Astrophysical sites for the main and weak r-processes

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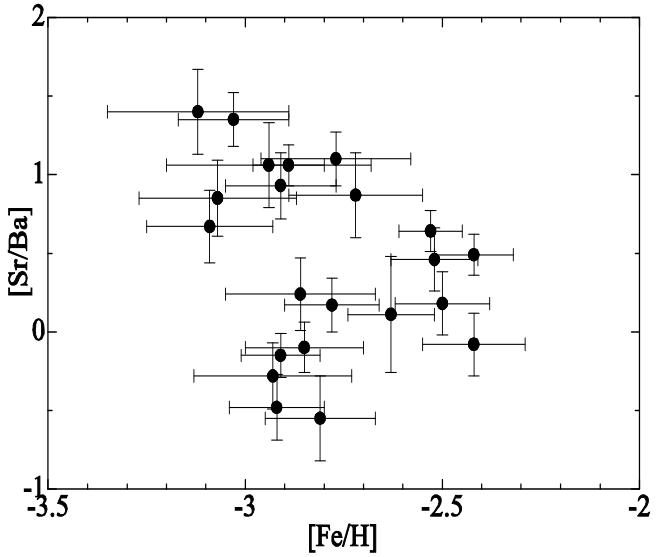
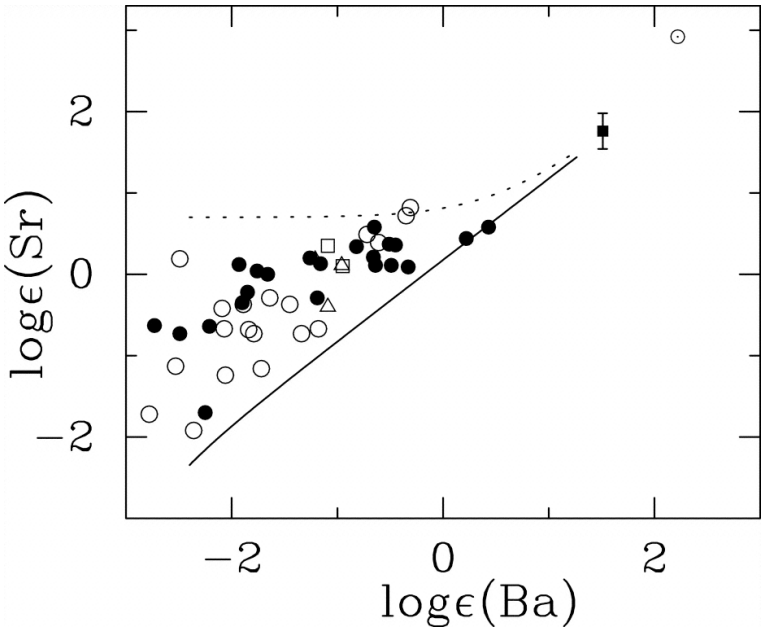
Two r-Processes in Field Stars

Honda et al. 2004





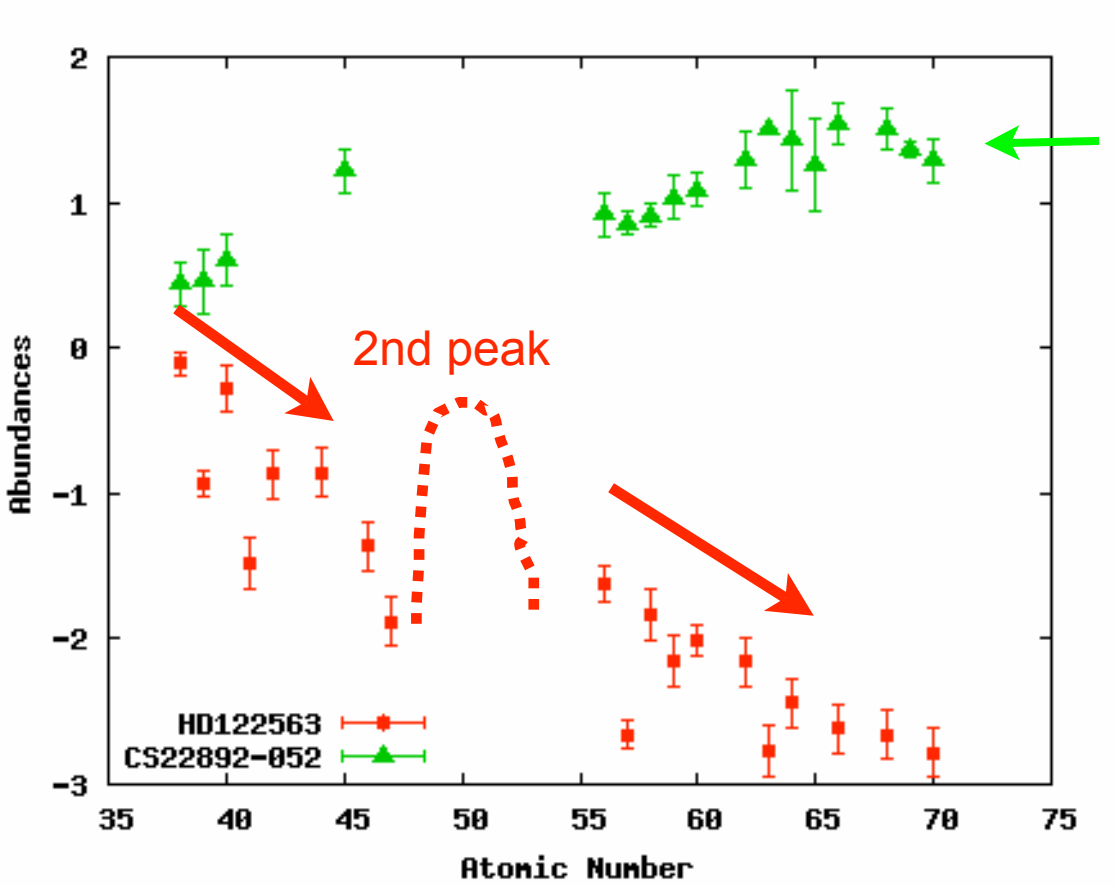
Two different processes enriched Sr,Y,Zr

Main r-process: enrich all elements (Sr,Y,Zr.....Th,U)
Weak r-process : enrich elements lighter than Ba (Sr,Y,Zr...Ba)

↑— Nucleosynthesis process and astrophysical site are not identified yet.

Abundance Pattern of Weak r-Process

- HD122563 (Honda et al. 2006)



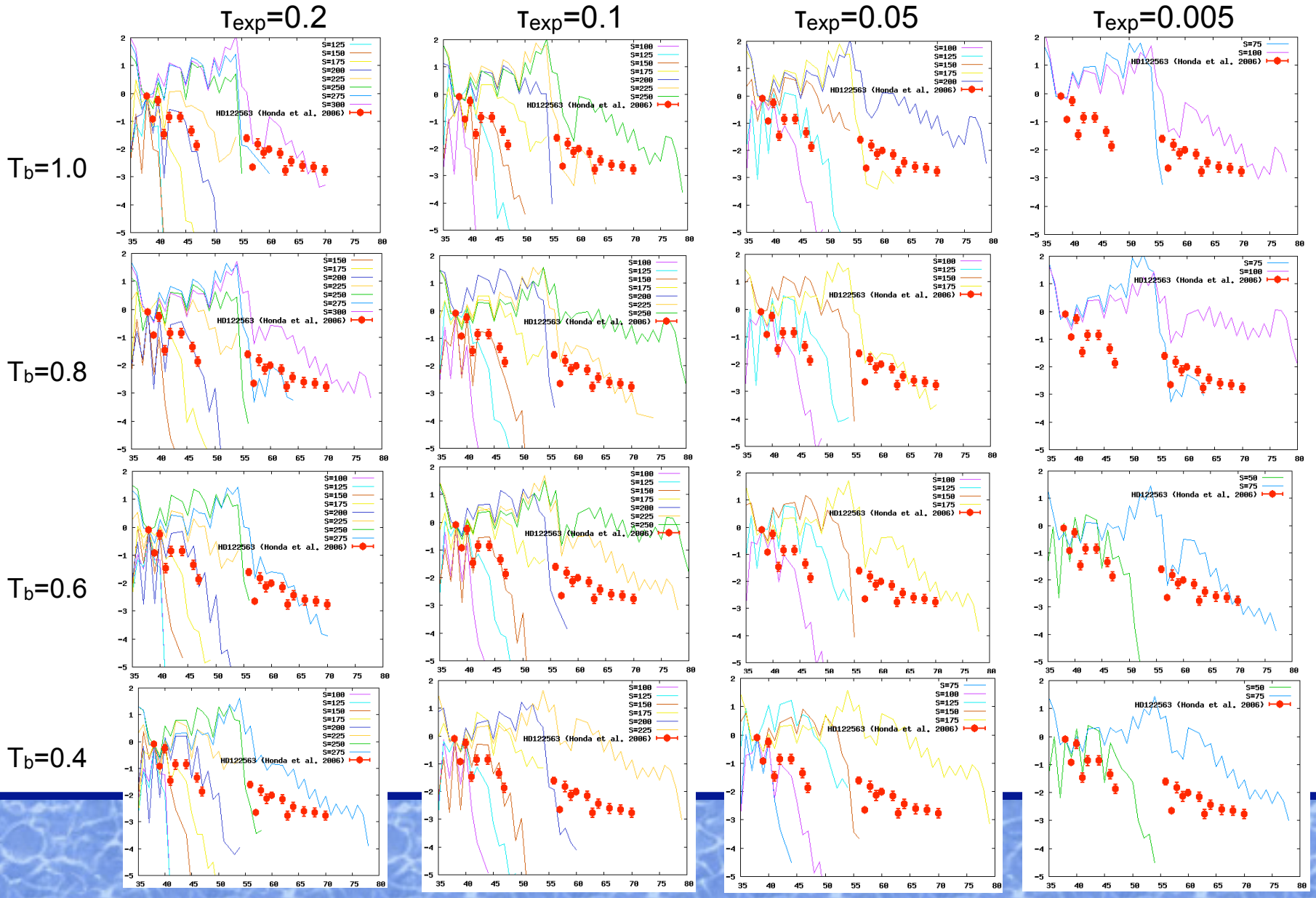
CS22892-052 (Main r-process)

Can we reproduce this abundance pattern with r-process?

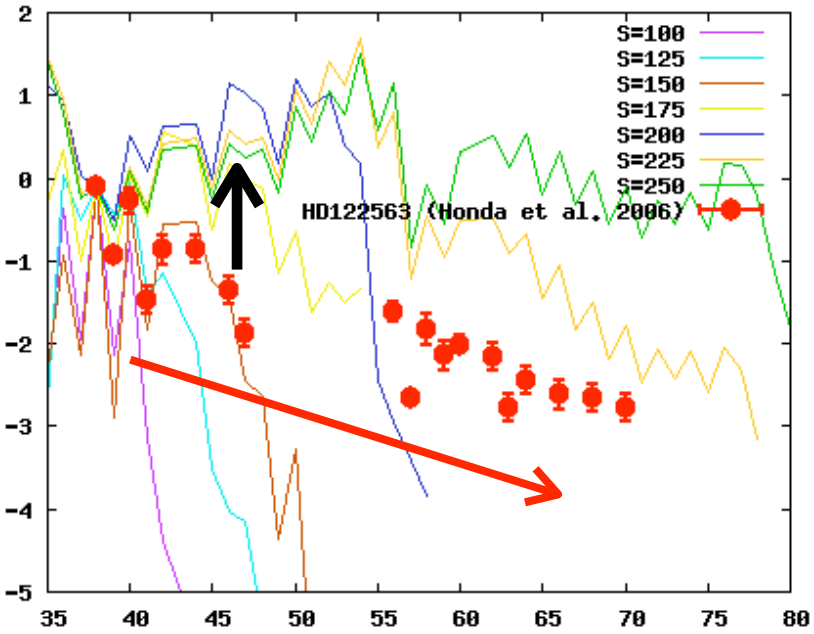
Theoretical Calculation

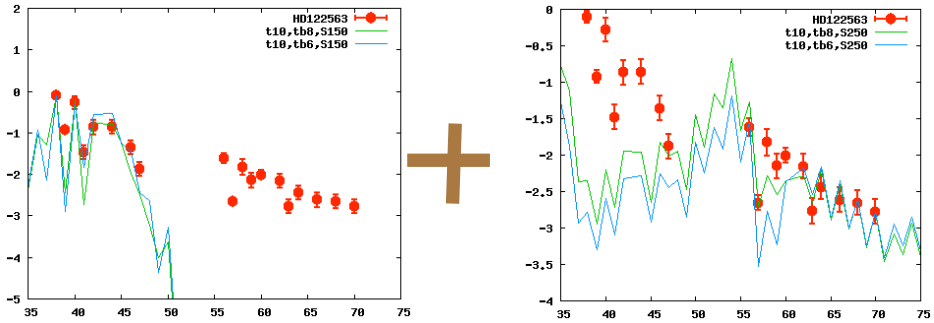
- Model
  - Adiabatic expansion (High entropy scenario)
    - $\rho(t)=9.0\ \exp(-t/\tau_{exp})+T_b$; $S\propto\rho/T^3$; $Y_e=0.45$
    - τ_{exp}=0.2,0.1,0.05,0.005 sec; S=75~300;T_b=0.4,0.6,0.8.1.0 GK
- Network Code
  - Full dynamical network code
    - based on Meyer et al. 2004, modified Orito, Terasawa & Otsuki (1997,2000,2003)
    - differential equations for ~4000 isotopes, ~10000 reactions
    - solves seed production and r-process at the same time
    - include neutron-capture of light elements

Conditions for the Weak r-process



Conditions for the Weak r-process

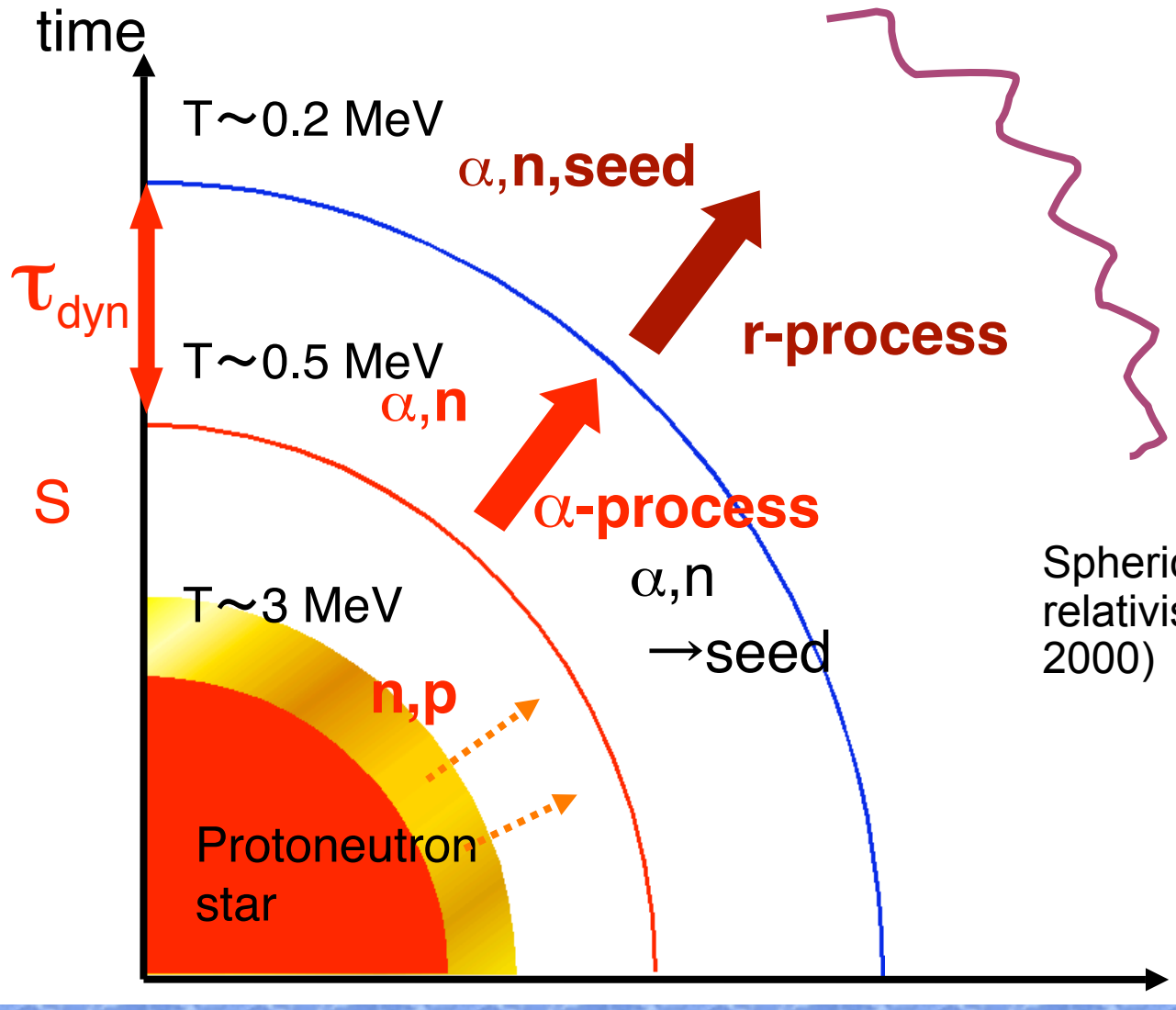




Time integral of all ejecta?(e.g., NDW)

The abundance pattern of HD122563 cannot be reproduced by a single calculation

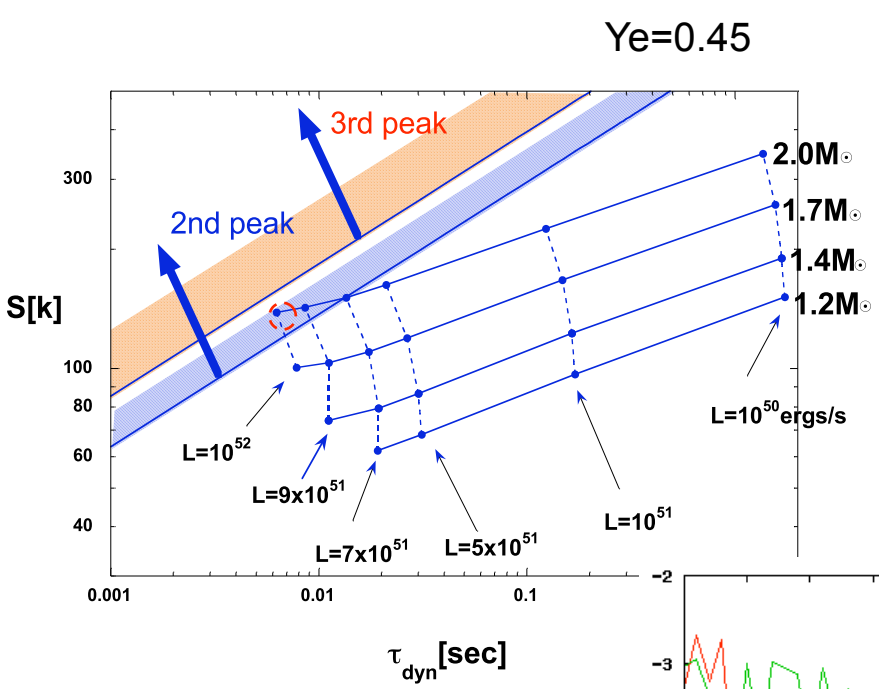
Weak r-process in Neutrino Driven wind

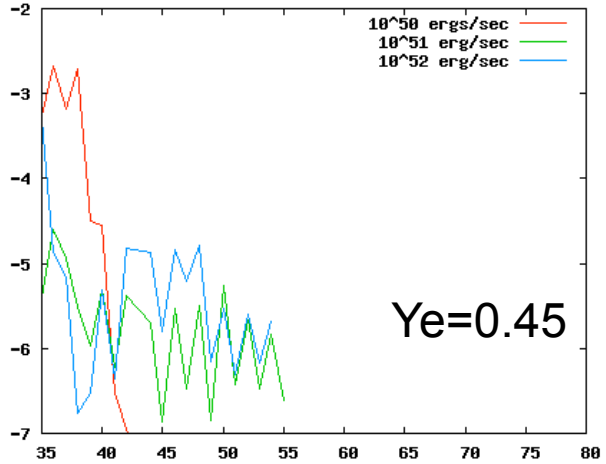


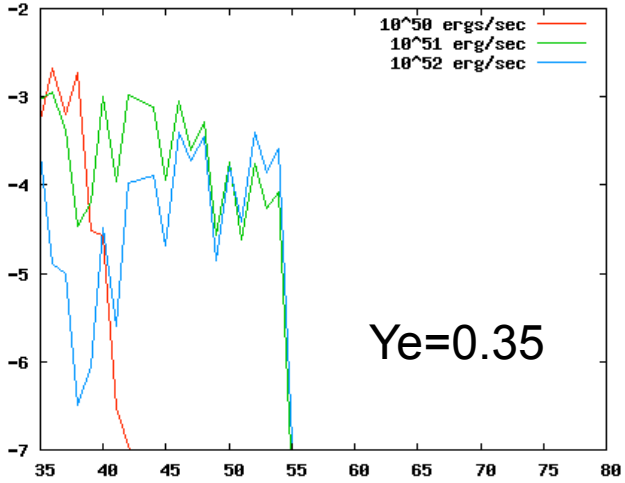
Spherical steady state flow in general relativistic framework(Otsuki et al. 2000)

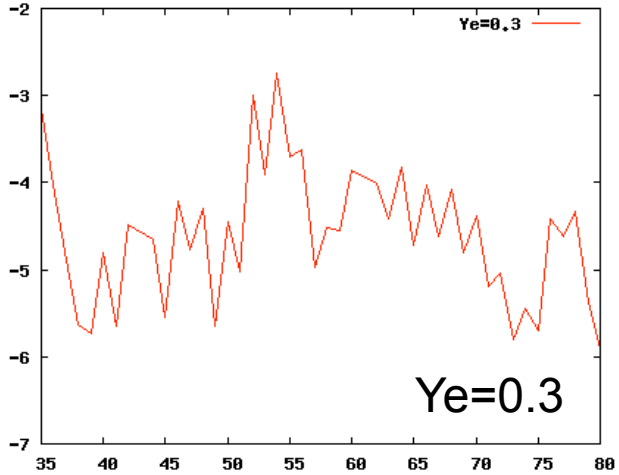
neutrino heating
$1.4M_{\odot}$, 10km
10^{50}~10^{52} ergs/sec

Weak r-process in Neutrino Driven wind





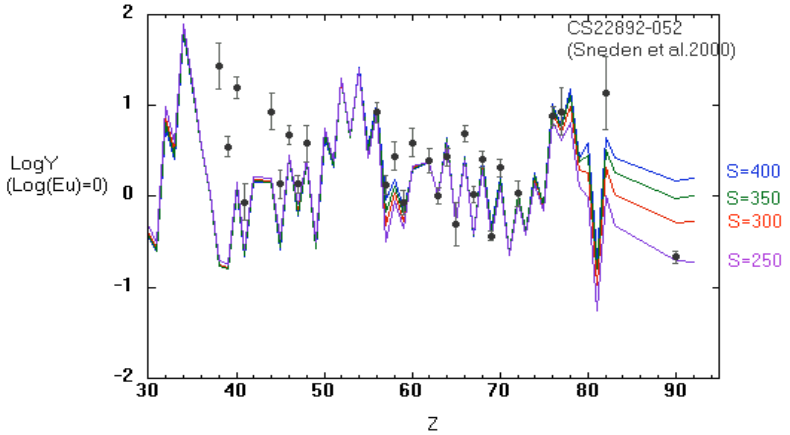


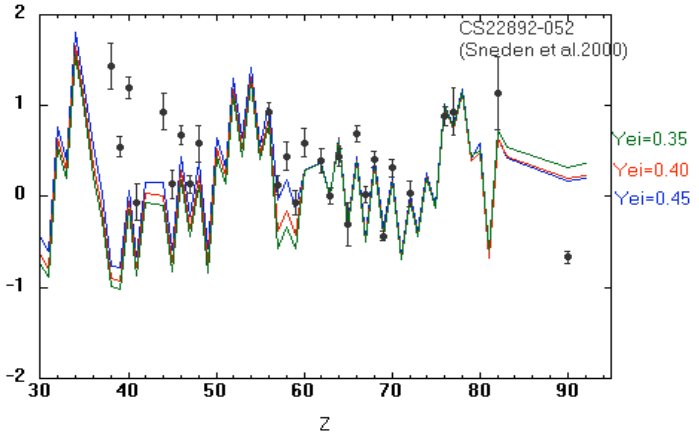


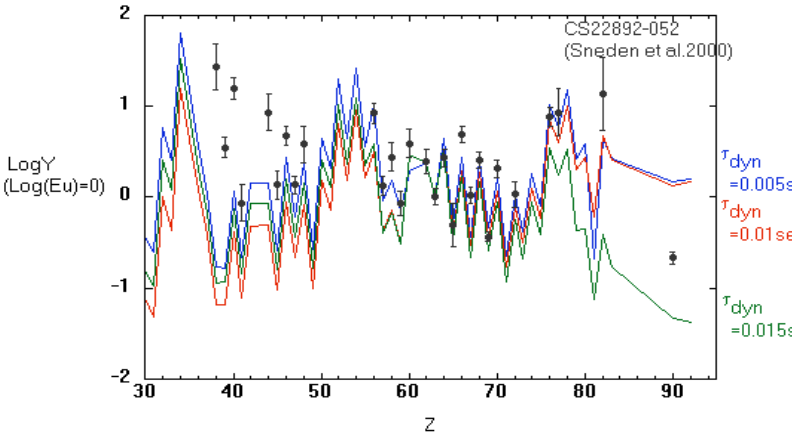
To reproduce 2nd peak tail,
Ye should be lower than 0.30!

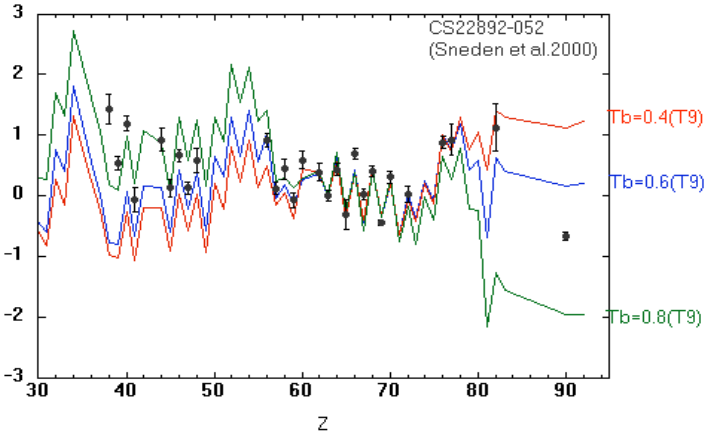
Conditions for the Main r-process

Actinide abundances strongly depend on nucleosynthesis environments.
---> Th/Eu ratios will constrain on environments.

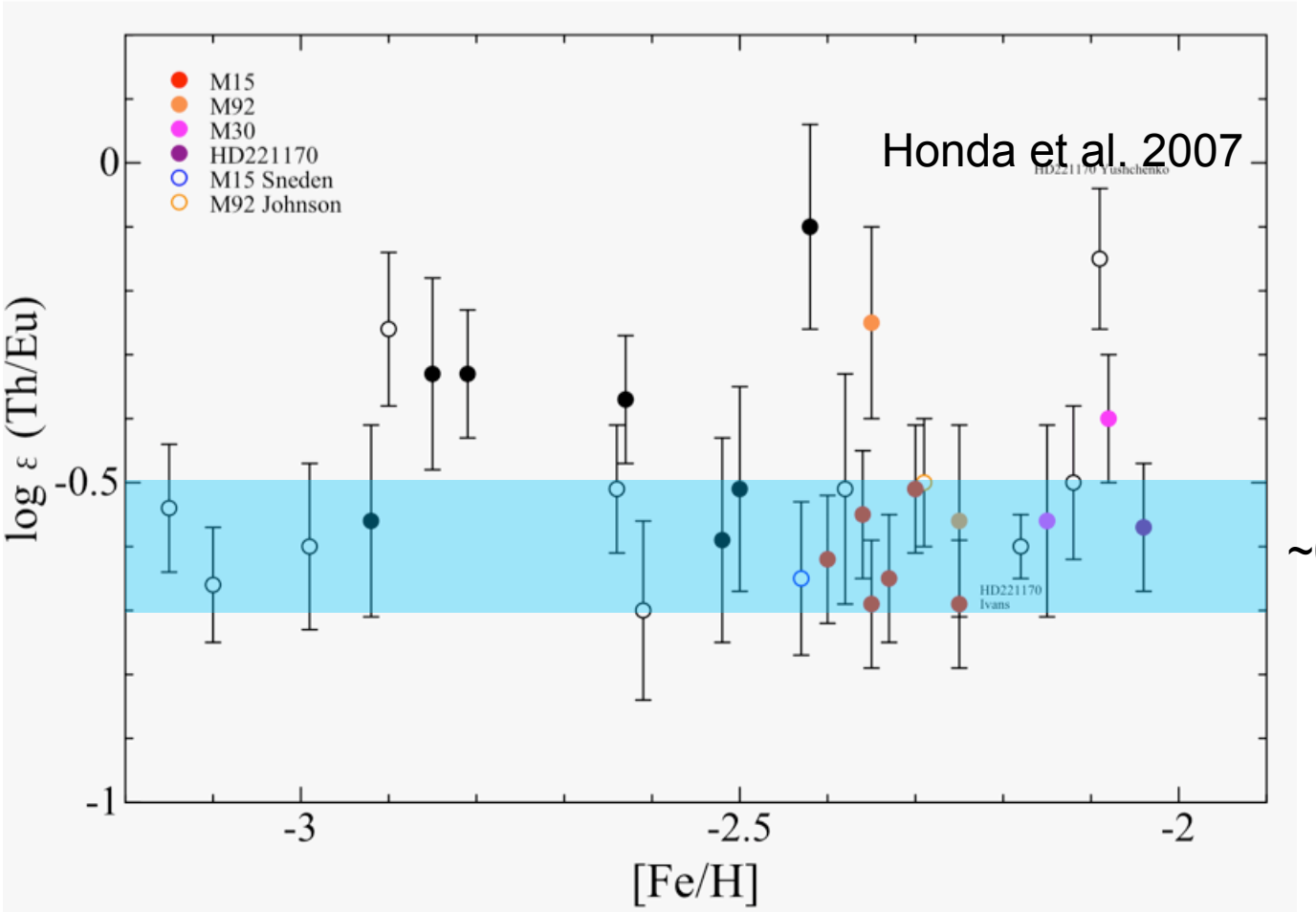








Th/Eu ratios in M15



Averaged
logε(Th/Eu) ~−0.57

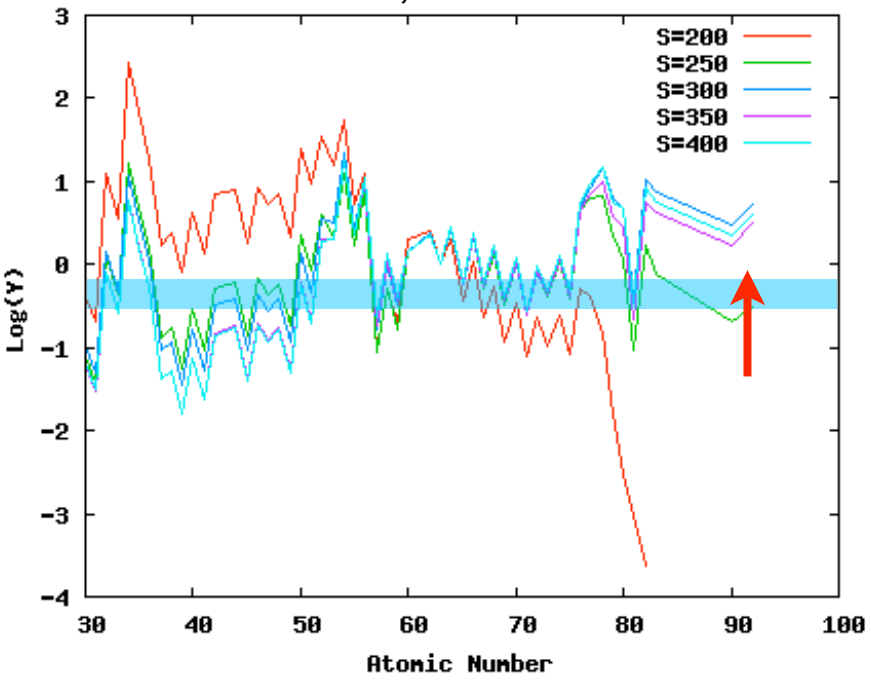
Initial logε(Th/Eu)~-0.29
for age of 13 Gys

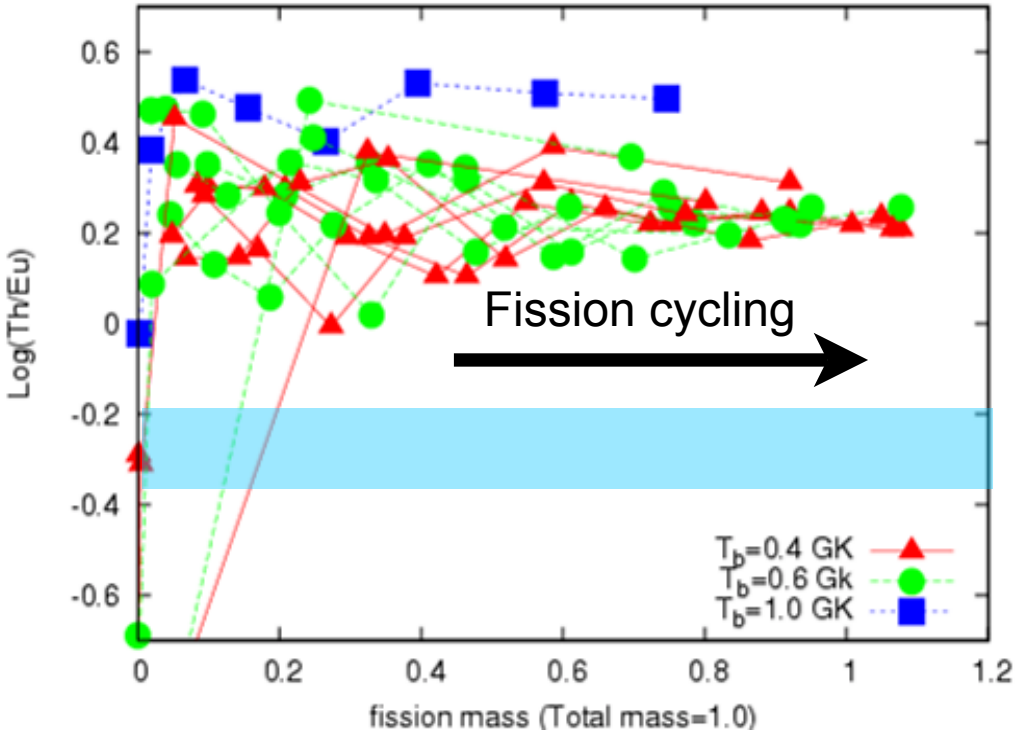
~0.2 dex

Conditions for the Main r-Process

S=200~400,
Ye=0.1~0.45,
Tb=0.6,0.4
fission at A=260

Ex. Tb=0.6, Ye=0.45





Fission cycling require too much Th/Eu ratios...?

Summary

- We studied conditions of r-process site(s) to reproduce observational results.
  - Weak r-process
    - It is difficult to reproduce observed weak r-process pattern with a single nucleosynthesis environment.
    - Steady state wind model (NDW) cannot reproduce 2nd peak tail unless Ye is extremely low (<0.3).
  - Main r-process
    - Observed Th/Eu can be a strong constrain of nucleosynthesis environments for main r-process.
    - Fission recycling require higher Th/Eu production ratio than observed value in the case with
      - Hilf + Klapdor,
      - FRDM+FRDM,
      - HFB9+FRDM