A contribution from the models: The νp-process

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Introducing the νp-Process: Symptoms

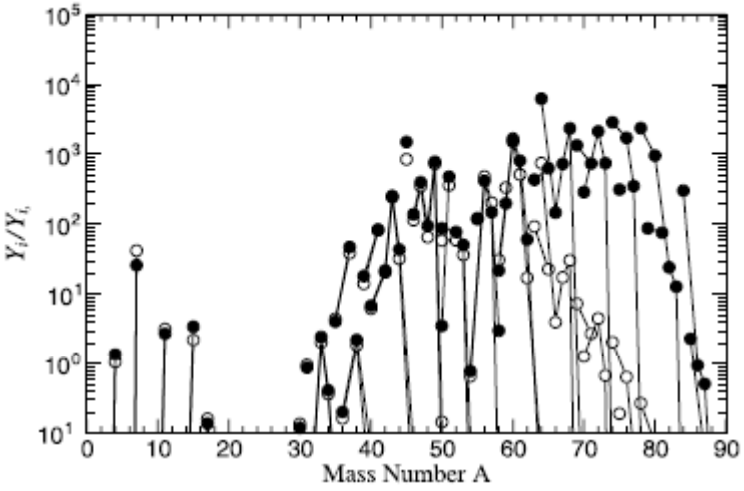
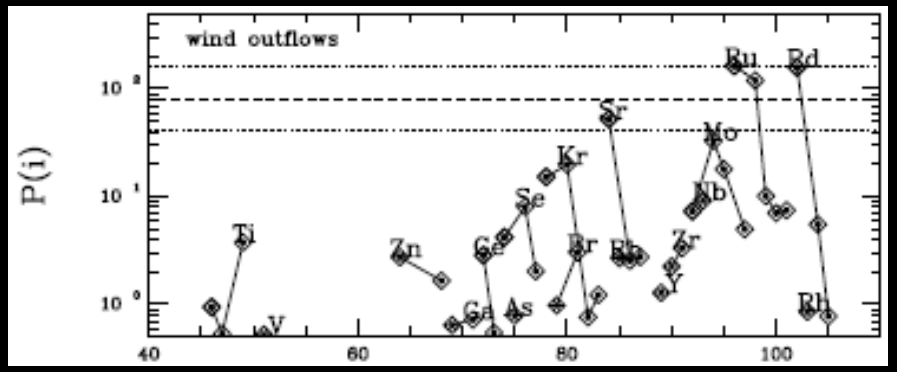
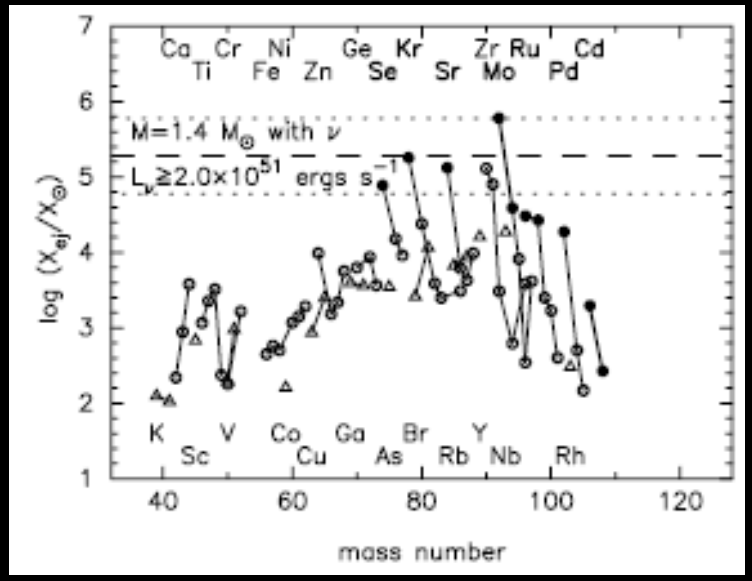


FIG. 5.—Abundances for model B07 relative to solar abundances (Lodders 2003). Two different calculations are shown, with neutrino-induced reactions in the network (*filled circles*) and without neutrino-induced reactions in the network (*open circles*).

Frohlich et al (2006)



Pruet et al (2006)



Wanajo (2006)

Introducing the νp-Process: Context

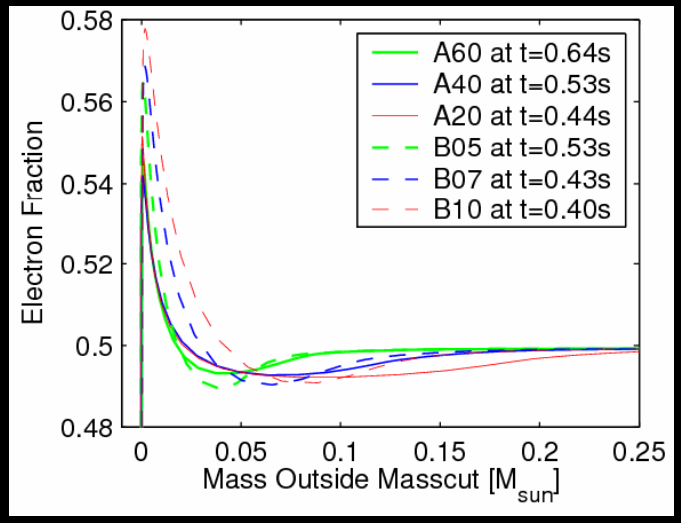
- Proton-rich ejecta from a 20Msun core collapse supernova by Liebendoerfer
- Proton-rich ejecta from a 15Msun core collapse supernova by Janka
- Semi-analytic model of proto-neutron star winds

- Ejected under the influence of neutrino interactions

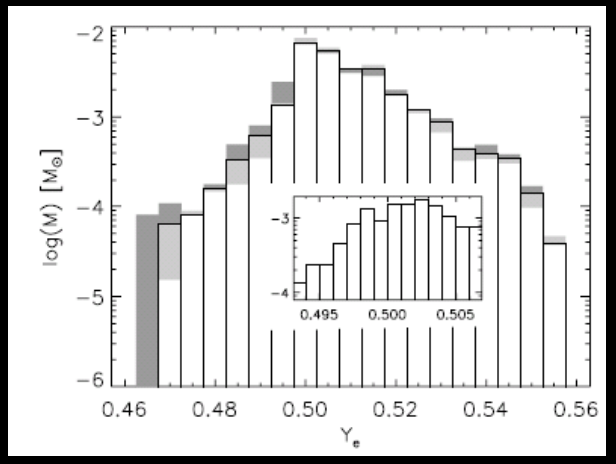
Introducing the νp-Process: Physics

- Dominant processes:

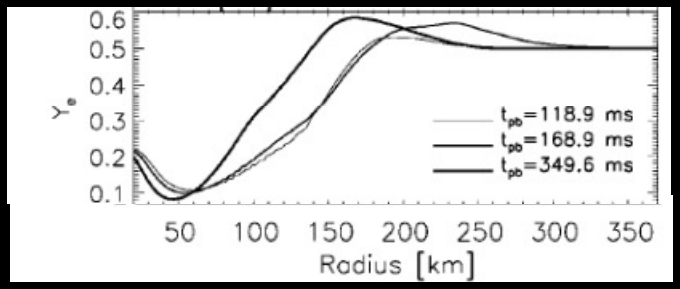
$$\nu_e + \mathrm{n} \leftrightarrow e^- + \mathrm{p}$$
$$\bar{\nu}_e + \mathrm{p} \leftrightarrow e^+ + \mathrm{n}$$



Liebendörfer et al (2001)
Frohlich et al (2006)



Buras et al (2006)



Rampp & Janka (2000)

→ Proton-rich ejecta

Introducing the νp-Process: Physics

- Dominant processes:

$$\nu_e + \mathrm{n} \leftrightarrow e^- + \mathrm{p}$$
$$\bar{\nu}_e + \mathrm{p} \leftrightarrow e^+ + \mathrm{n}$$

- proton-rich and a-rich freeze-out from QSE
  - Enhancement of waiting-point nuclei:
    64Ge → 64Zn, 68Se → 68Zn, 72Kr → 72Ge, 76Sr → 76Se, 80Zr → 80Kr, 84Mo → 84Sr

Introducing the νp-Process: Physics

- Dominant processes:

$$\nu_e + \mathrm{n} \leftrightarrow e^- + \mathrm{p}$$
$$\overline{\nu}_e + \mathrm{p} \leftrightarrow e^+ + \mathrm{n}$$

- proton-rich and a-rich freeze-out from QSE

- Neutron source: $\overline{\nu}_e + p \rightarrow n + e^+$

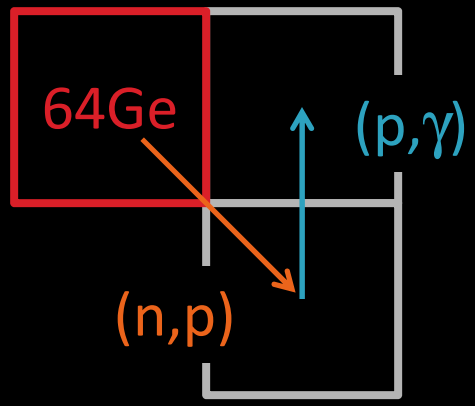
Introducing the νp-Process: Physics

- Dominant processes:

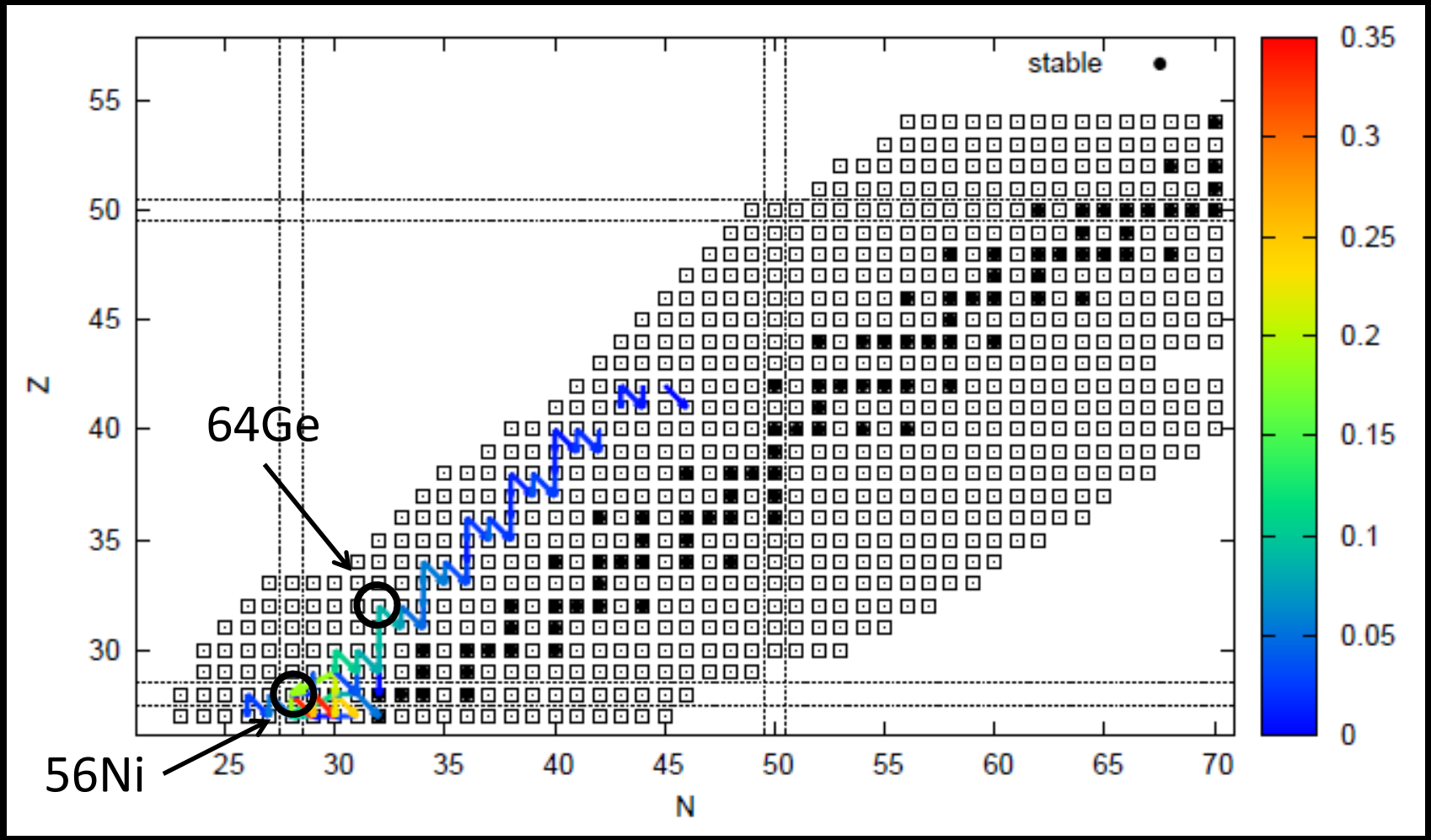
$$\nu_e + \mathrm{n} \leftrightarrow e^- + \mathrm{p}$$
$$\overline{\nu}_e + \mathrm{p} \leftrightarrow e^+ + \mathrm{n}$$

- proton-rich and a-rich freeze-out from QSE
- Neutron source: $\overline{\nu}_e + p \rightarrow n + e^+$
- Reaction sequence:

64Ge (n,p) 64Ga
64Ga (p,γ) 65Ge



The νp-process path



The Quest

LEPP

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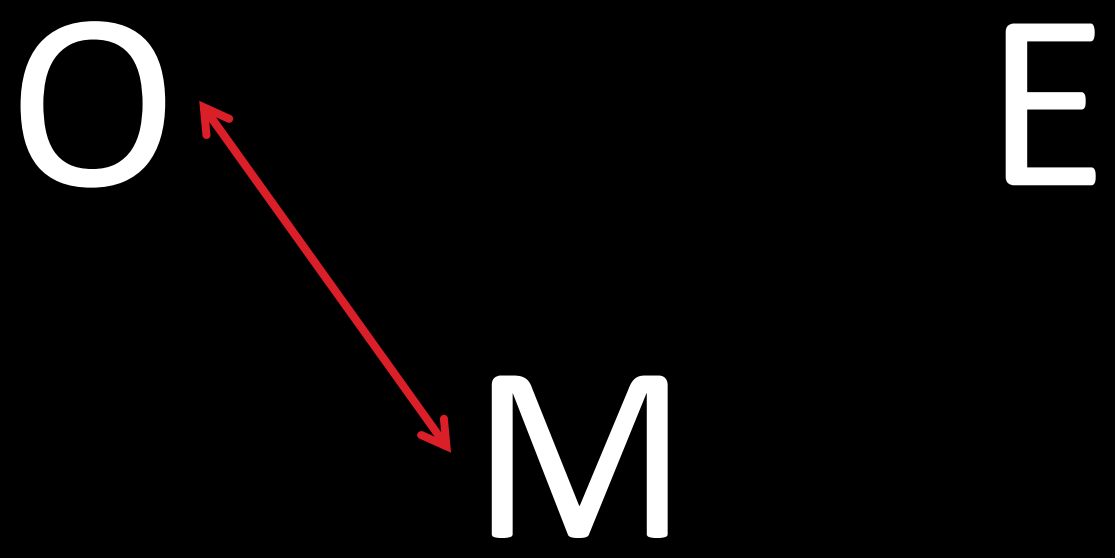
M

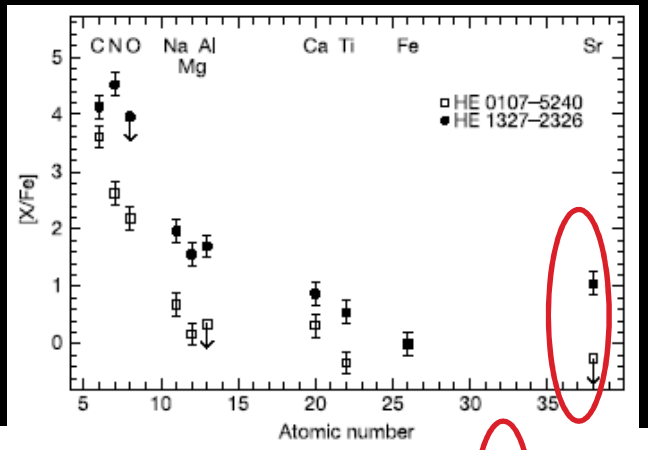
(adapted from yesterday's discussion)

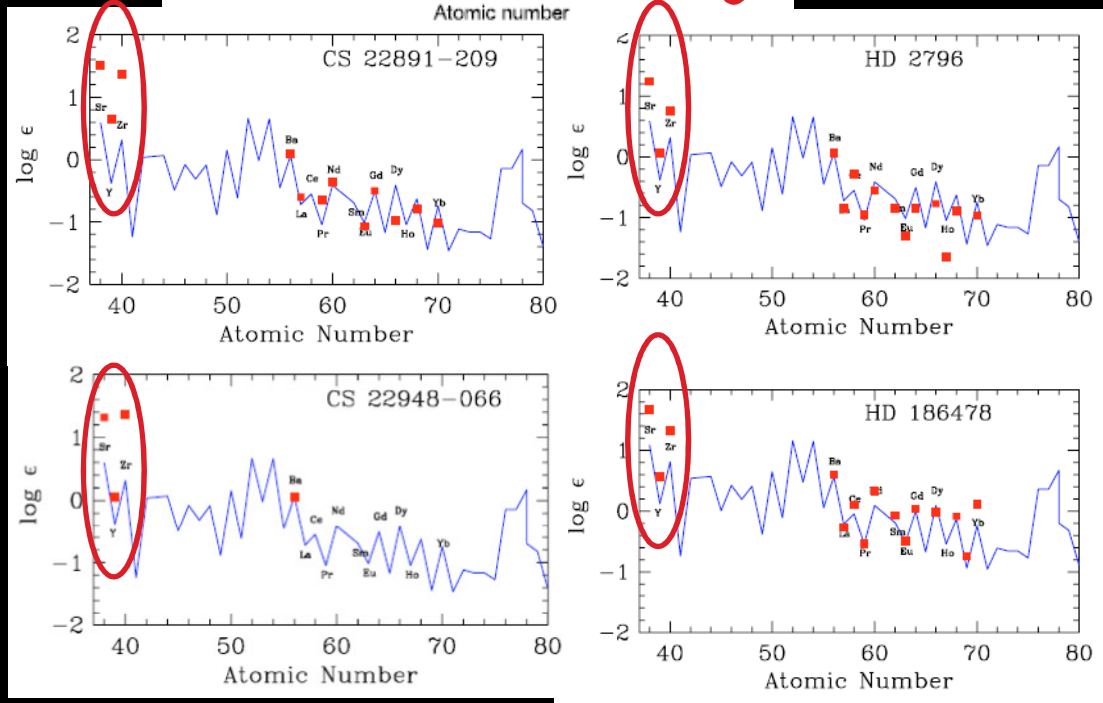
Observations

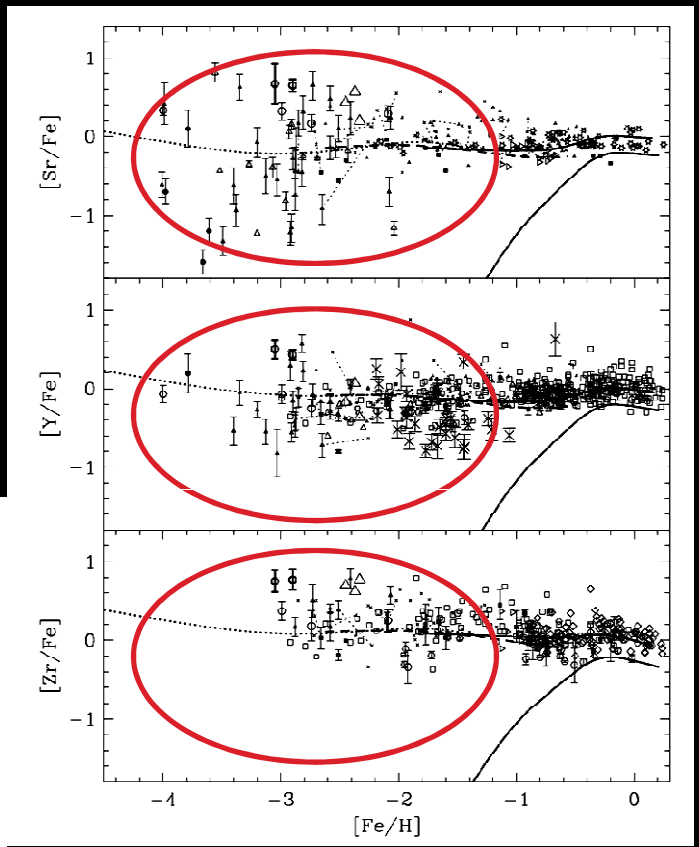
LEPP



Observations



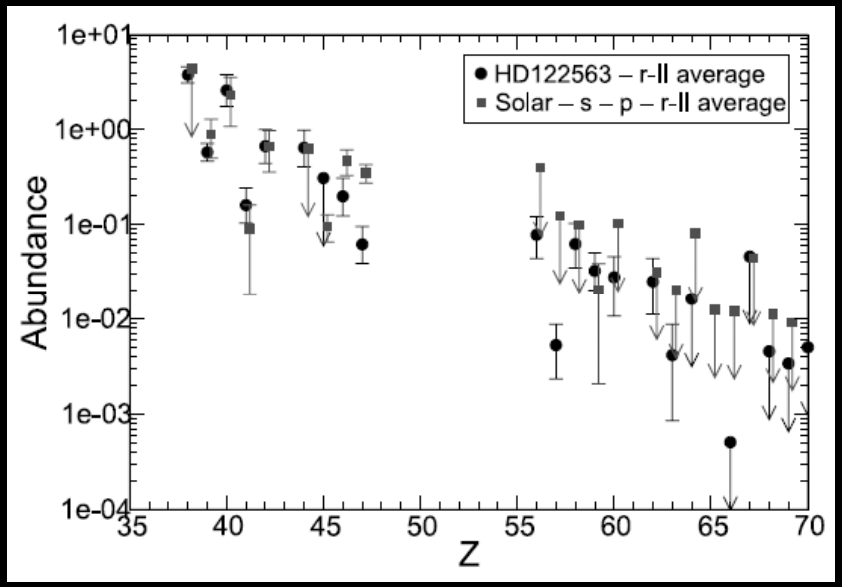




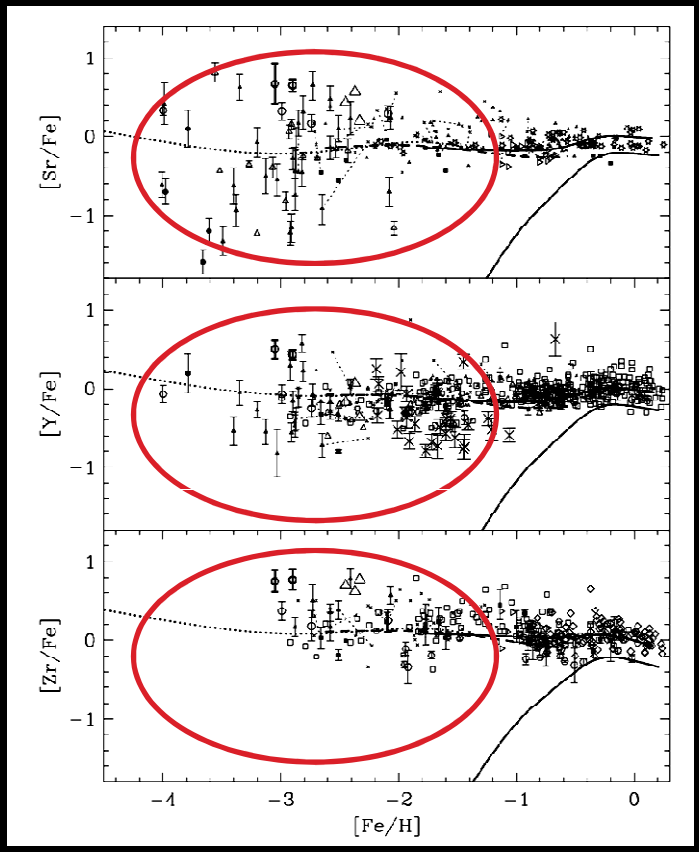
Travaglio et al (2004)

Francois et al (2004)

Observations



Montes et al (2007)

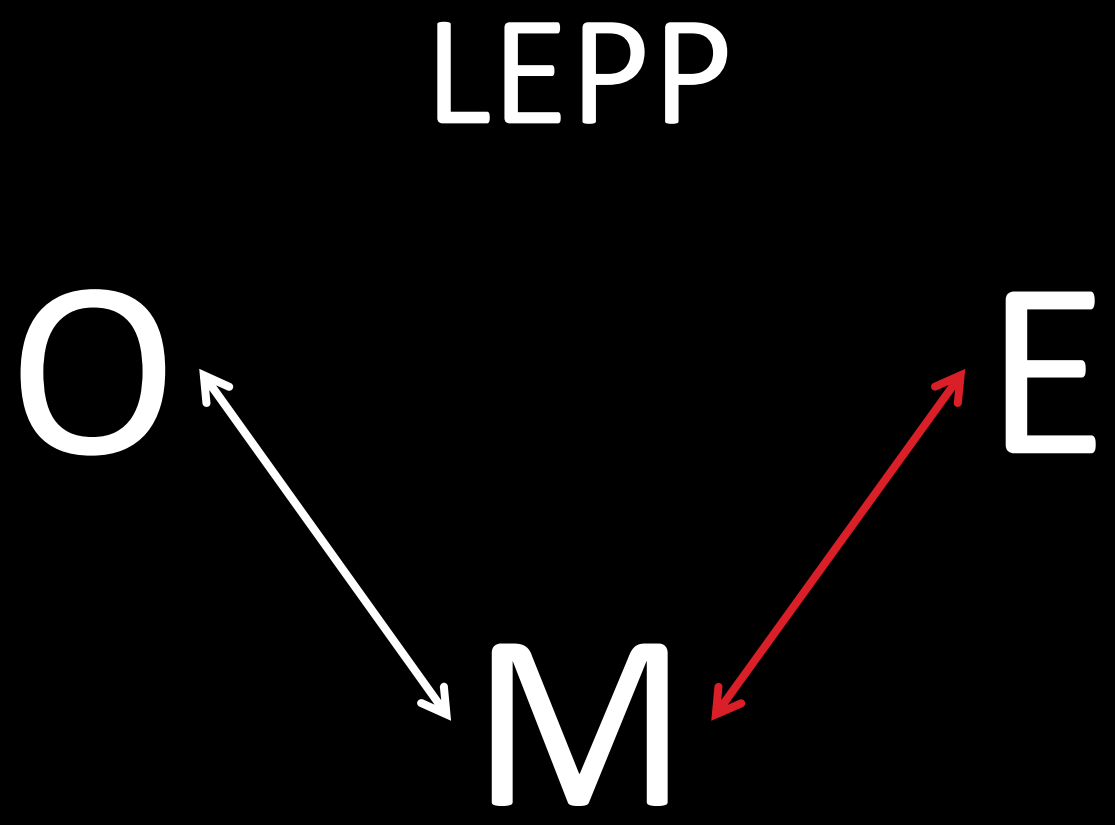


Travaglio et al (2004)

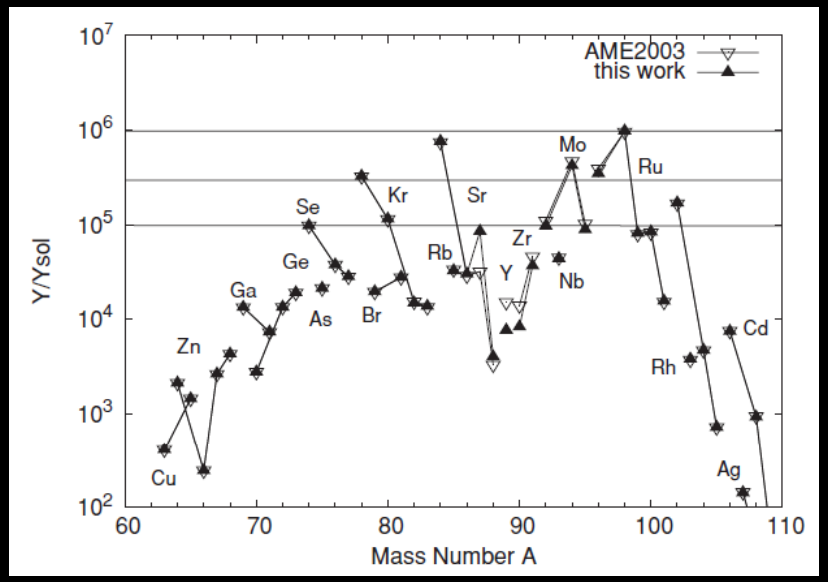
Stellar LEPP and solar LEPP

Suggest *lighter element primary process (LEPP)* to explain abundances of Sr, Y, Zr

Connecting models with experiments



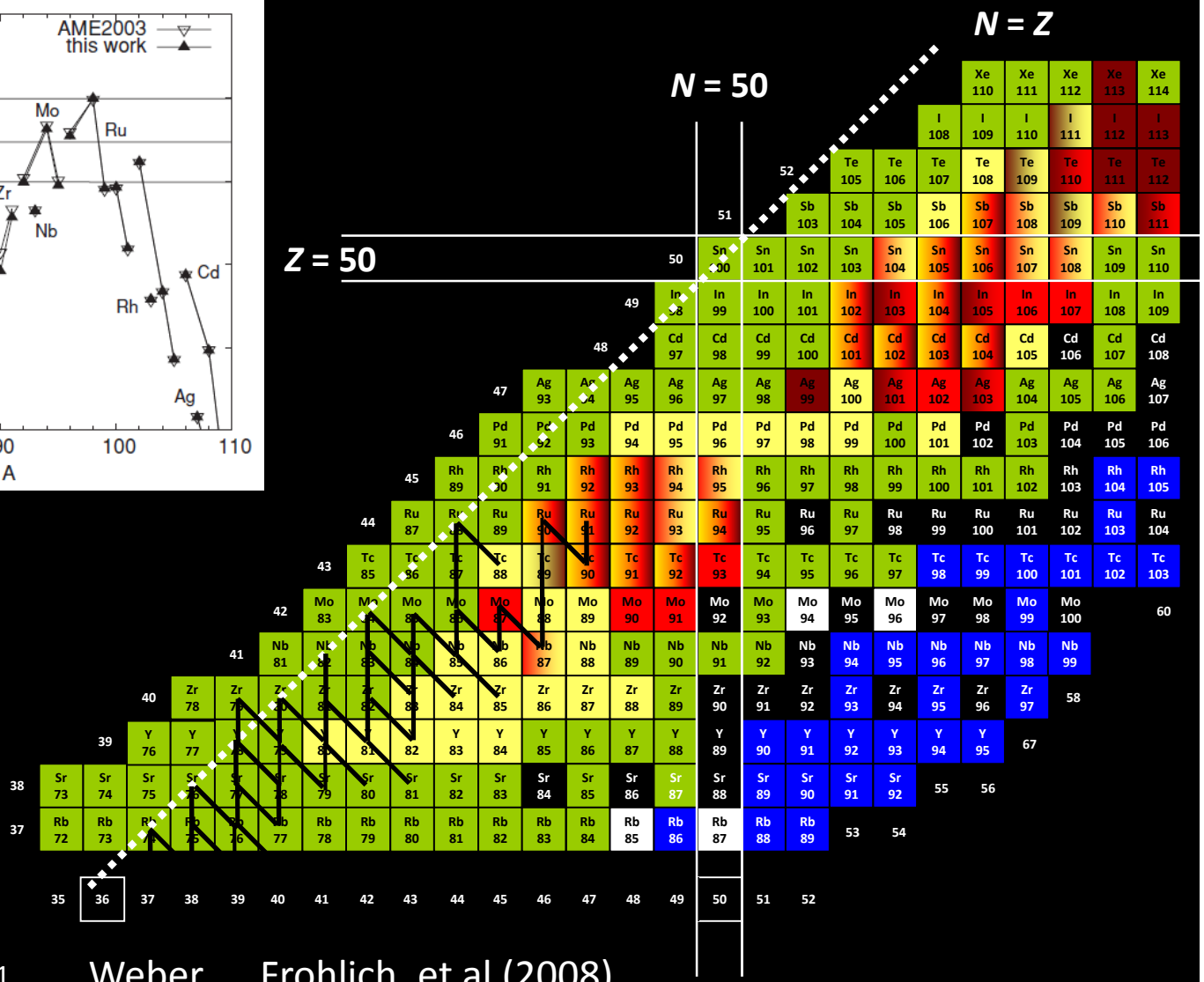
Penning Trap Mass Measurements



CANADIAN TRAP
at Argonne NL

SHIPTRAP

JYFLTRAP



Weber, …,Frohlich, et al (2008)

More on mass measurements

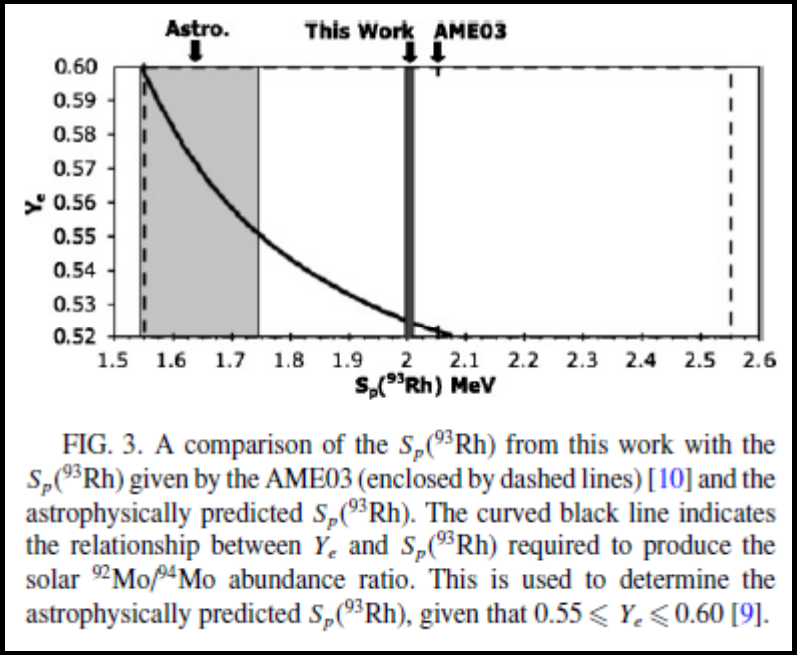
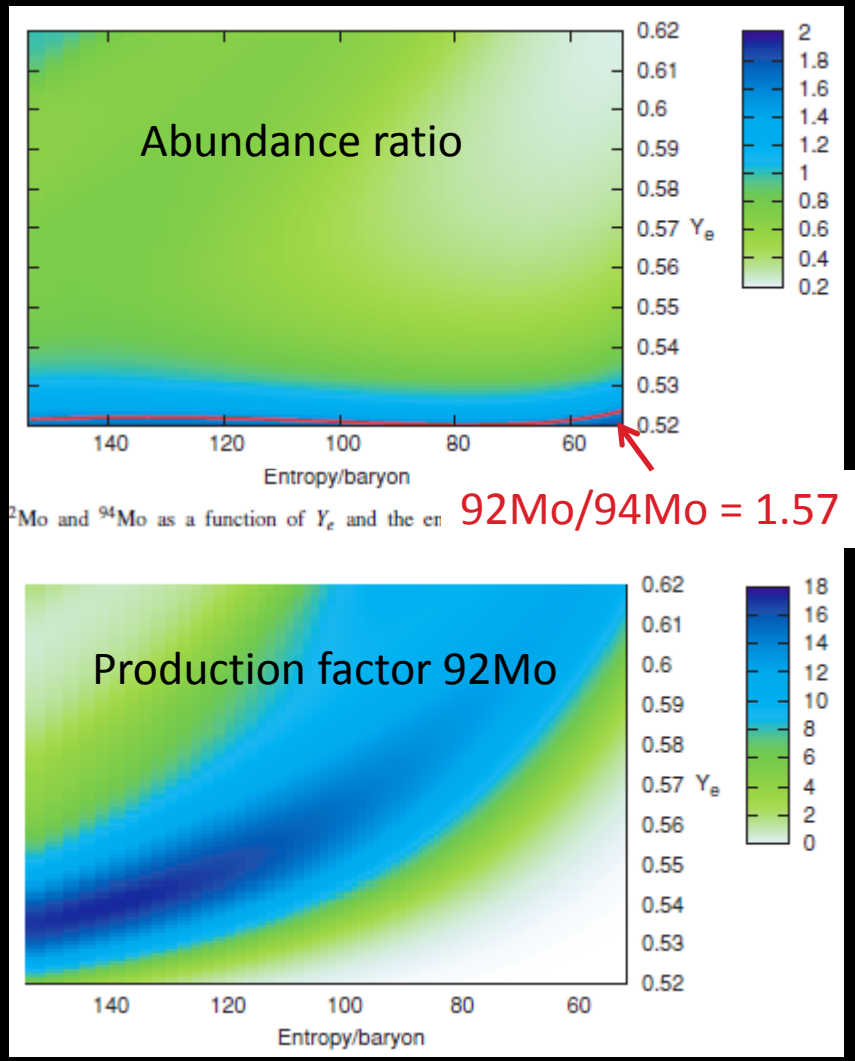


FIG. 3. A comparison of the $S_p(^{93}\mathrm{Rh})$ from this work with the $S_p(^{93}\mathrm{Rh})$ given by the AME03 (enclosed by dashed lines) [10] and the astrophysically predicted $S_p(^{93}\mathrm{Rh})$. The curved black line indicates the relationship between Y_e and $S_p(^{93}\mathrm{Rh})$ required to produce the solar $^{92}\mathrm{Mo}/^{94}\mathrm{Mo}$ abundance ratio. This is used to determine the astrophysically predicted $S_p(^{93}\mathrm{Rh})$, given that $0.55 \leqslant Y_e \leqslant 0.60$ [9].

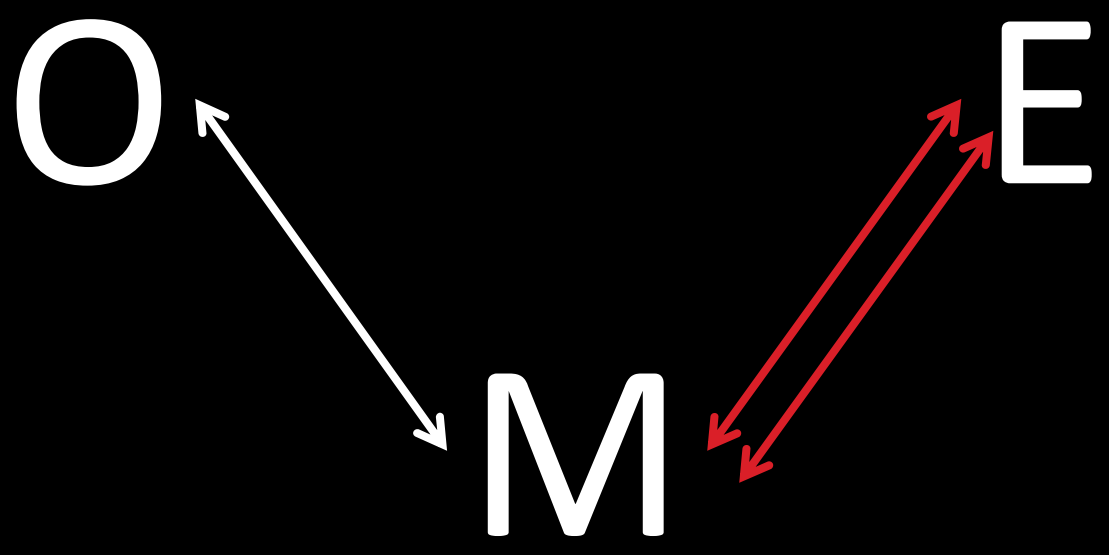
Fallis et al (2008)



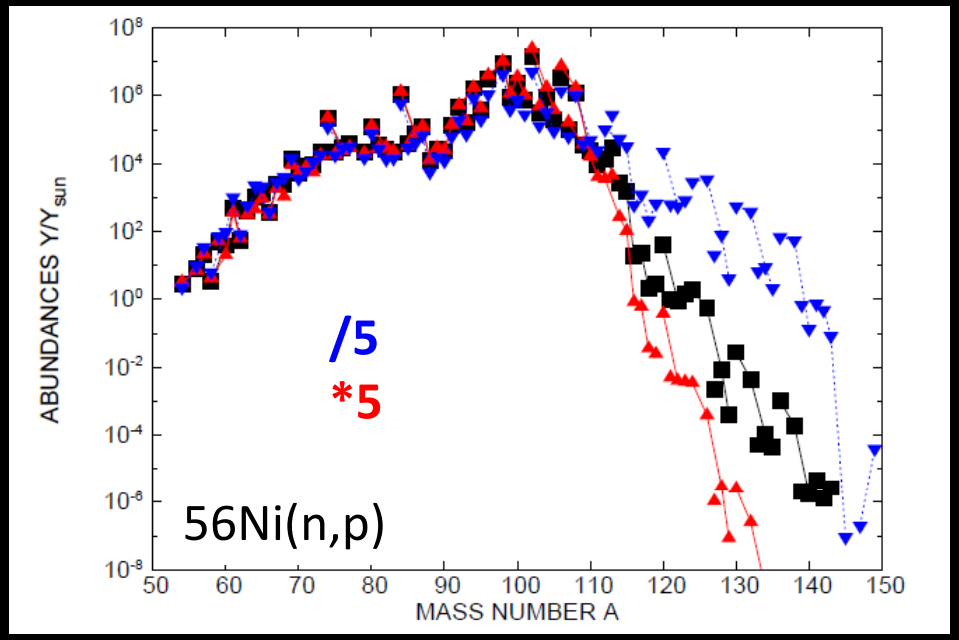
Fisker et al (2009)

Connecting models with experiments

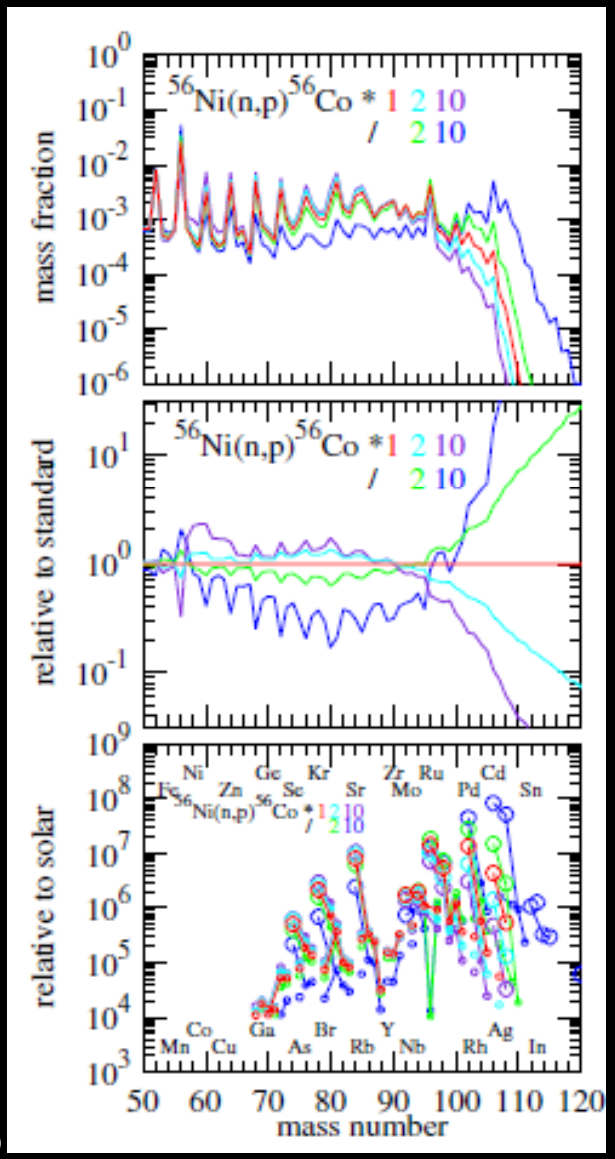
LEPP



Critical (and not so critical) reactions



Frohlich et al (2011)



Wanajo (2006)

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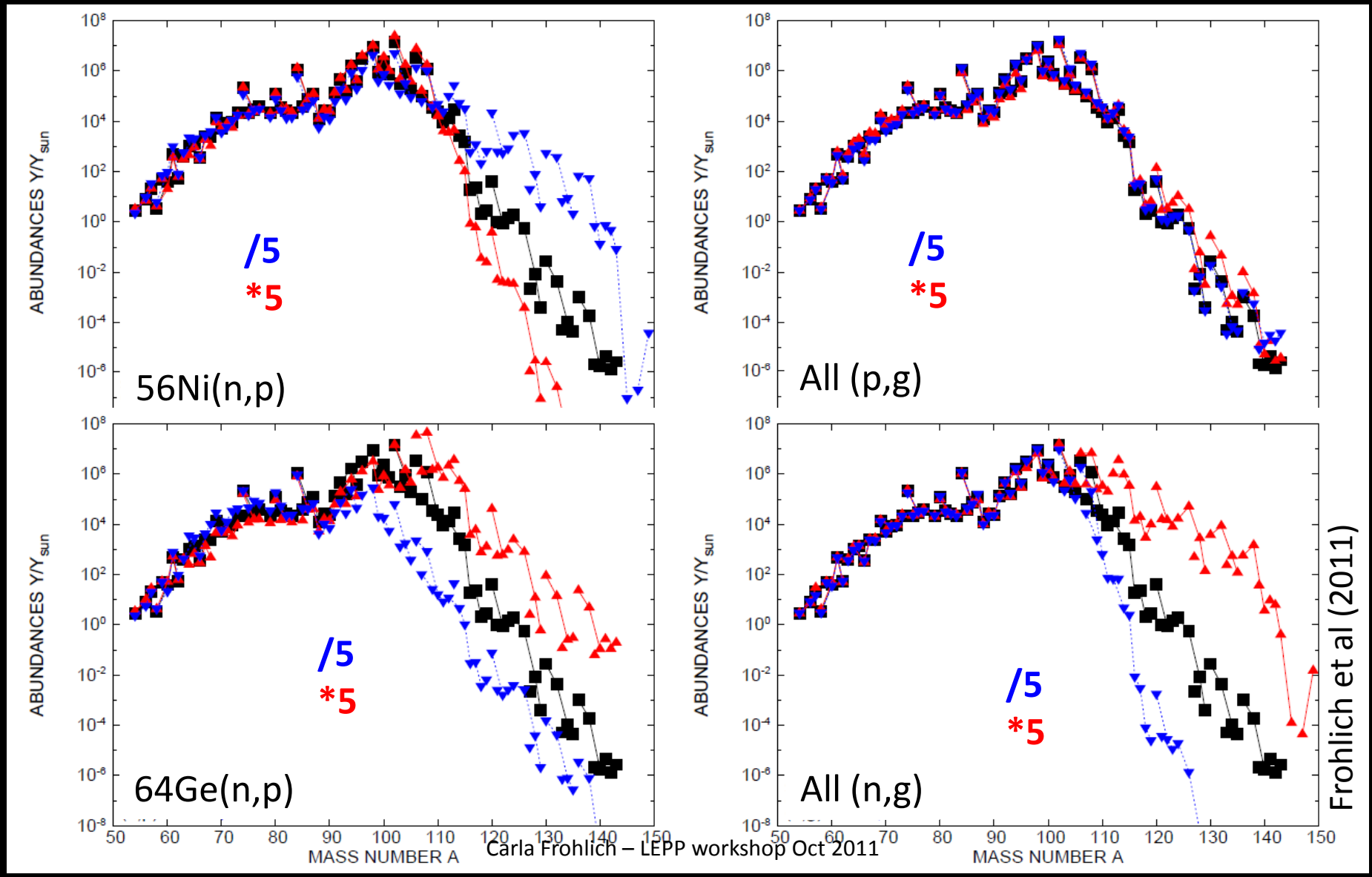
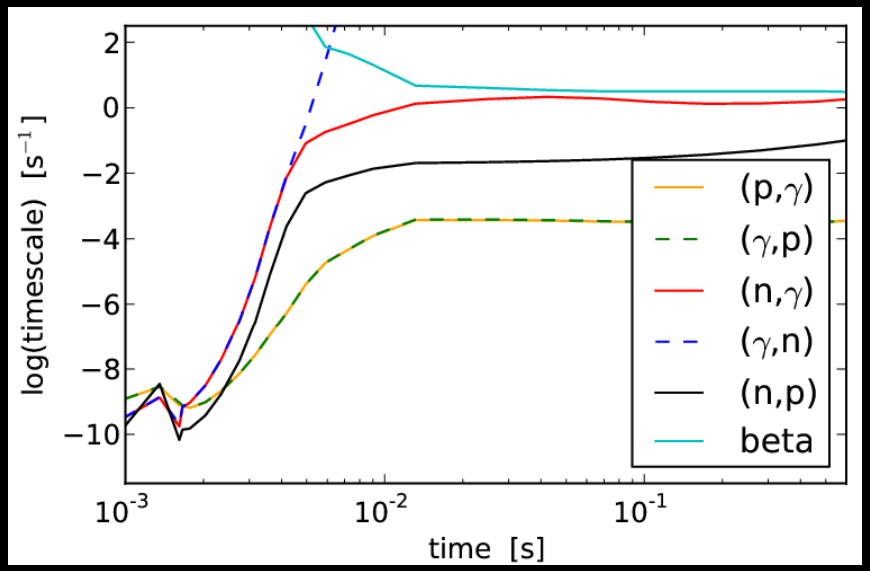
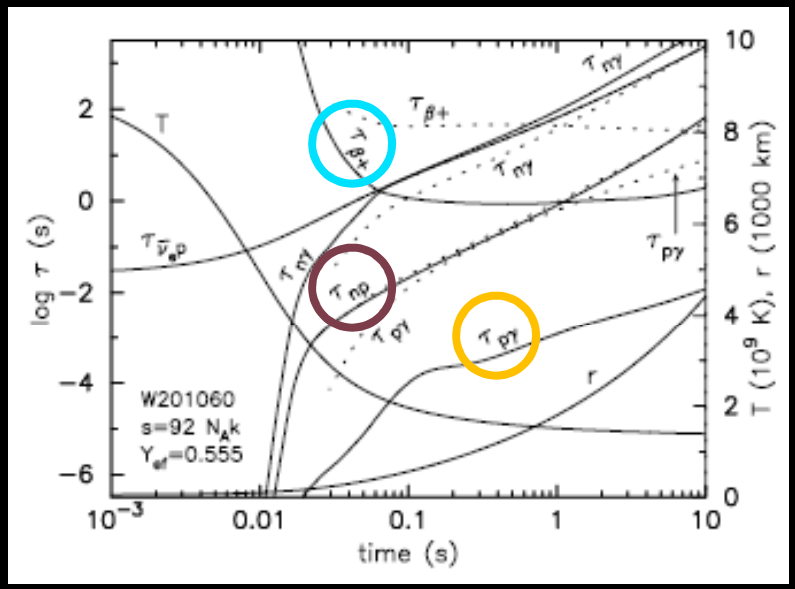


Mean lifetimes



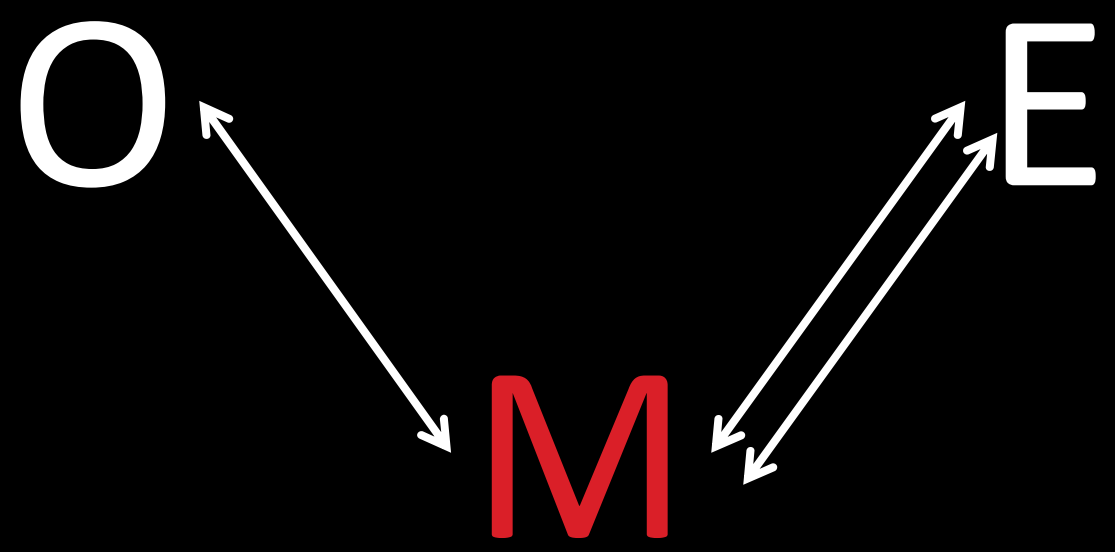
Frohlich et al (2011)



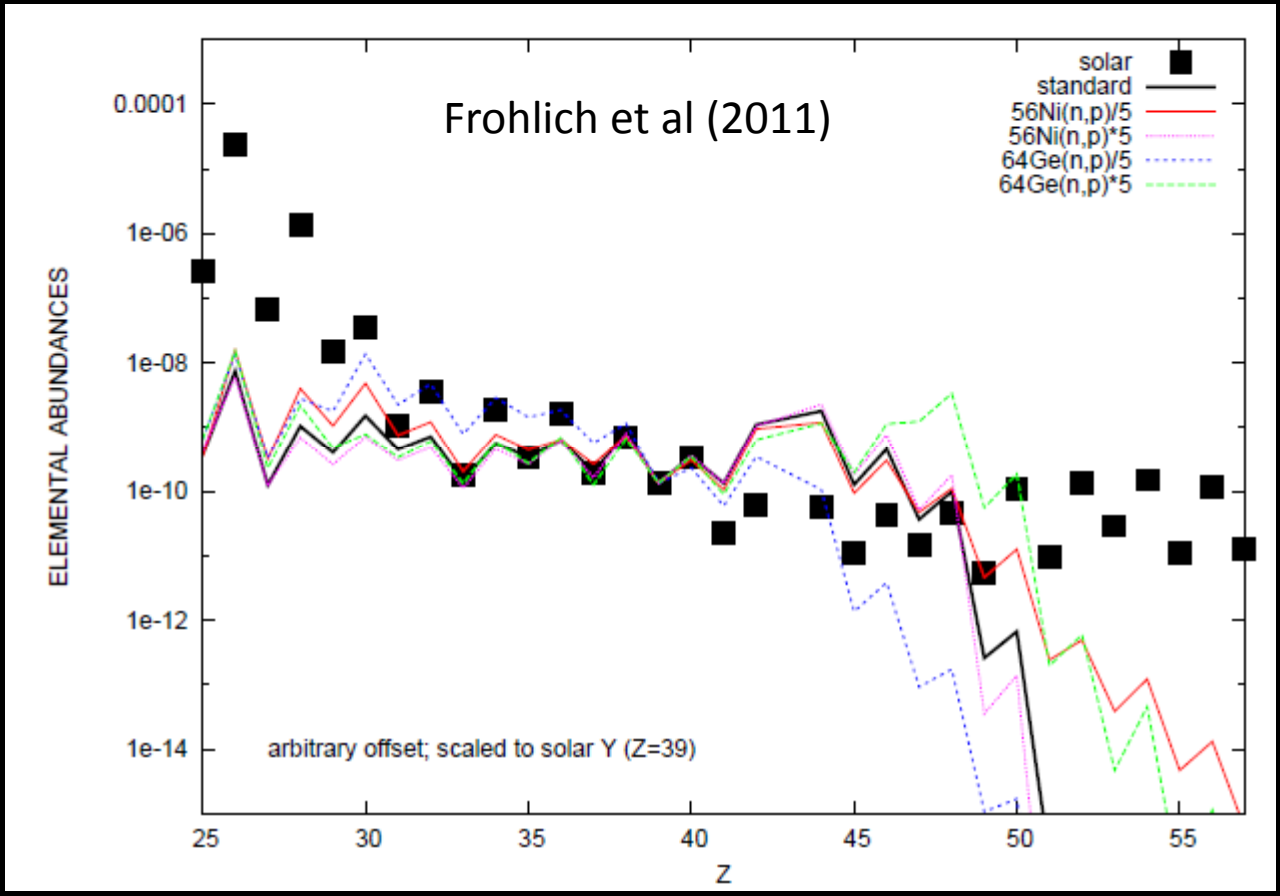
Wanajo (2006)

Understanding the models

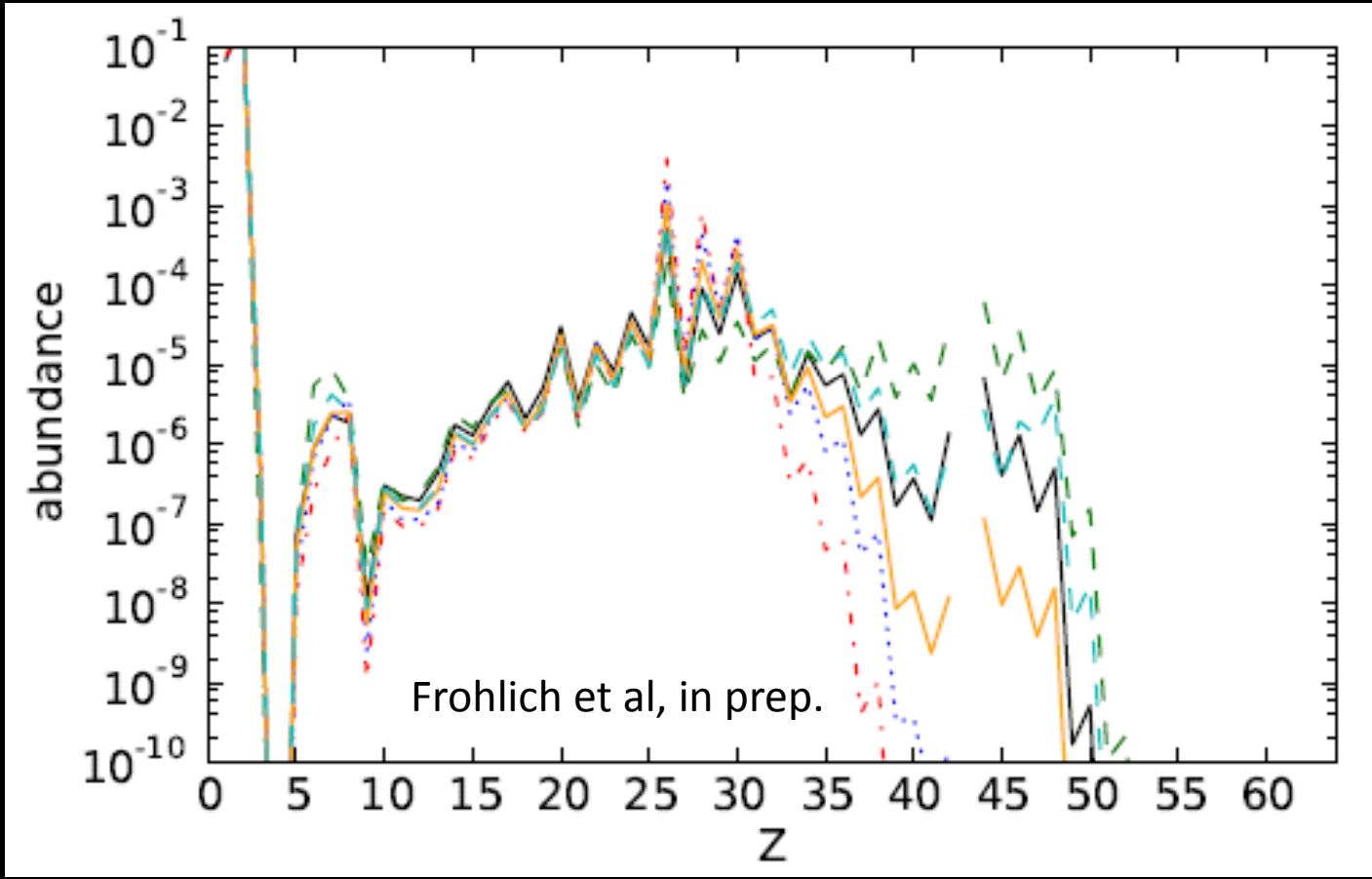
LEPP



Elemental abundances



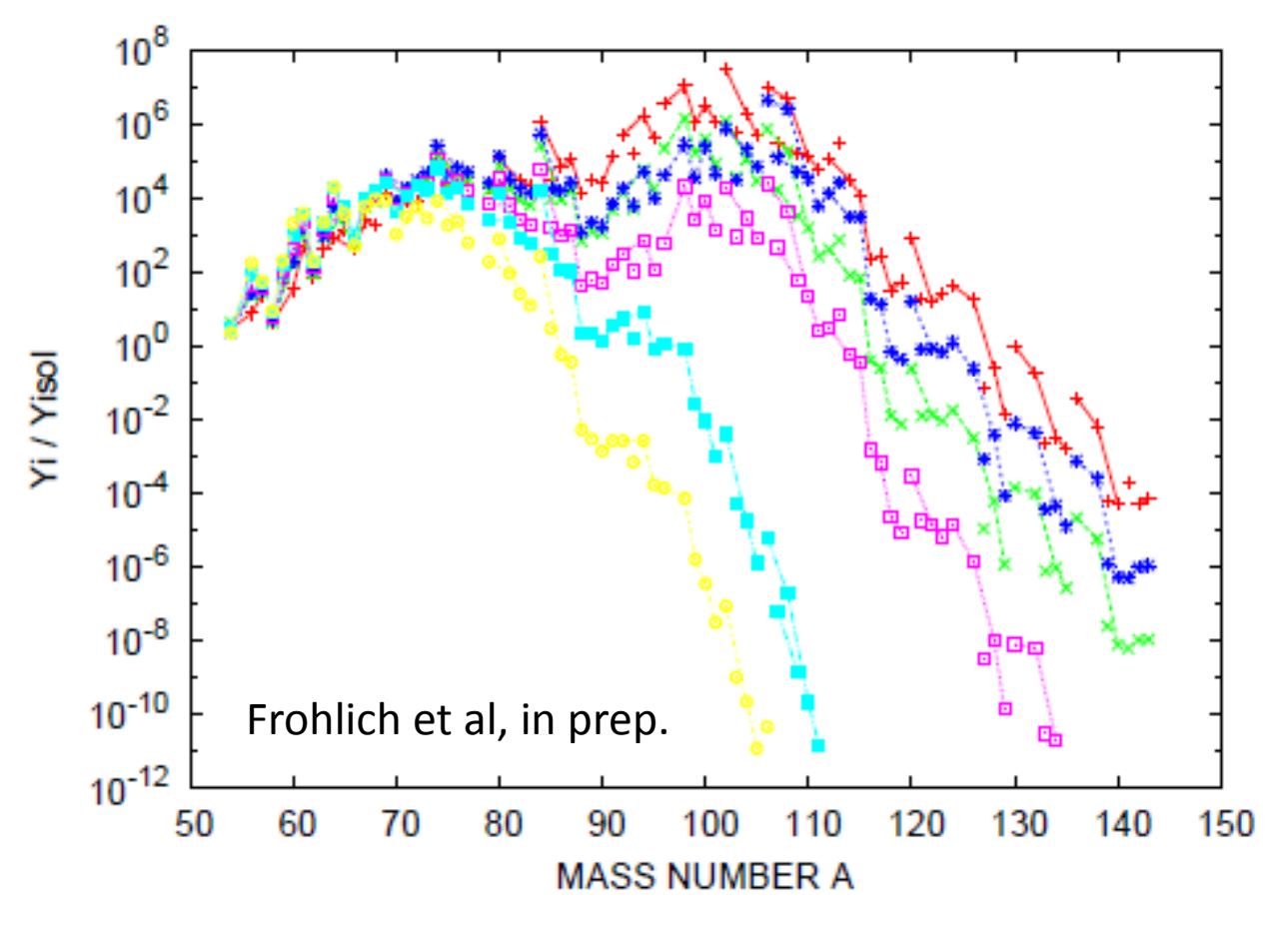
Wind trajectories



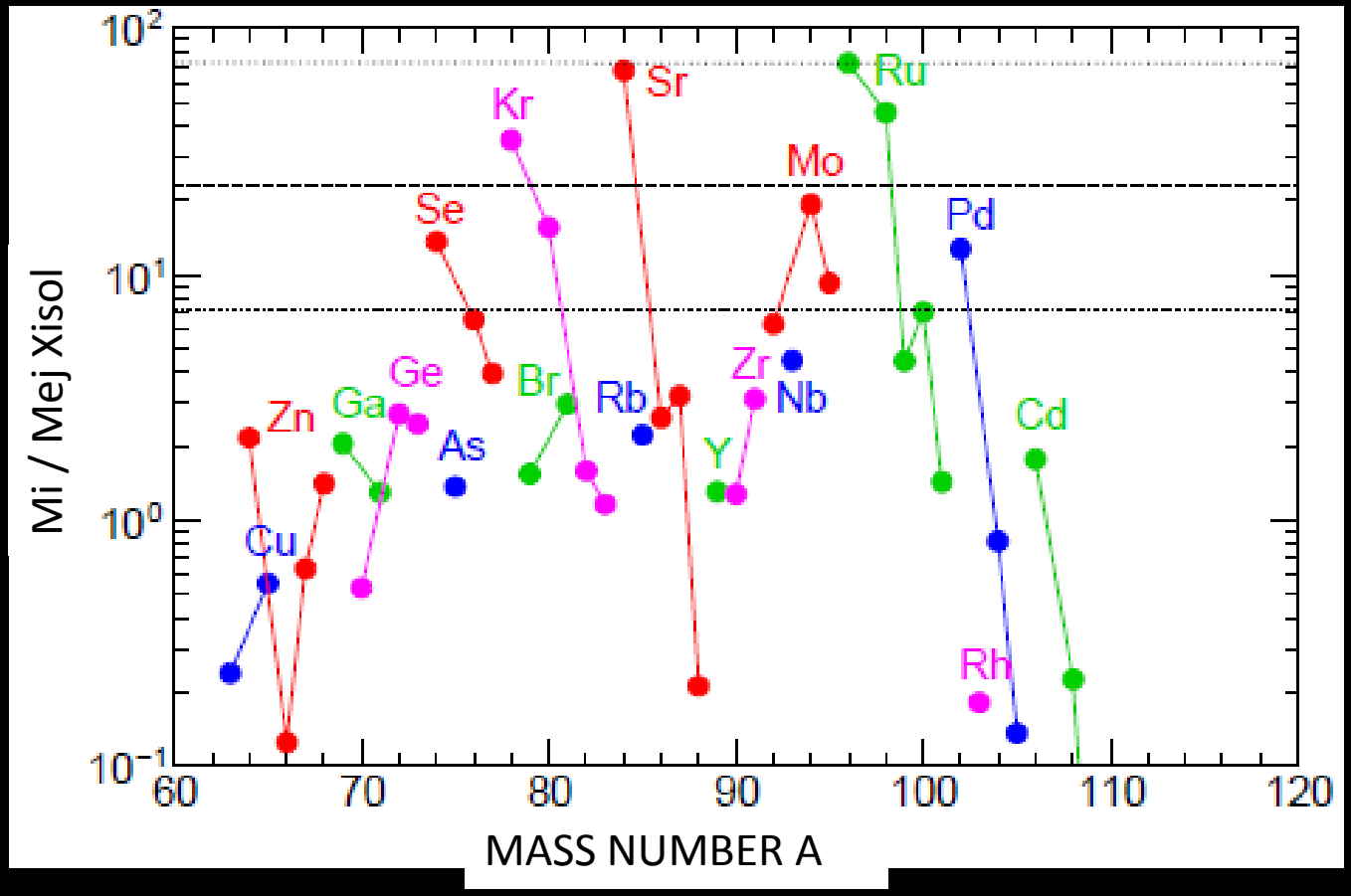
Trajectories: 15Msun ccSN

Janka et al (2003); similar to Pruet et al 2006;

Isoptopic abundances

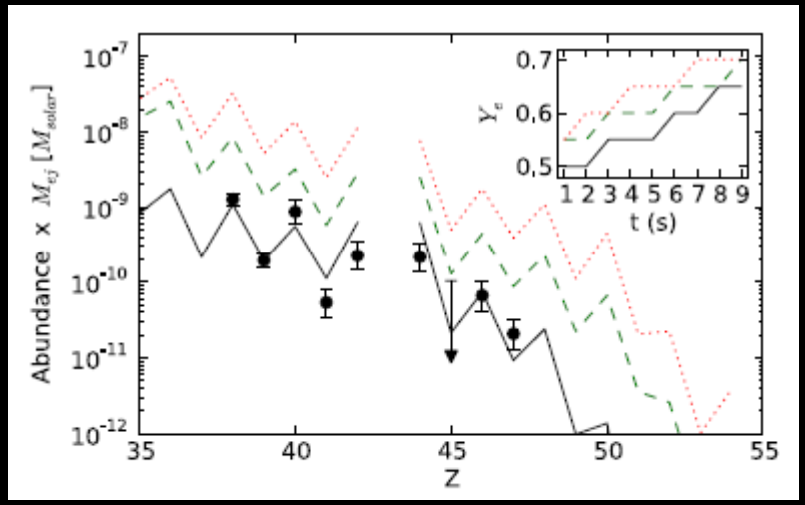


Isoptopic abundances

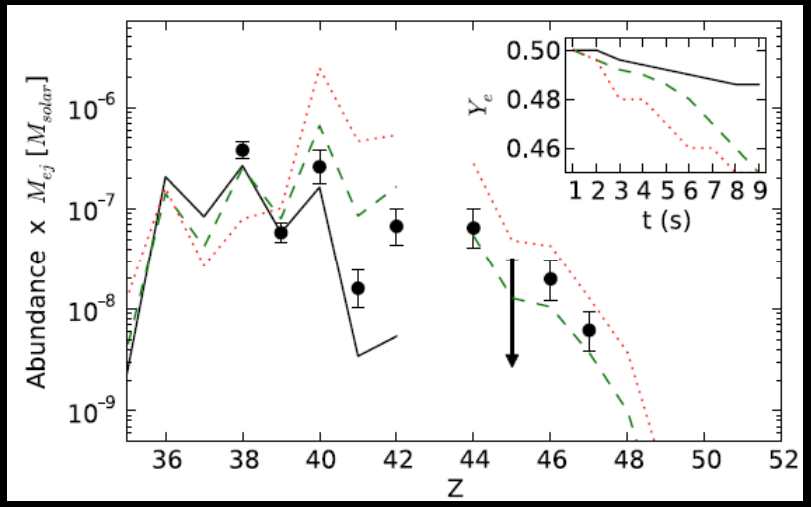


Impact of Ye

- Proton-rich



- Neutron-rich

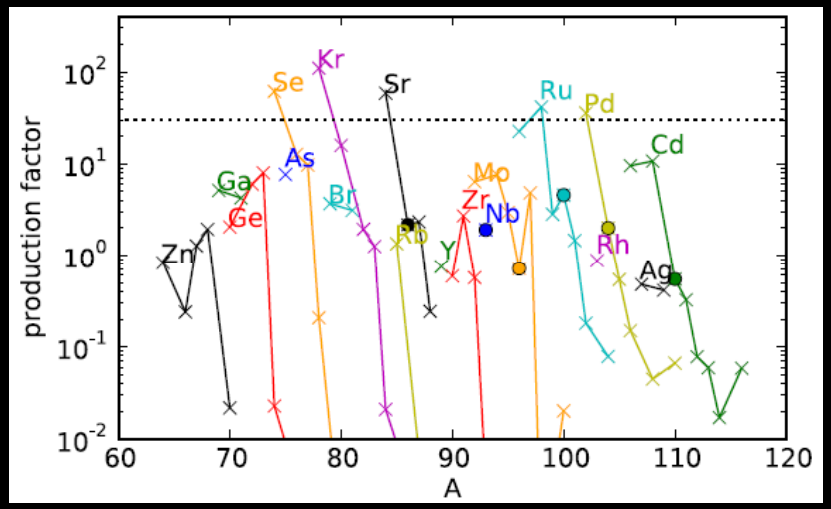


- Production of p-nuclei
- Overproduction at A=90

Arcones & Montes (2011)

Impact of Ye

- Proton-rich



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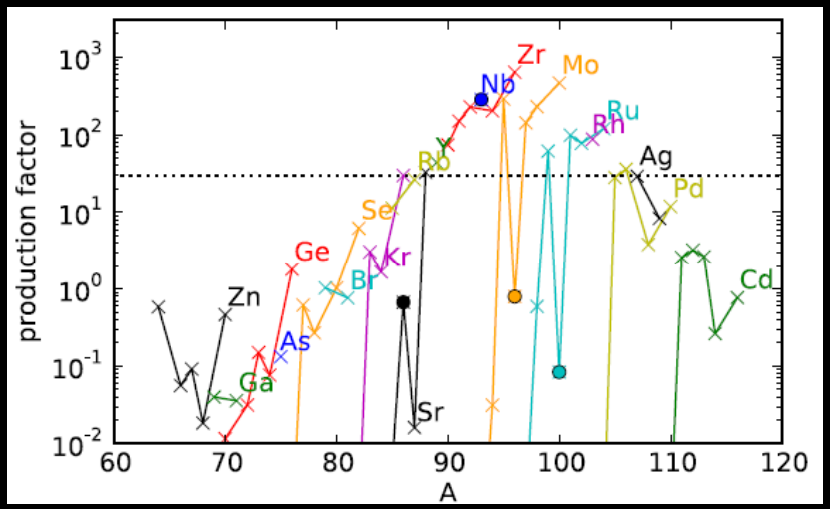

- Production of p-nuclei
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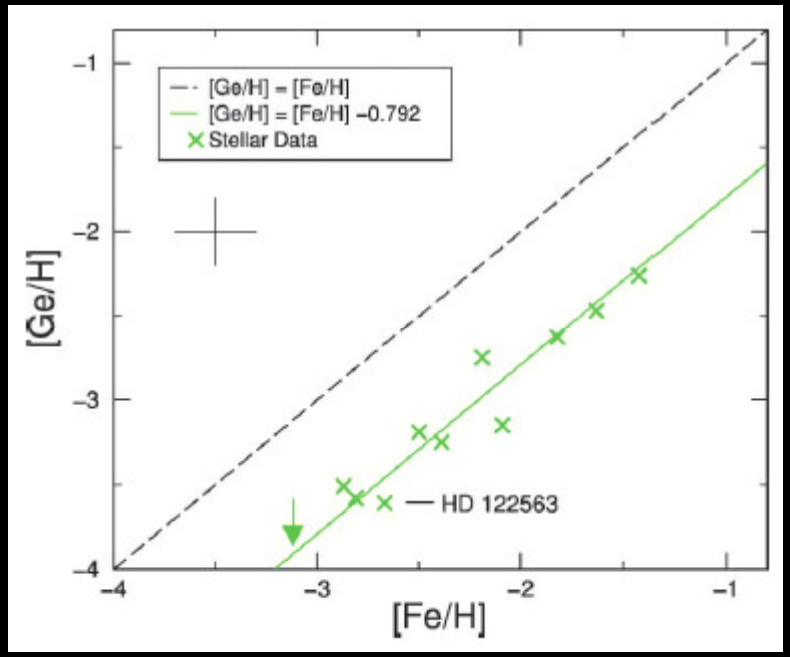
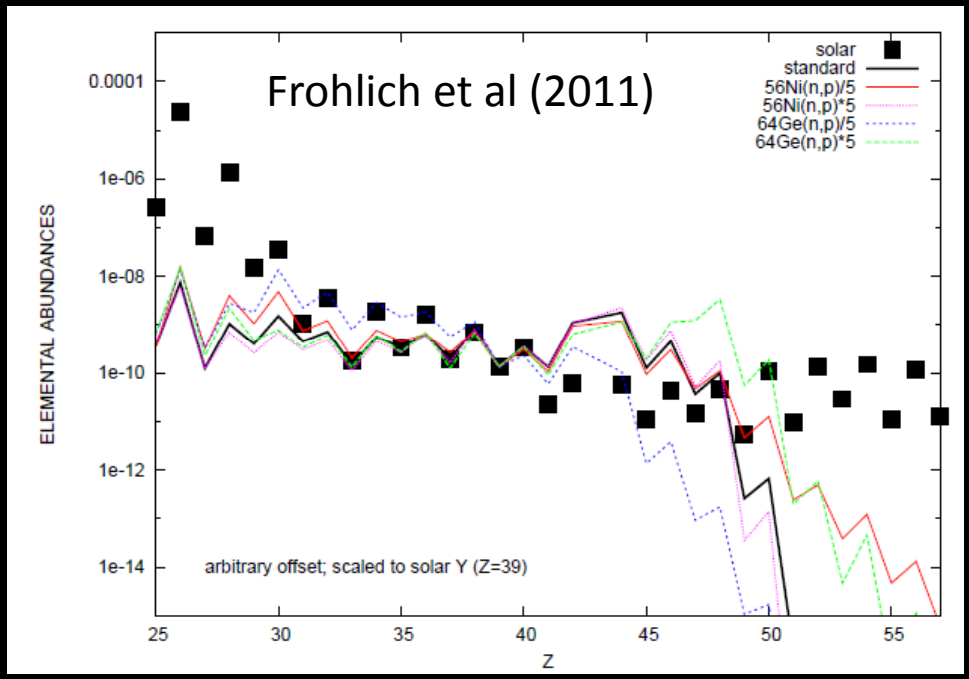
Arcones & Montes (2011)

Germanium



Cowan et al (2005)



Frohlich et al (2011)

Summary

LEPP

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Summary

LEPP

LEPP?
i-process?
n-process?
νp-process?
→ not yet settled

O E M

Summary

Amount and quality of data increasing

→ complex picture

LEPP

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Summary

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LEPP

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O

M

E

Nuclear masses: precision matters

Reaction rates: details matter

→ nuclear physics matters

Summary

Amount and quality of data increasing

→ complex picture

LEPP

LEPP?
i-process?
n-process?
νp-process?
→ not yet settled

O

Range of conditions possible, even within trajectories from one model

→ contribution from νp-process depend on details of SN model

M

E

Nuclear masses: precision matters

Reaction rates: details matter

→ nuclear physics matters