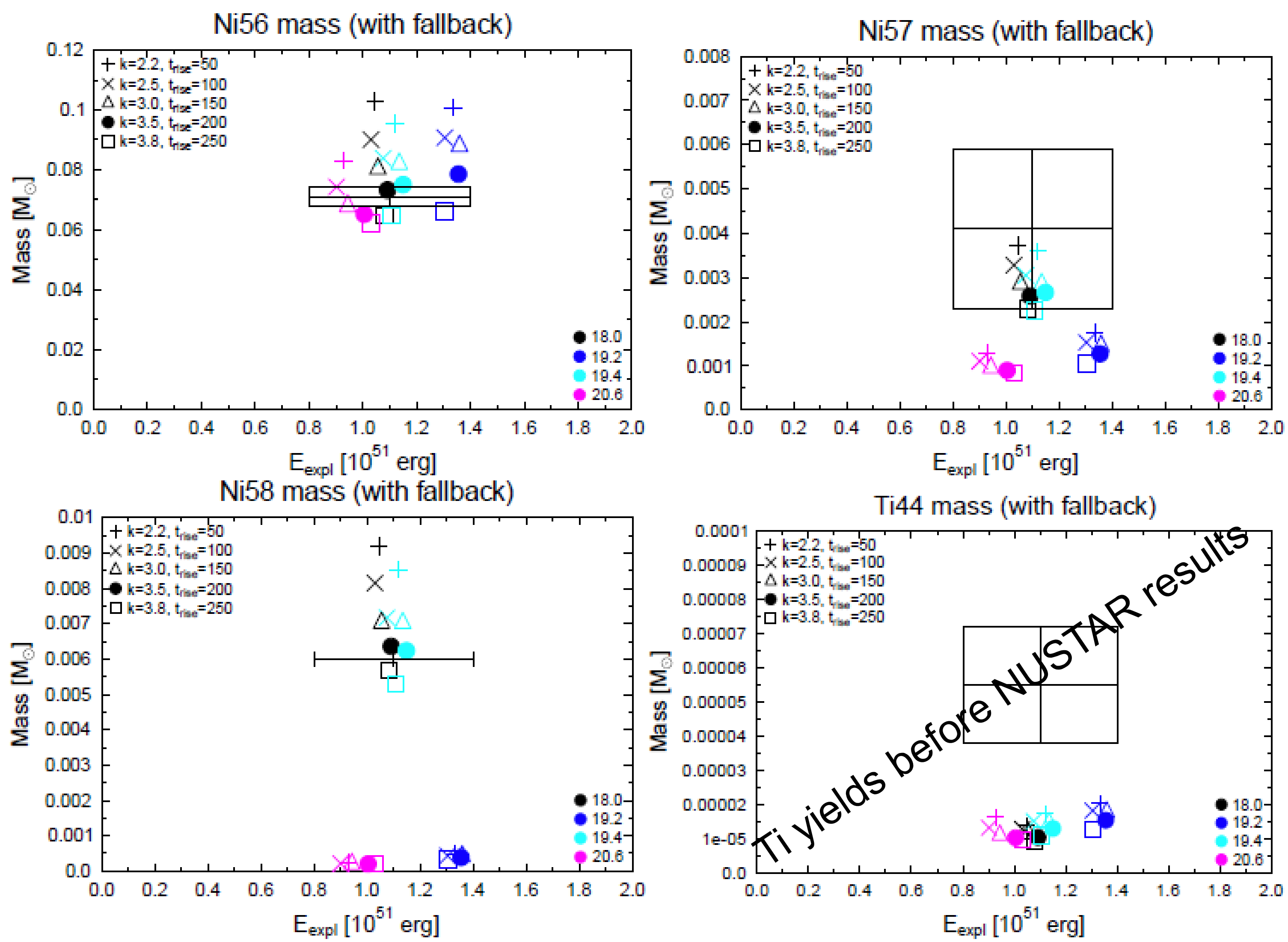




- 1D without PUSH: drastic decrease in heating by electron-type neutrinos after the onset of the explosion

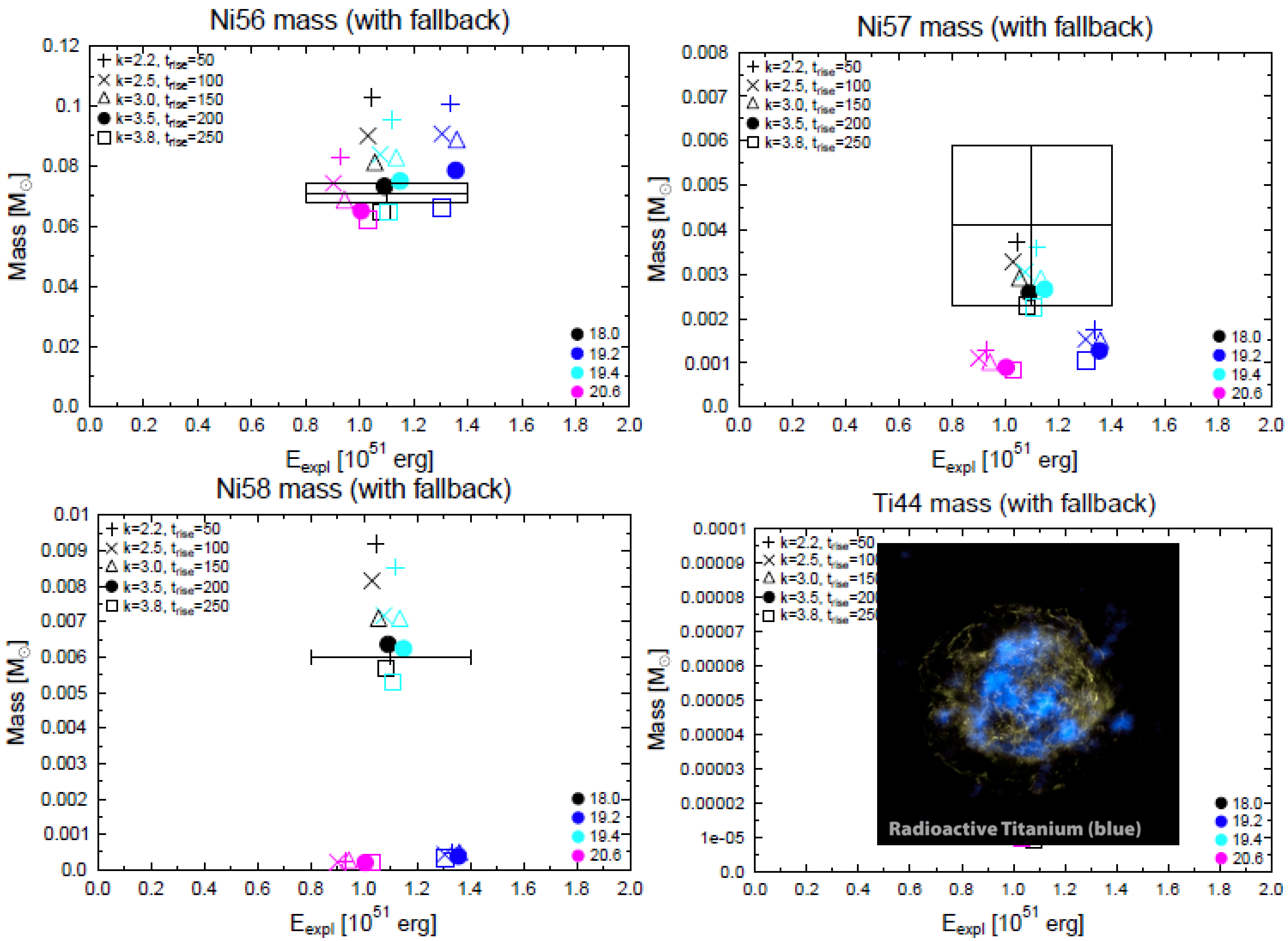
Perego, et al (2015)

SN1987A: Calibration of PUSH



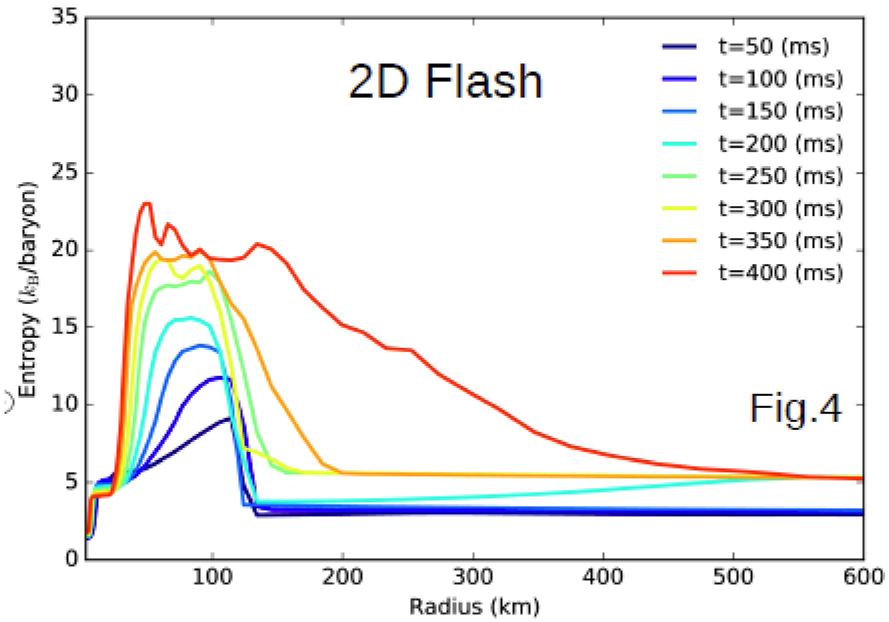
Perego et al (2015)

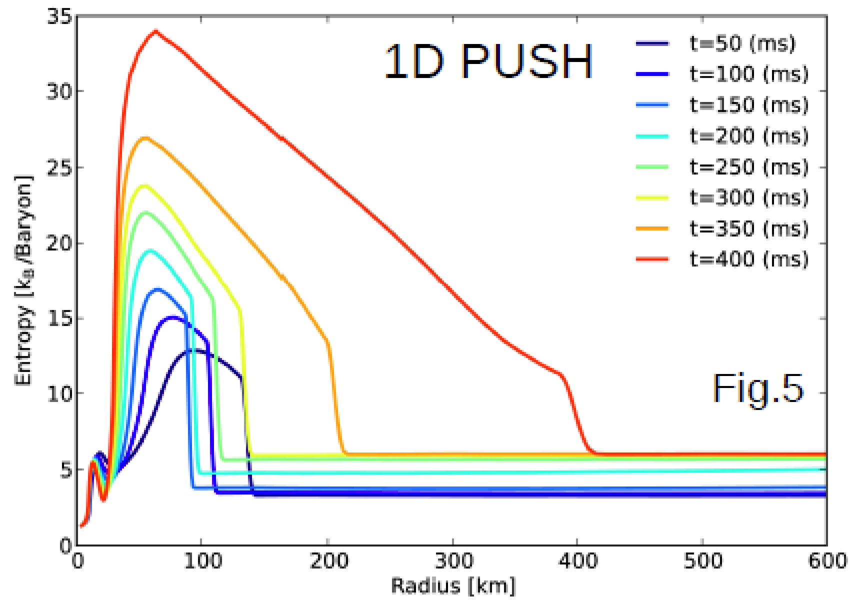
SN1987A: Calibration of PUSH



Perego et al (2015)

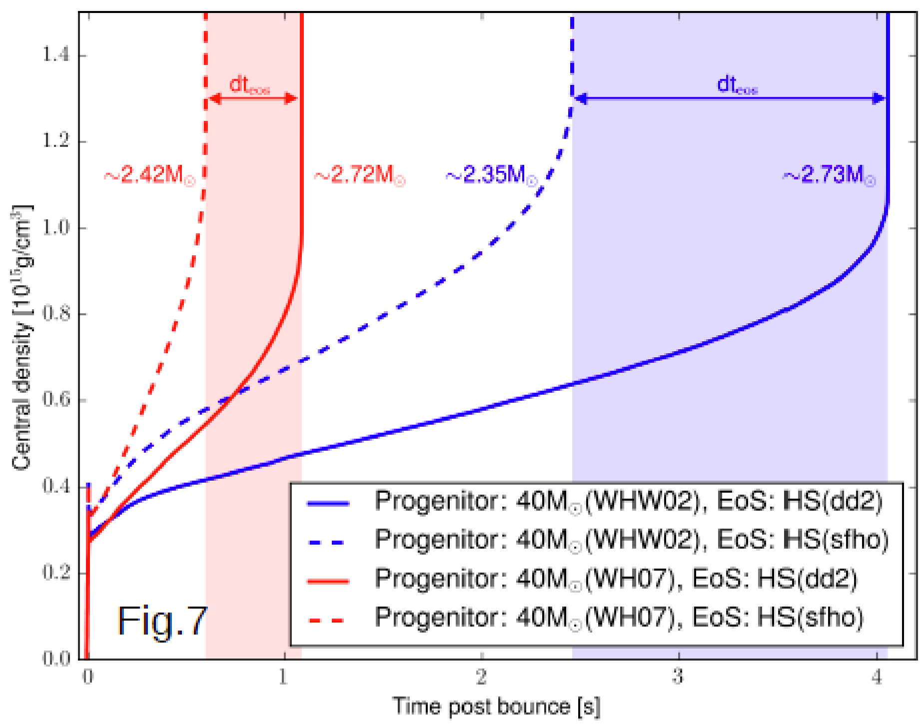
Comparison to multi-D





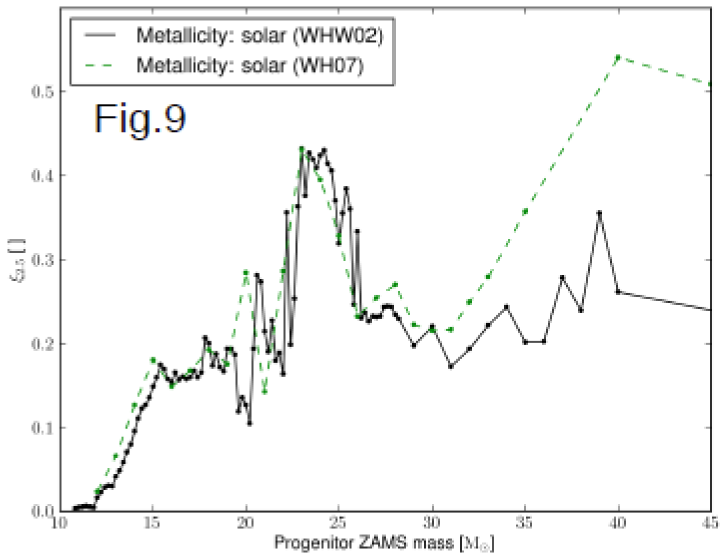
Ebinger et al (in prep)

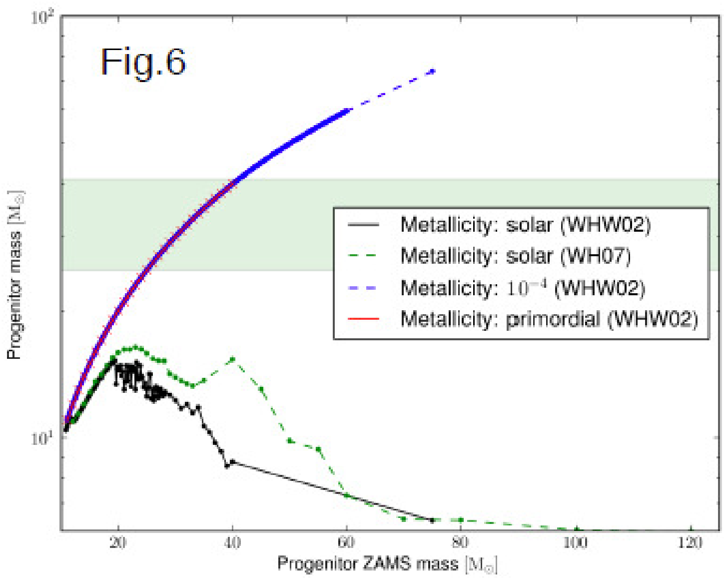
BH formation: EOS dependence

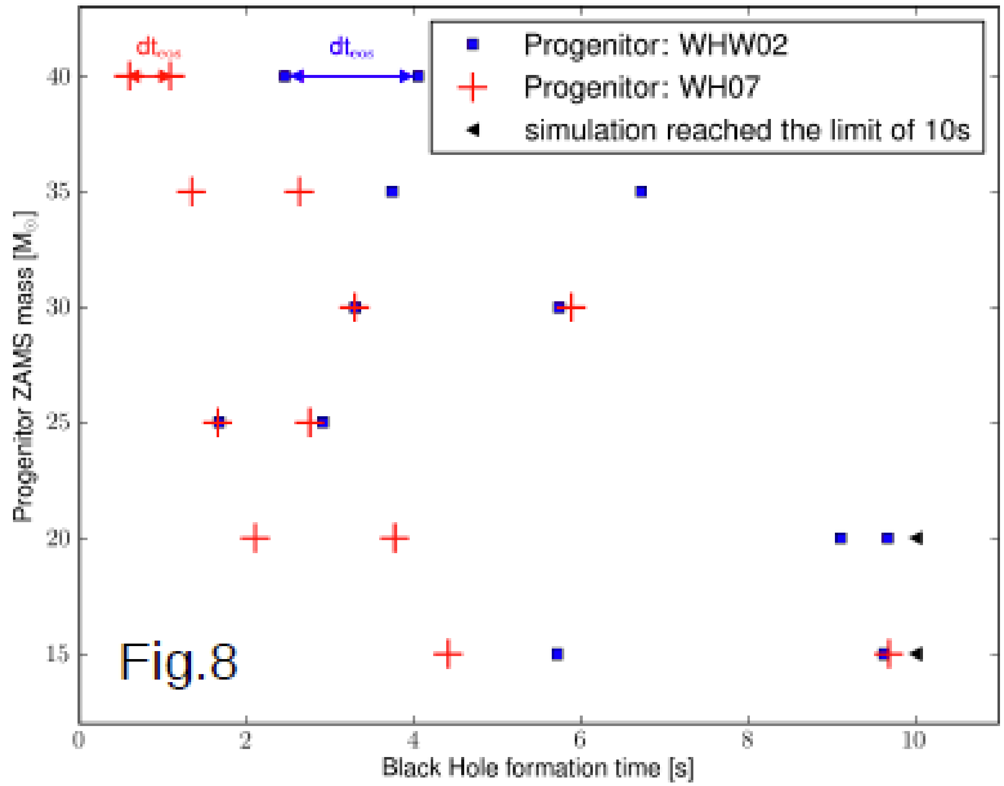


Ebinger et al (in prep)

BH formation: Progenitor dependence



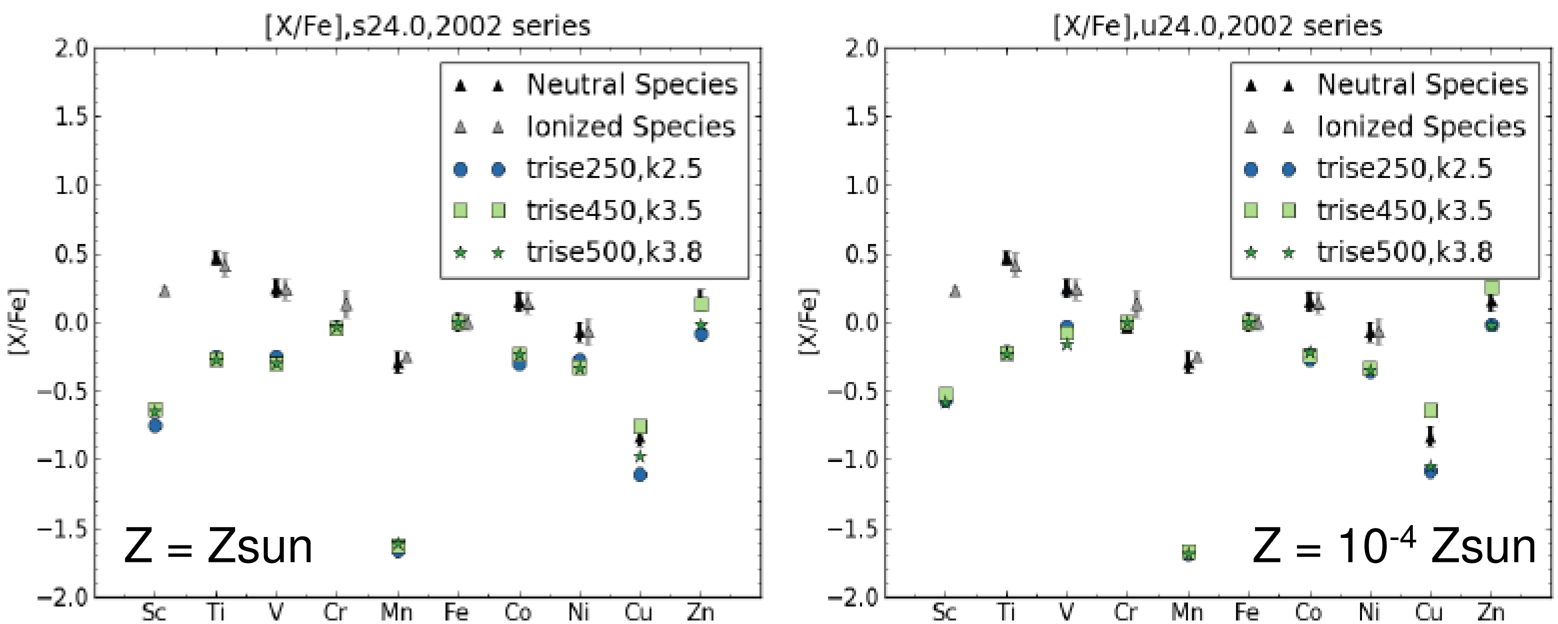




Ebinger et al (in prep)

Fe-group nucleosynthesis

- Comparison with metal-poor stars
  - Data (HD 84937): Sneden et al (2016) with improved laboratory data for Fe-group elements
  - Mn is a puzzle

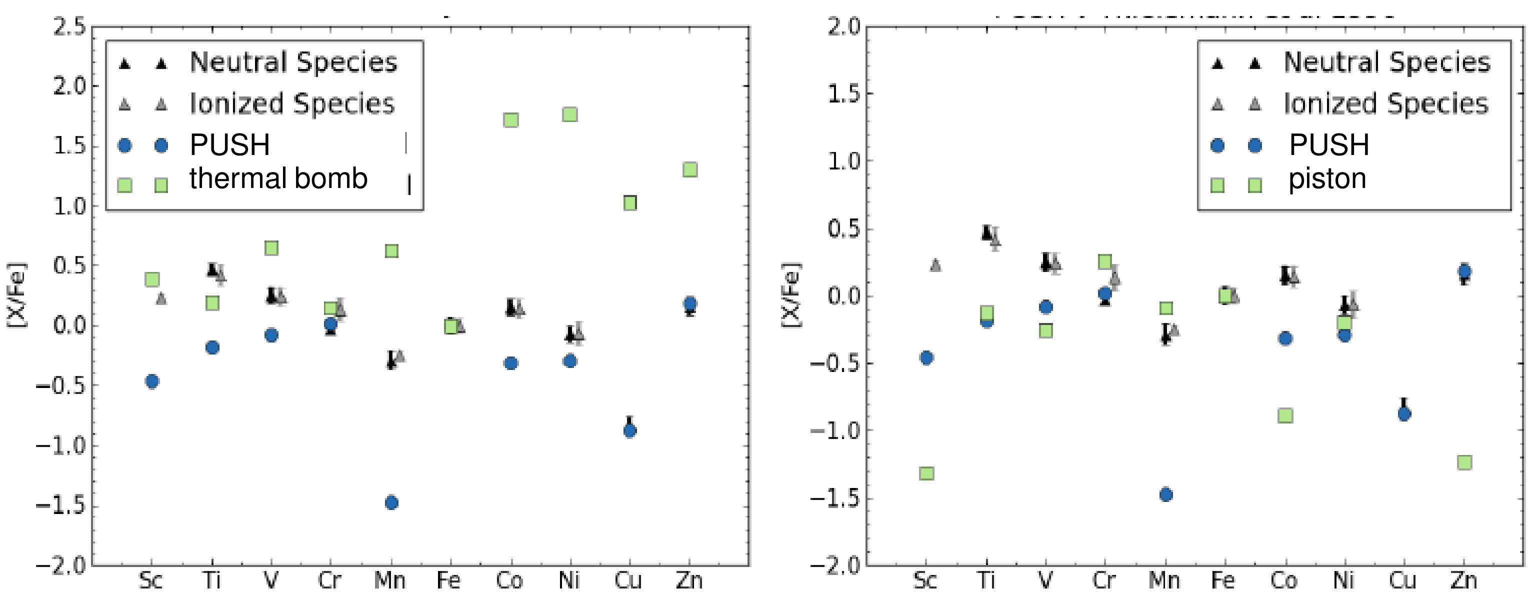


Sinha et al (in prep)

Fe-group nucleosynthesis

- Comparison with previous studies (piston and thermal bomb)
  - For Fe-group: PUSH yields are comparable or a better match to observations than previous predictions

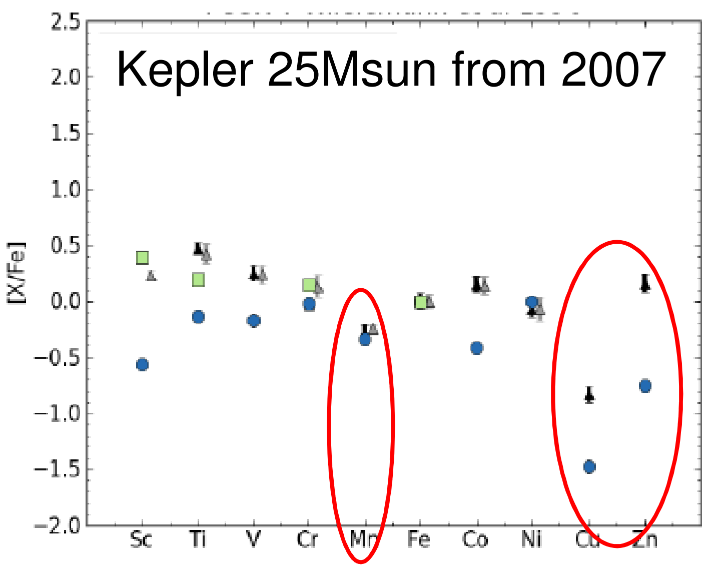
Progenitor ZAMS mass: 25 Msun

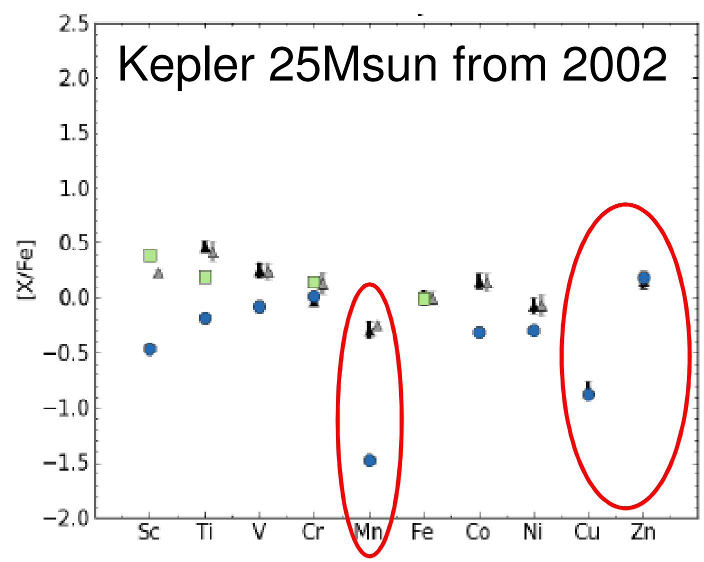


Sinha et al (in prep)

Fe-group nucleosynthesis

- Comparison of different progenitor models
  - Not much variation due to exact values of PUSH parameters (see earlier slide)
  - WH07 progenitors: improved Mn !
  - Need to better understand stellar evolution





Sinha et al (in prep)

Conclusions

- It matters what we start with (progenitor structure; details of stellar evolution)
- It matters how we explode it (piston/thermal bomb vs PUSH vs multi-D)
- It matters what we compare to (metal-poor stars, chemical evolution; light curves, radioactivities)

- Stay tuned for BHs and CCSN yields from PUSH