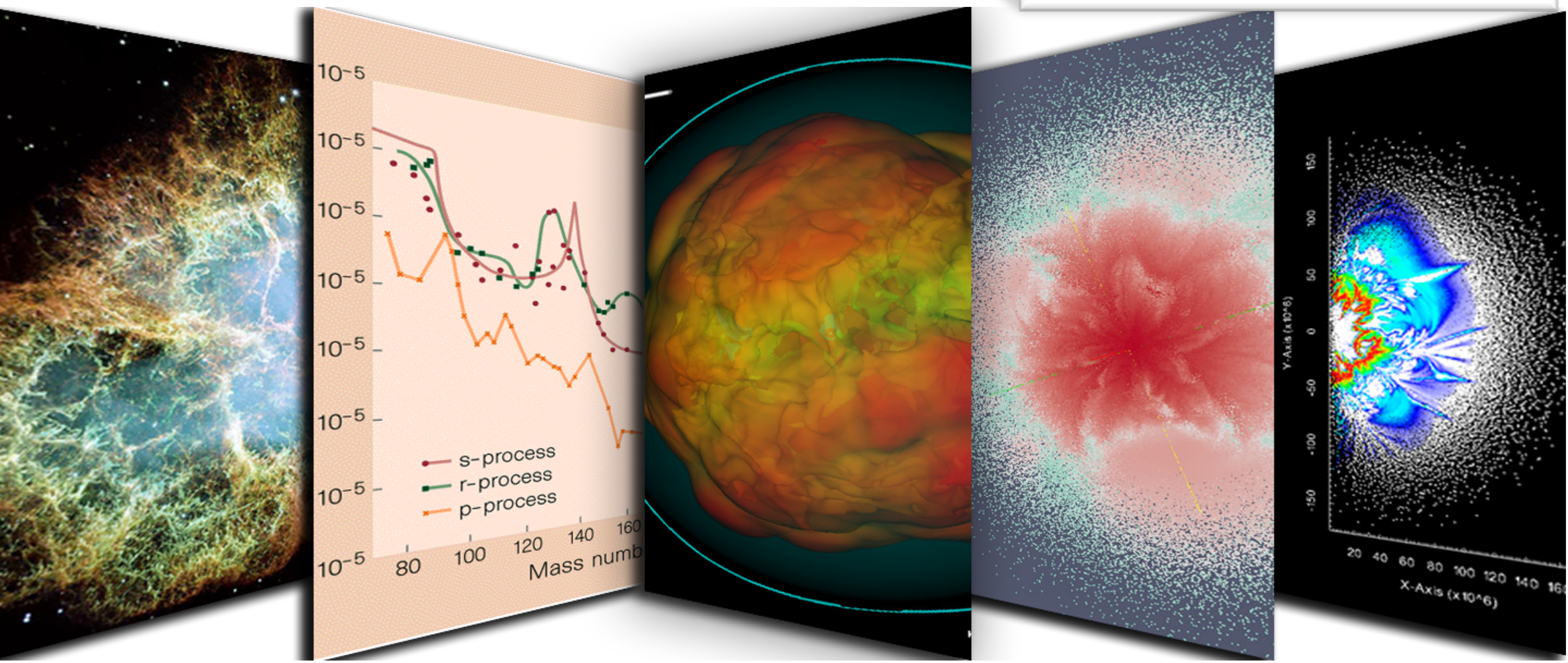
NAS-CE project:
Nuclear Astrophysics in Supernovae and Chemical Evolution



Claudia Travaglio
INAF - Torino (Italy)

Work done, Collaborations, facilities

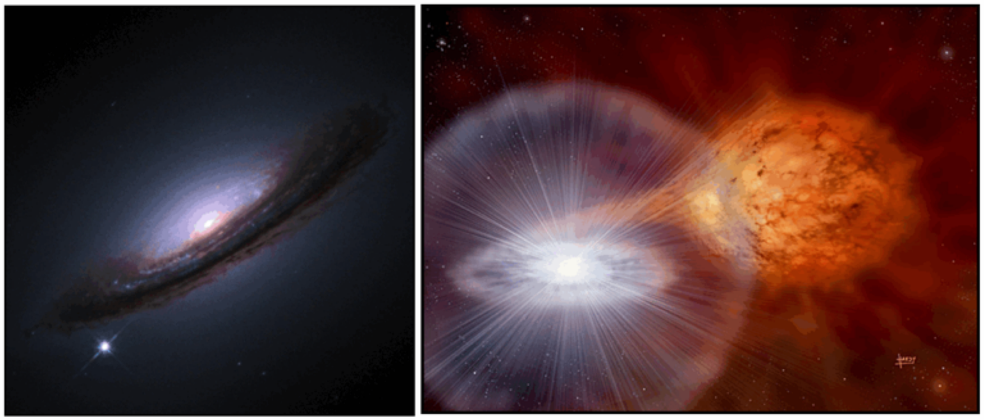
- Nucleosynthesis in thermonuclear supernovae (collaboration with F.-K. Roepke, University of Heidelberg)

- Nucleosynthesis in core collapse supernovae (in collaboration with T.-H. Janka & A. Wongwathanarat, MPA-Munich; L.A. Squillante, Turin)

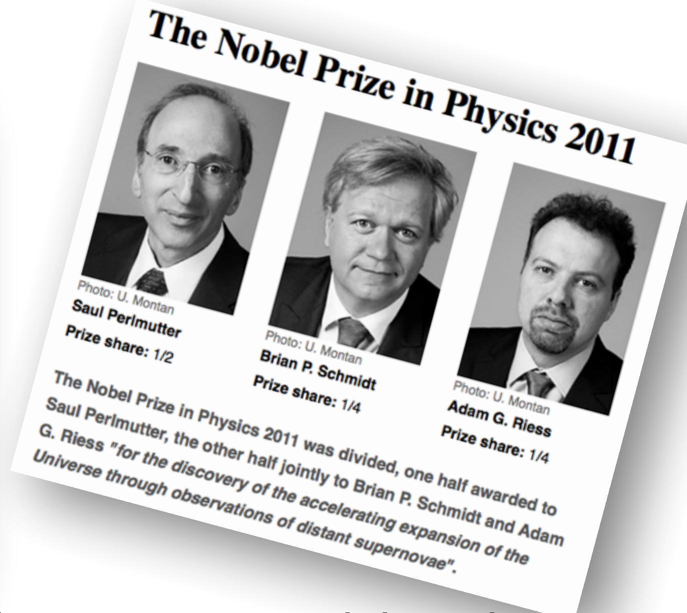
- Chemo-dynamical evolution in the cosmos: simple approach and SPH (in collaboration with S. Bisterzo, INAF-Turin and B. Cote', MSU)

- Computer facilities: University of Frankfurt (ref. R. Reifarth), B2FH (ref. C. Travaglio)

Thermonuclear supernovae



SN 1994d in NGC 4526 — White dwarf with companion



Although the observations suggest a **single-degenerate** model, other recent studies have shown evidence for explosions birthed under the **double-degenerate** model or **WD mergers**. This means that the precursors to some Type Ia supernova may host companion stars, while others pair up with white dwarfs.

Conclusion: what is a Type Ia is still under debate, who is the progenitor, how behave the binary system, which chemistry comes from there…..it is all still under debate. This is fundamental to understand their contribution to chemical enrichment of the cosmos but also to use them to measure cosmological distances.

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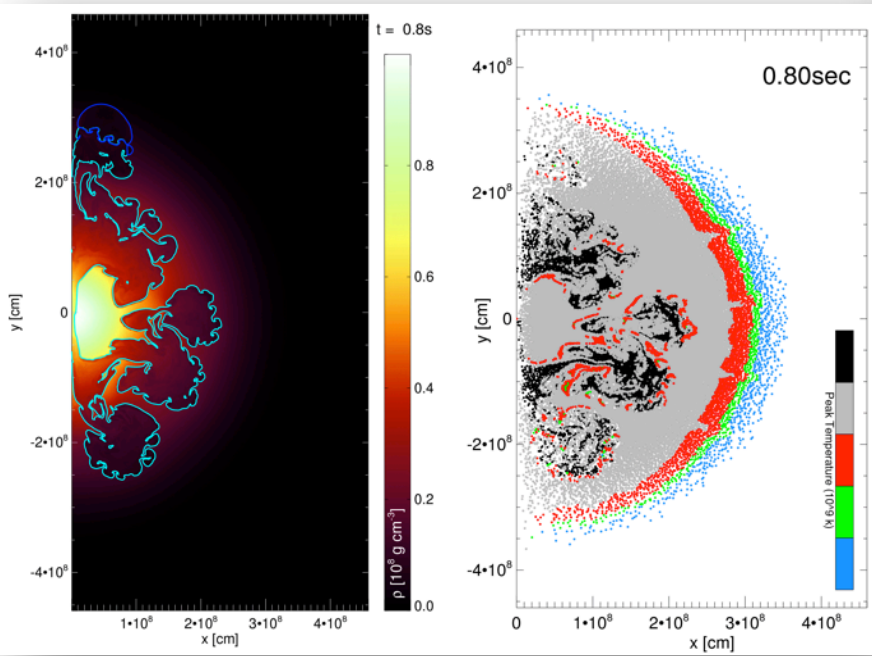
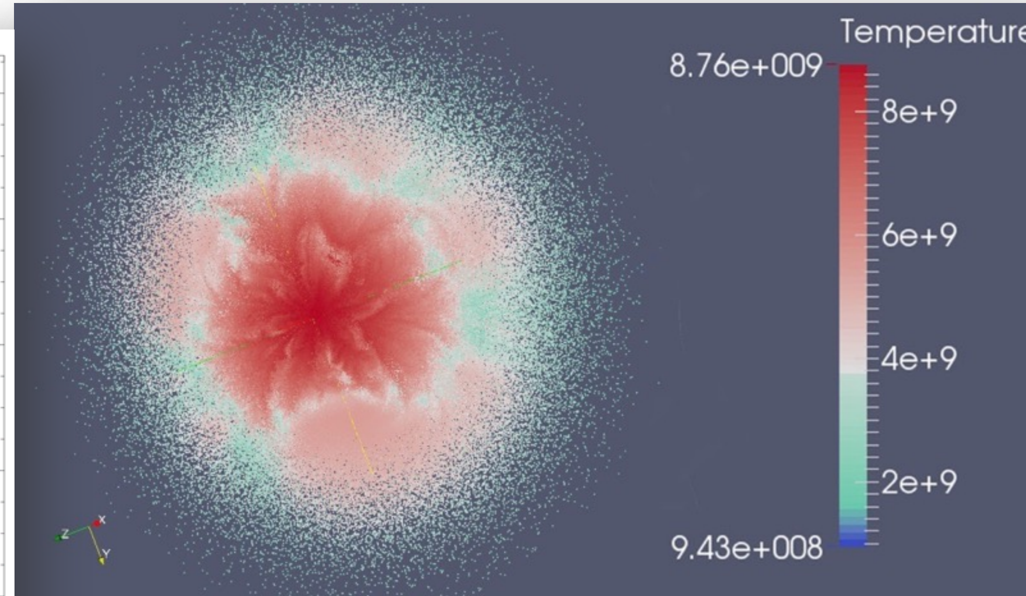
Single degenerate scenario, standard M_{CH}

SNIa **2D**, 51200 tracers, Roepke, Travaglio et al.



SNIa, **3D**, 1 million tracers, Seitenzahl, Ropke, Travaglio et al.



Nucleosynthesis code: **TONiC, Torino Nucleosynthesis Code (*Travaglio et al. 2011*)**, ~3000 isotopes, includes electron captures, neutron captures, alpha captures and photodisintegrations and an updated reaction rates network (using Basel reaclib 2009 for theoretical rates and the most updated experimental measurements available)

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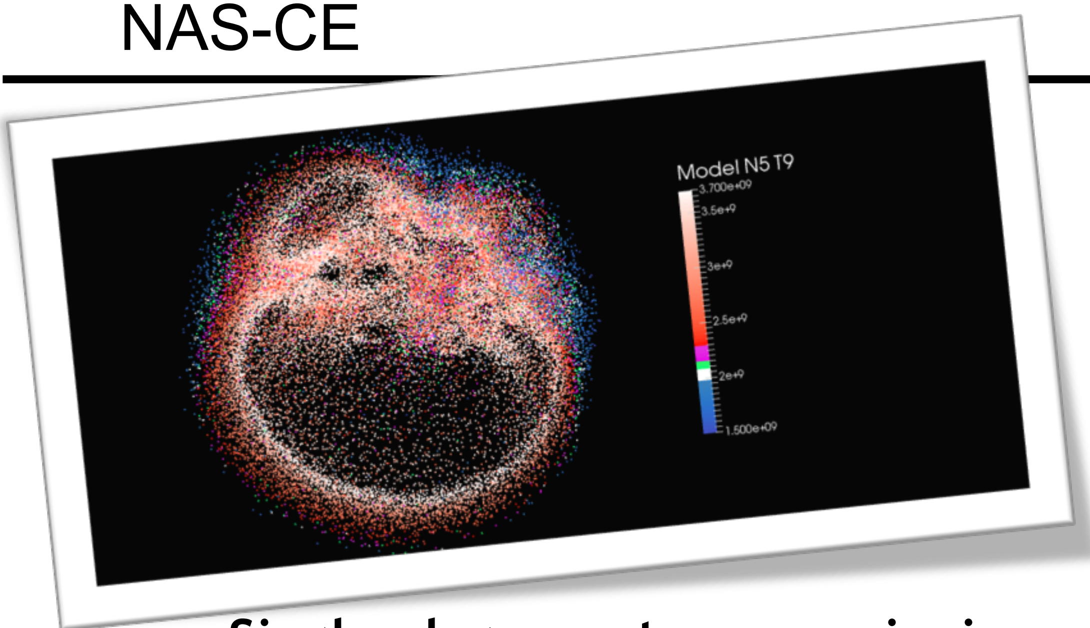


WE DEMONSTRATED THAT ...

Single degenerate scenario is needed: it is very important to explain the observed abundances in the Solar System (*Travaglio et al. 2015, Travaglio et al. 2017 in prep.*).

ONGOING PROJECT

In collaboration with Prof. F. Roepke (University of Heidelberg) we are analyzing, using the same methodology, **white dwarf merger systems** as possible/alternative source of thermonuclear supernovae.

☒ Mn

(Bravo, A&A 2012, Seitenzahl et al. A&A 2013, Travaglio et al. 2017 in prep.)

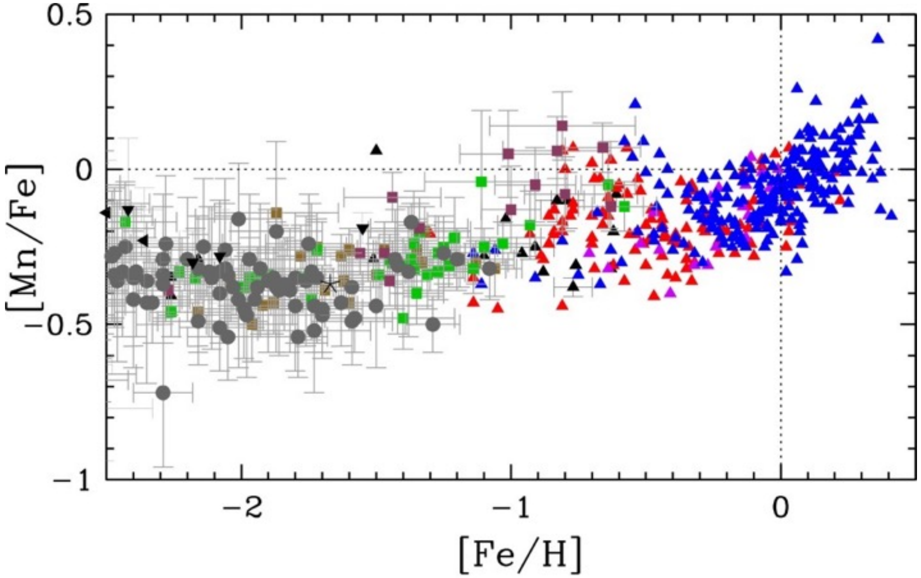
❑ p-process

(Travaglio et al. ApJ 2015)

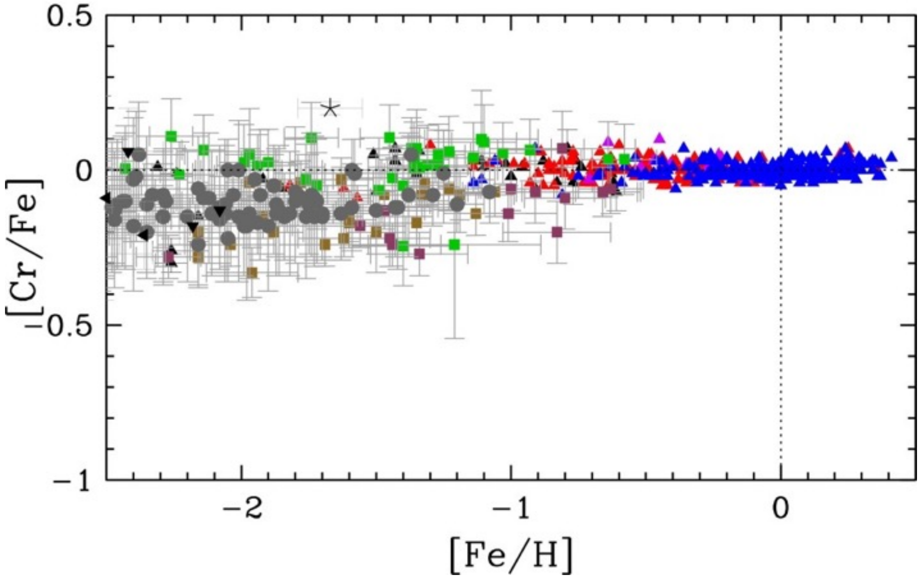
Hints from observations

In our Galaxy and in external galaxies (like dSph) Mn and Cr have been observed in many unevolved stars at different ages/metallicities.

What can we learn from these observations?

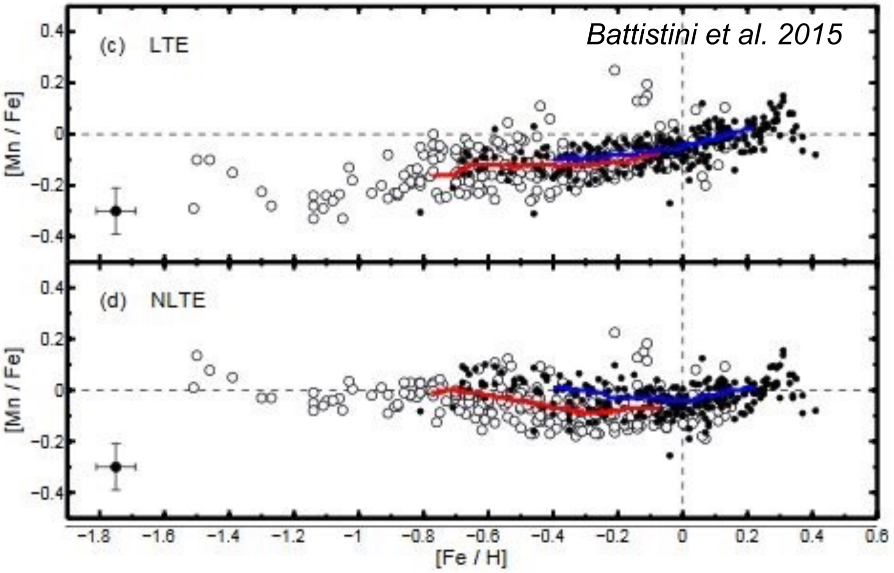


Mn



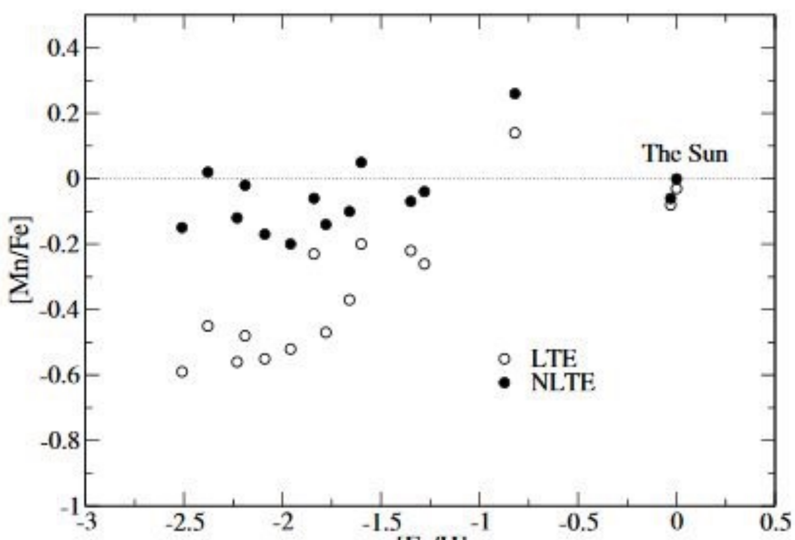
Cr

Ref.
Battistini & Bensby (2015), blue triangles (thin disk), red triangles (thick disk), black triangless(halo), grape triangles (unclassified).
Ishigaki, Aoki, & Chiba (2013), squares (sienna and green are outer/inner halo stars), purple squares (thick disk).
Roederer et al. (2014), grey circles

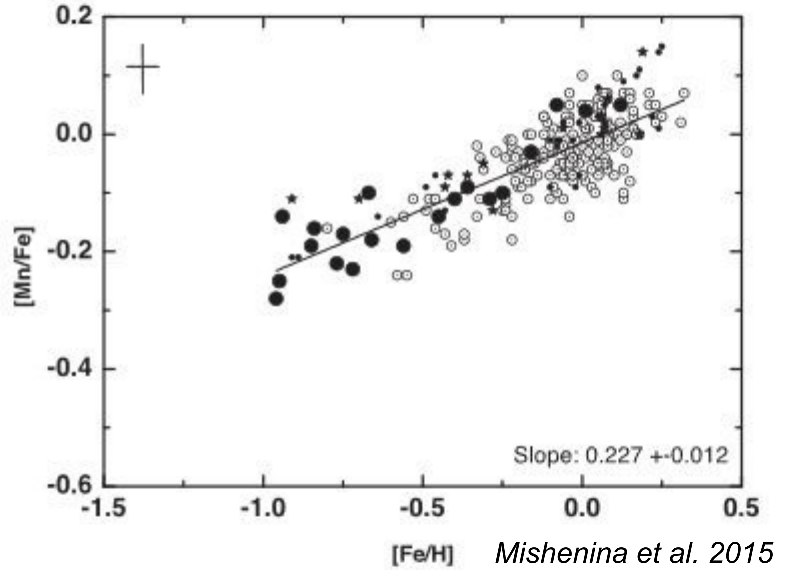


Mn: LTE/NLTE open problem

The development of an adequate model of Mn atoms to account for the effects of deviations from LTE is complicated by the absence of detailed computations of atomic data, such as photoionization cross-section or parameters of radiative and shock transitions.
The use of approximations such as an H-like approximation for Mn atoms, yields NLTE corrections that are not robust.
Taking all this into account, we believe instead that the LTE determinations for the Mn abundance are correct within the given uncertainty of 0.1 dex. *(Mishenina et al. 2015)*

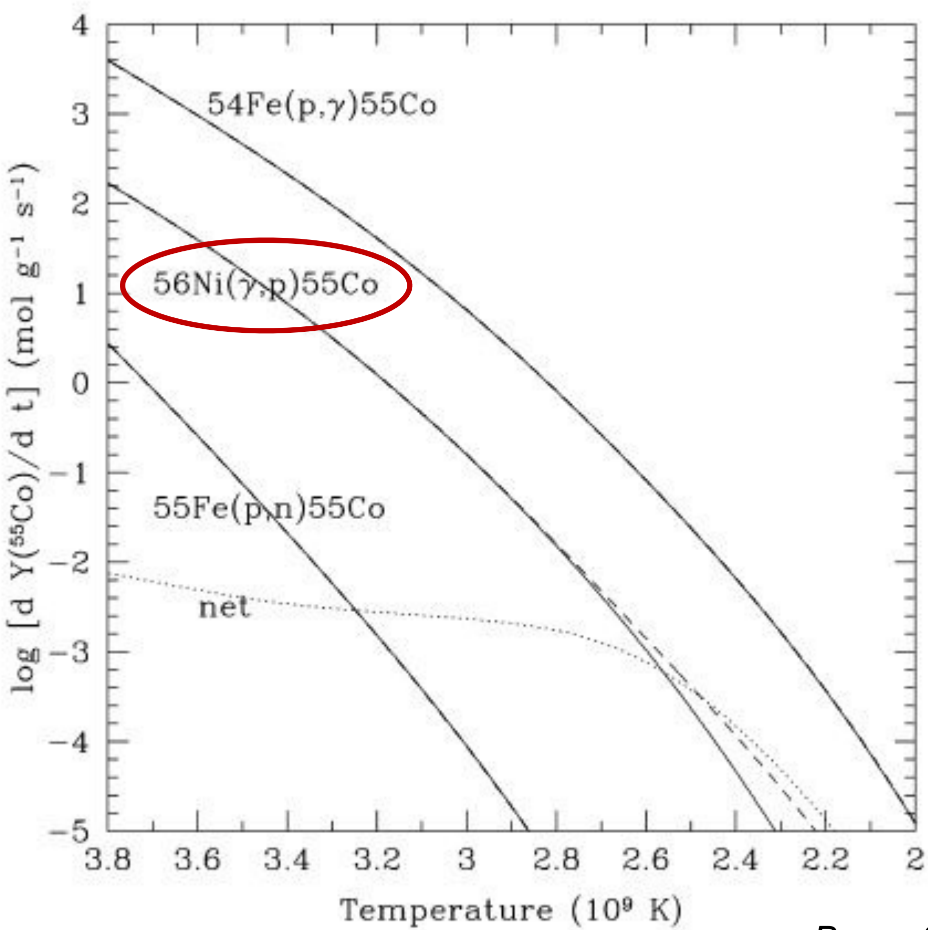


Bergemann et al. 2008



Mishenina et al. 2015

Where does the observed Mn it come from?



Bravo 2013

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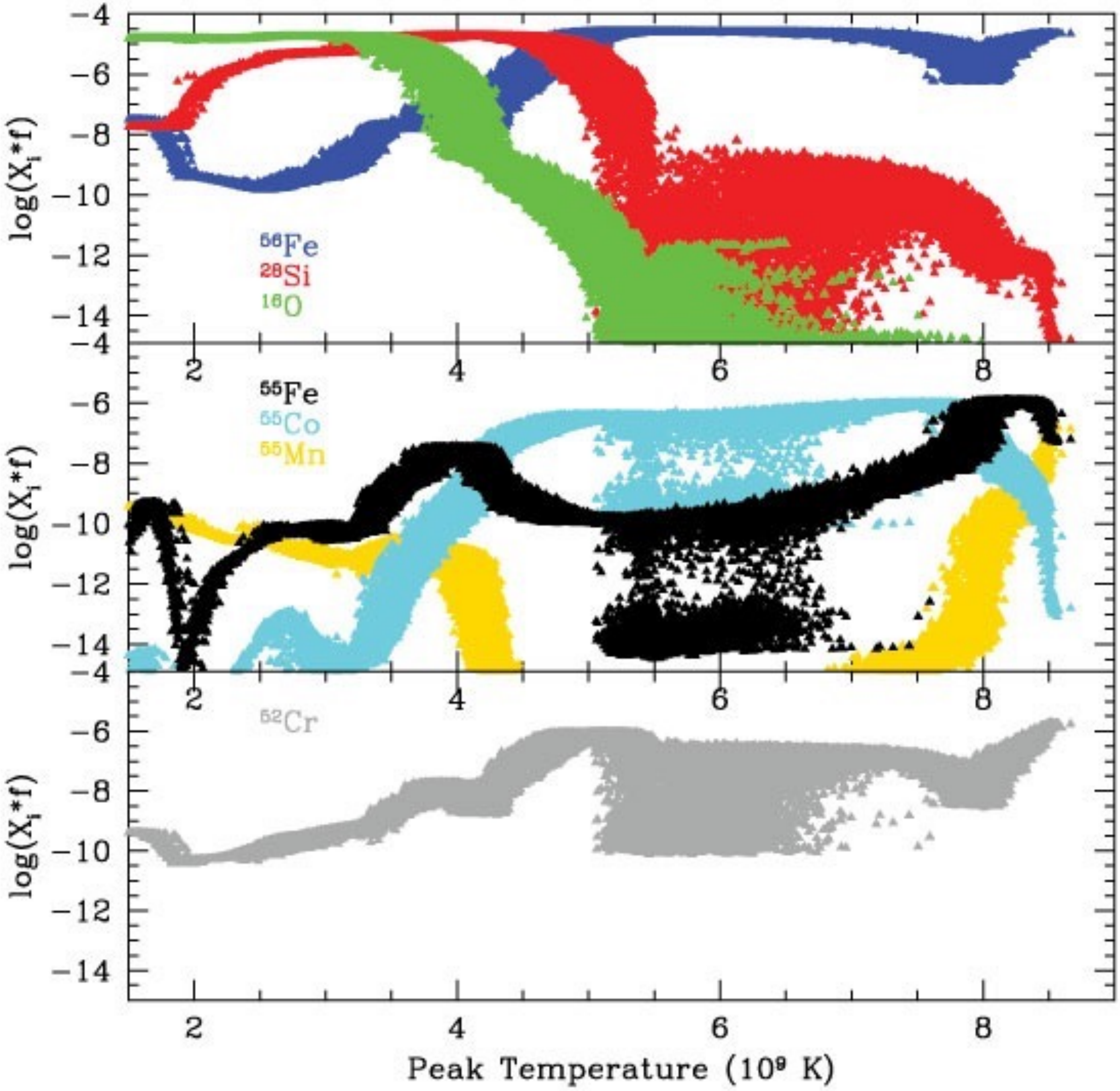
SNIa single degenerate scenario 2D, 51200 tracer particles



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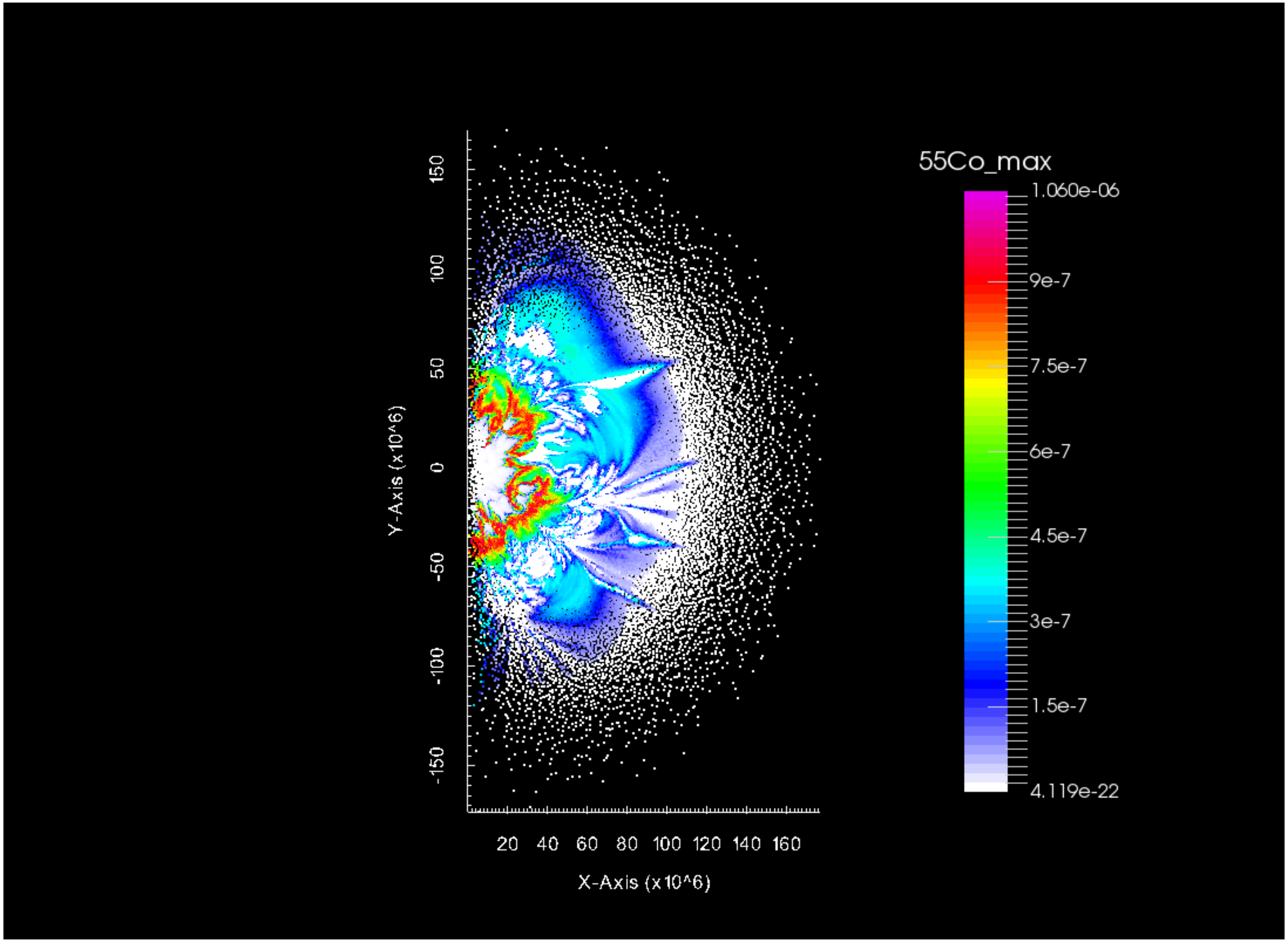
^{55}Co in a thermonuclear supernova



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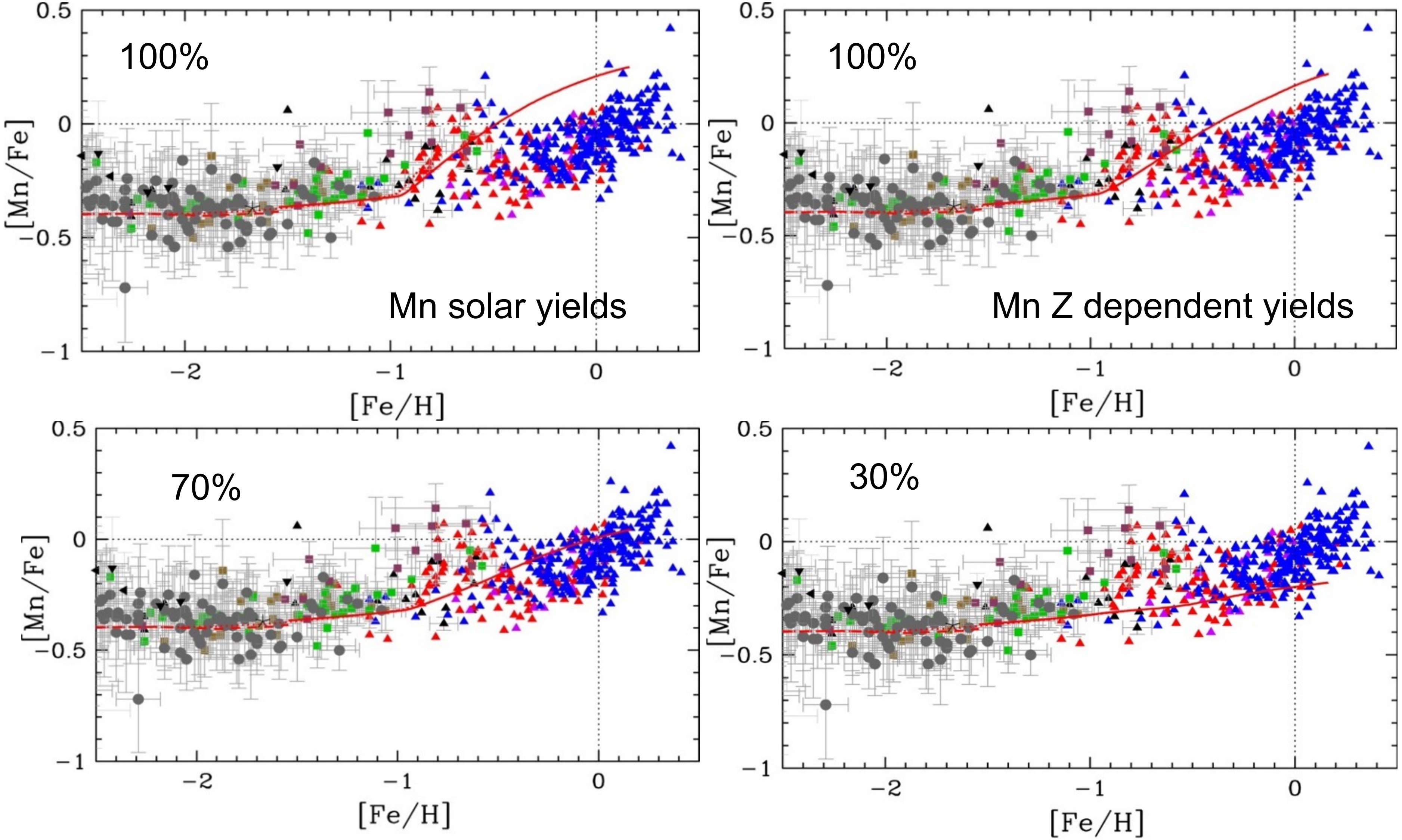
Rate of single degenerate scenario *Travaglio et al. 2017a (in preparation)*



Conclusion

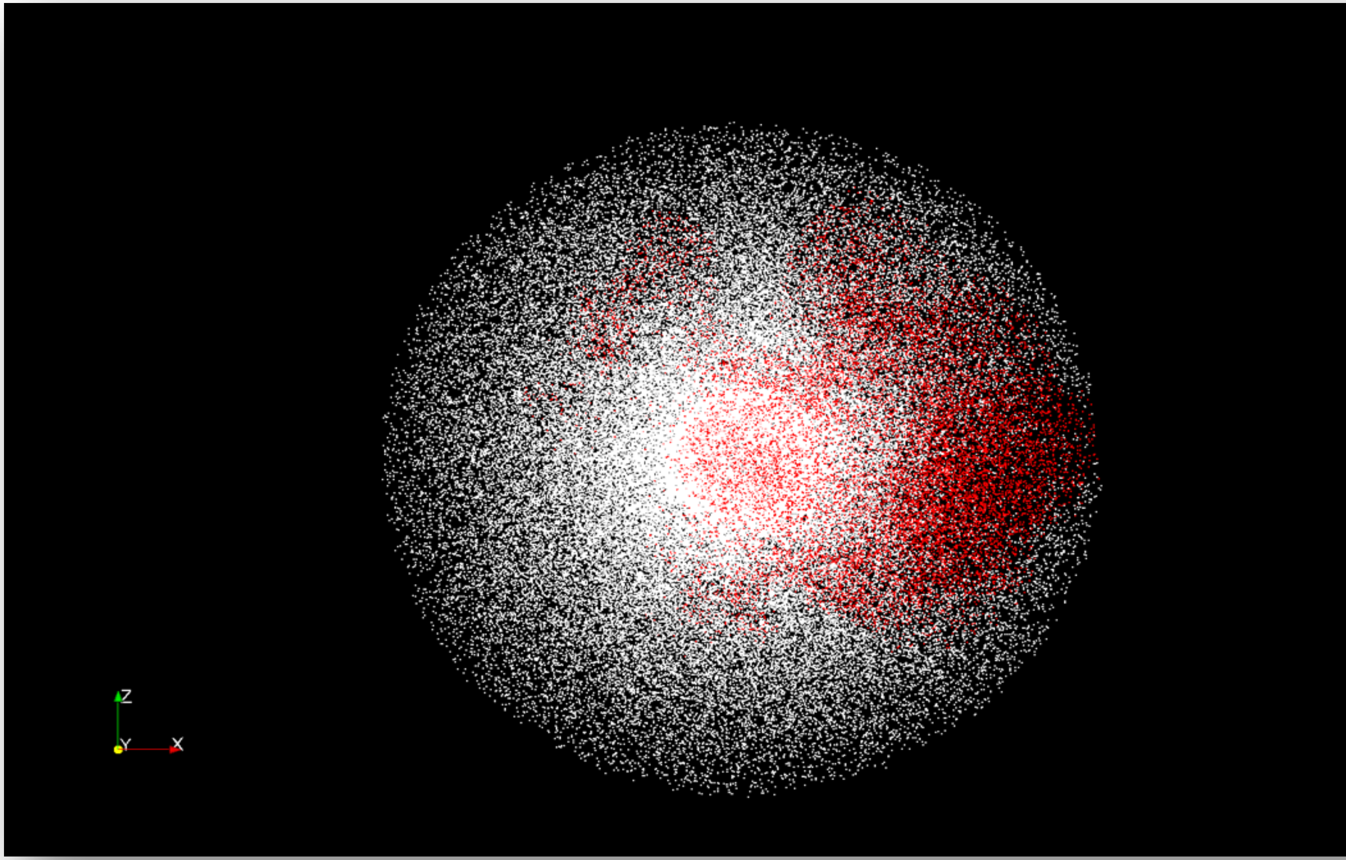
SNIa single degenerate scenario with a rate of **30-50%** is needed to explain the observed Mn and p-nuclei

(Travaglio et al. 2017a,b, in preparation)

Nucleosynthesis in 1D - 3D SNII: new project

Post-processing of tracer particles is required for nucleosynthesis predictions beyond the built-in small network.

W15-1-cw from A. Wongwathanarat et al. 2015. Work done on tracers done by myself + L.A. Squillante



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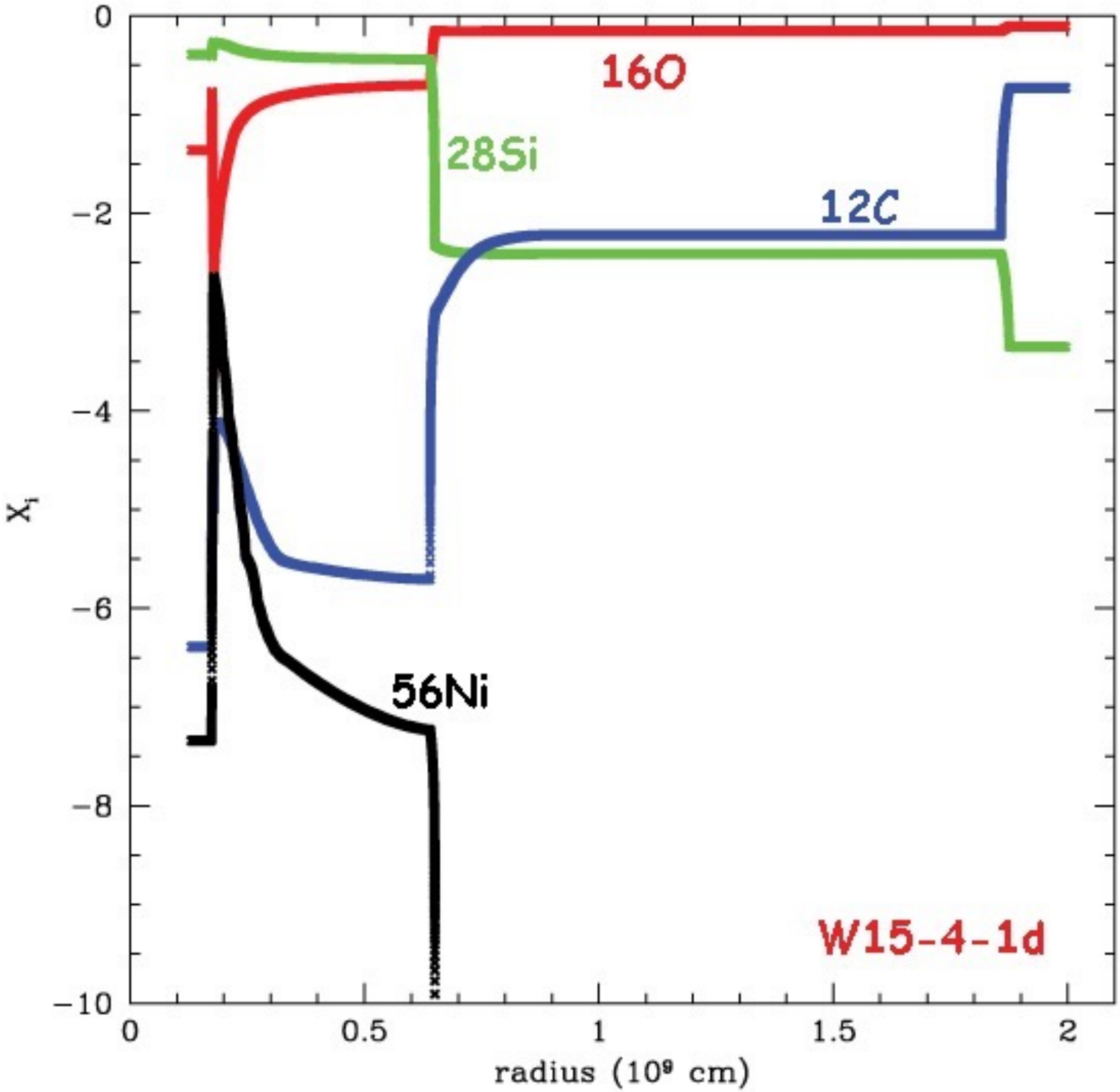
1 D



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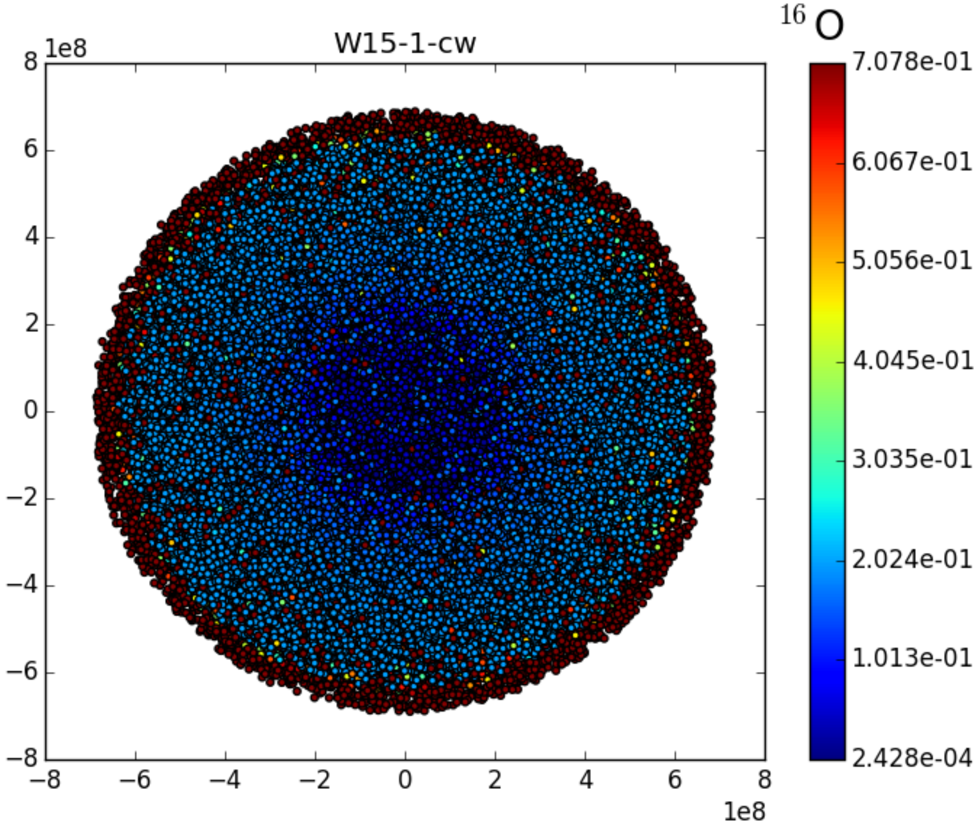
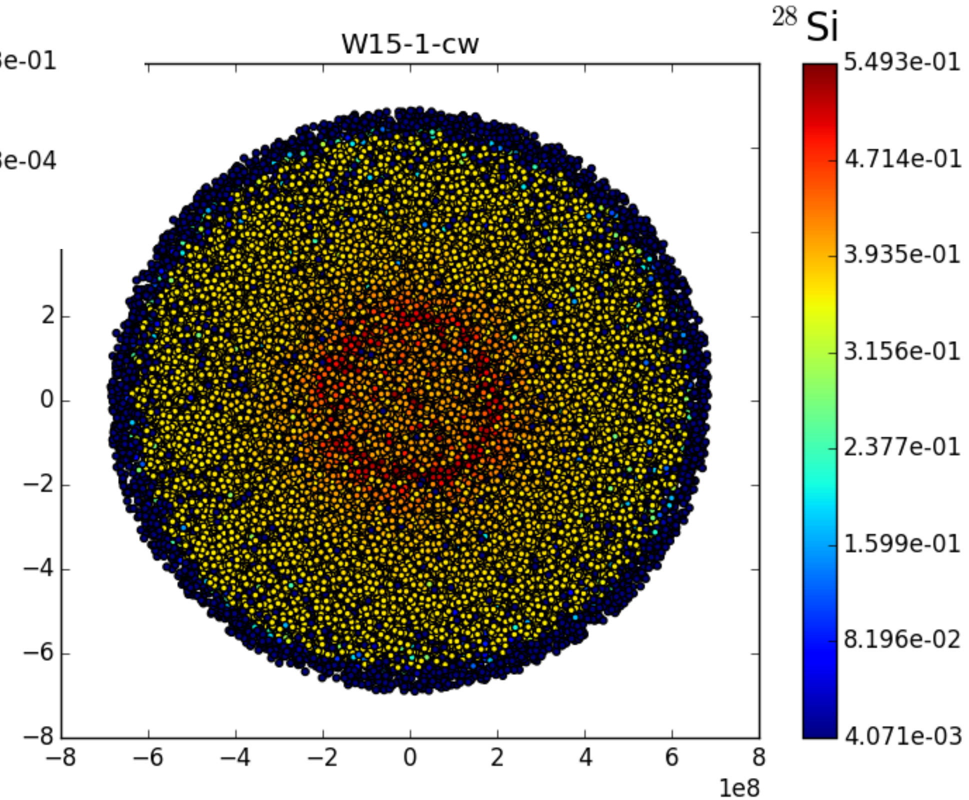
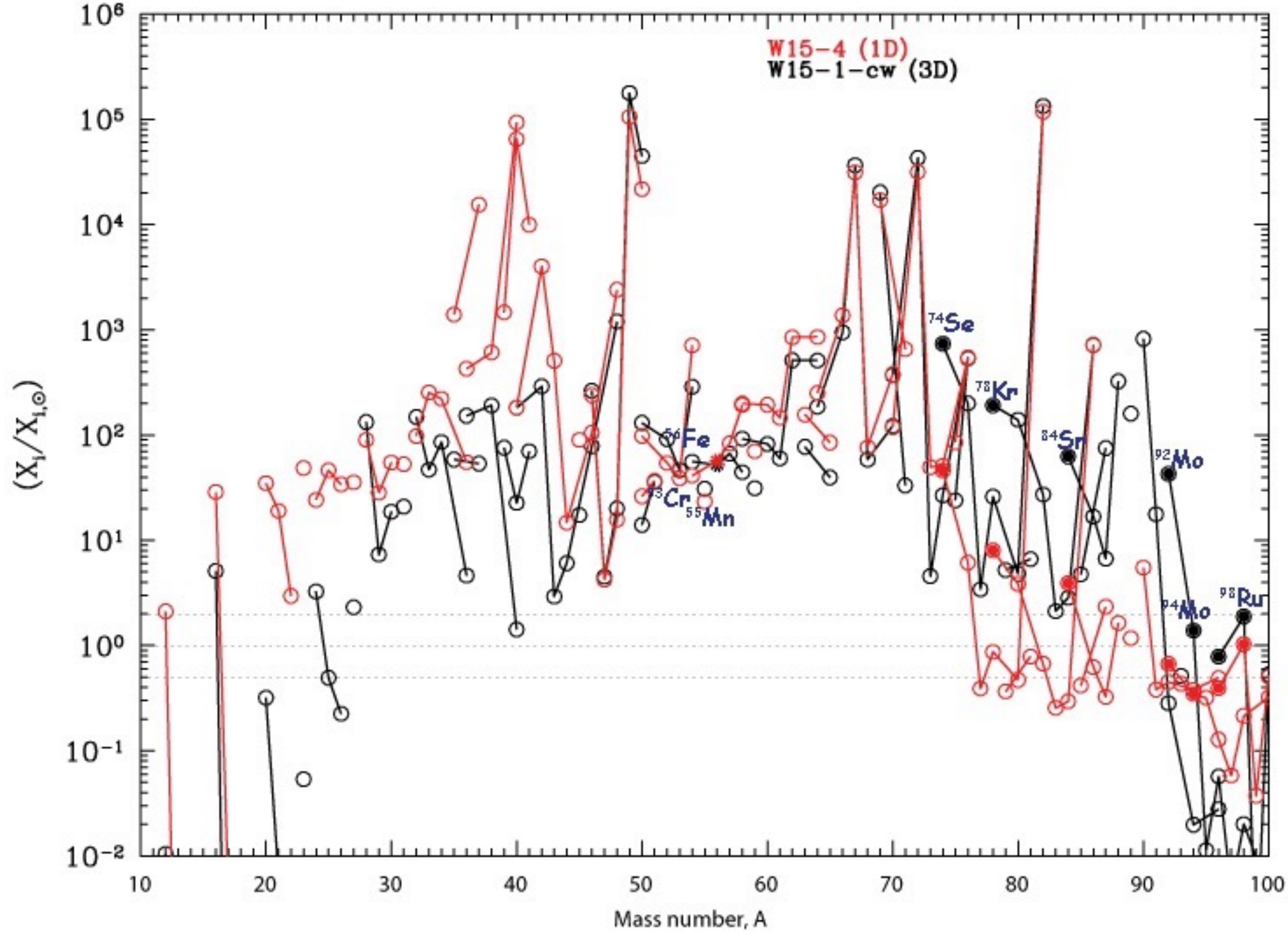

W15-1-cw
^{16}O
7.078e-01
6.067e-01
5.056e-01
4.045e-01
3.035e-01
2.024e-01
1.013e-01
2.428e-04
1e8
1e8

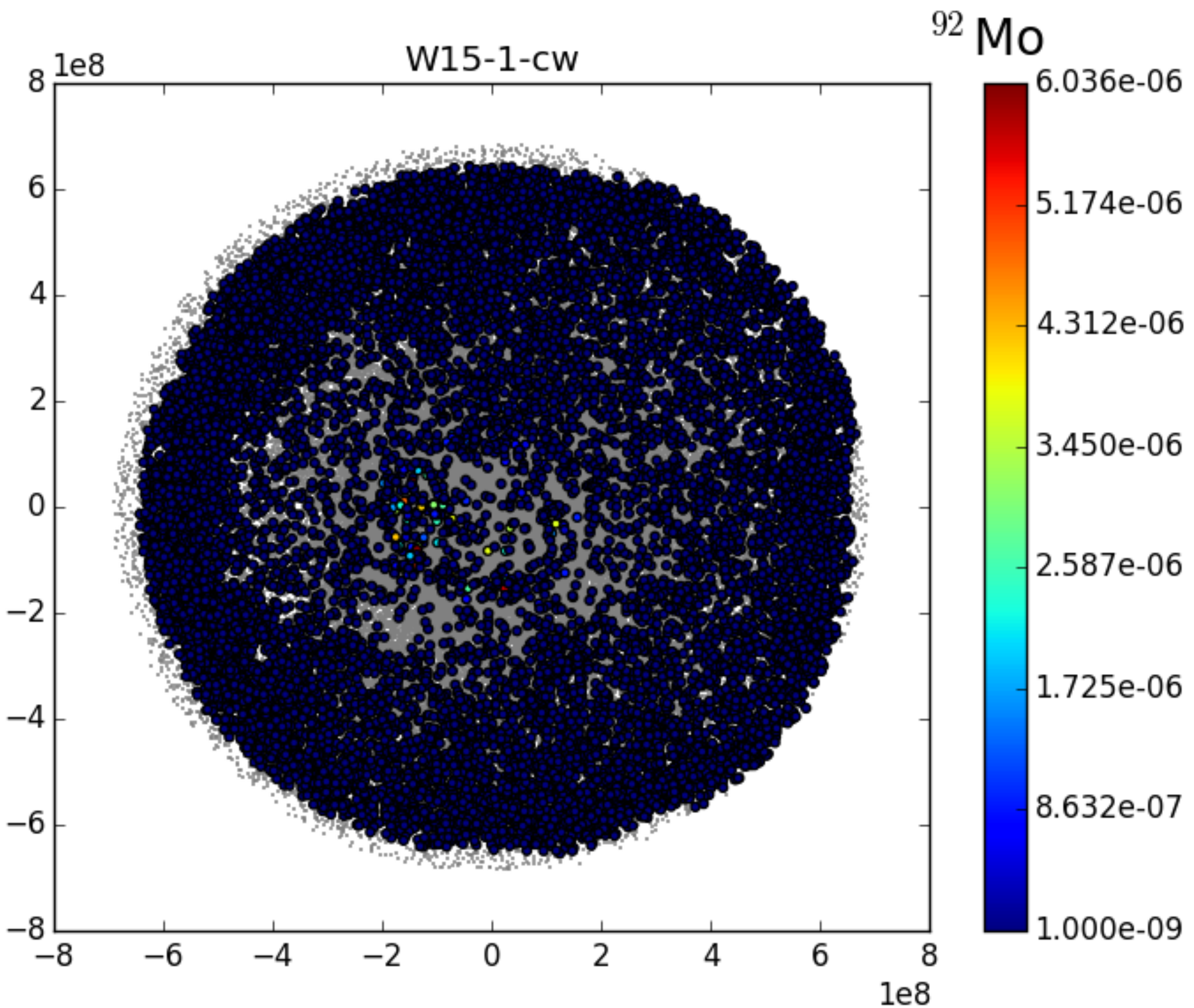
3D


W15-1-cw
^{28}Si
5.493e-01
4.714e-01
3.935e-01
3.156e-01
2.377e-01
1.599e-01
8.196e-02
4.071e-03
1e8

NAS-CE

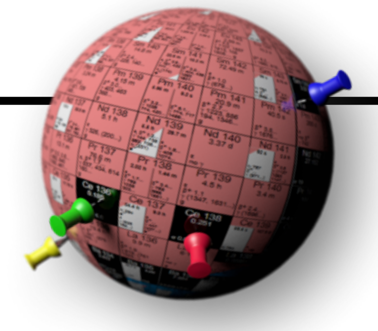

W15-4 (1D)
W15-1-cw (3D)
$(X_i/X_{i,\odot})$
Mass number, A
^{74}Se
^{78}Kr
^{84}Sr
^{92}Mo
^{94}Mo
^{98}Ru
^{56}Fe
^{53}Cr
^{55}Mn
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10
20
30
40
50
60
70
80
90
100

NAS-CE



W15-1-cw
1e8
8
6
4
2
0
−2
−4
−6
−8
−8
−6
−4
−2
0
2
4
6
8
1e8
^{92}Mo
6.036e-06
5.174e-06
4.312e-06
3.450e-06
2.587e-06
1.725e-06
8.632e-07
1.000e-09

NAS-CE



WORK IN PROGRESS/PLANS

- NAS-CE will calculate nucleosynthesis in different **3D SNII models** and make a detailed comparison with new 1D results, with spectra/ remnant and with chemical abundances at different ages of the cosmos (in collaboration with MPA-Munich group, ref. T.-H. Janka)
- NAS-CE will calculate nucleosynthesis in **white-dwarf mergers** to investigate them as possible source of thermonuclear explosions (in collaboration with University of Heidelberg, ref. F.K. Roepke)
- NAS-CE will develop a new approach to **chemo-dynamical evolution** in order to optimize and combine the latest studies of chemistry and dynamics at different ages of our Galaxy as well as external objects (in collaboration with G. Few, University of Hull, UK).