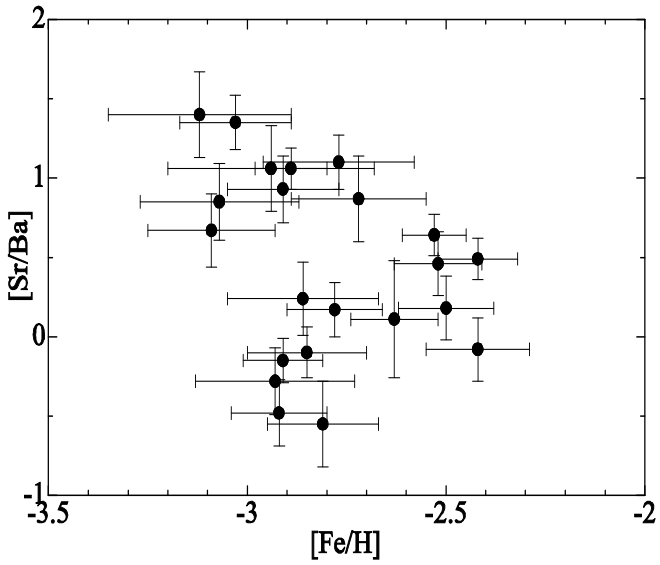
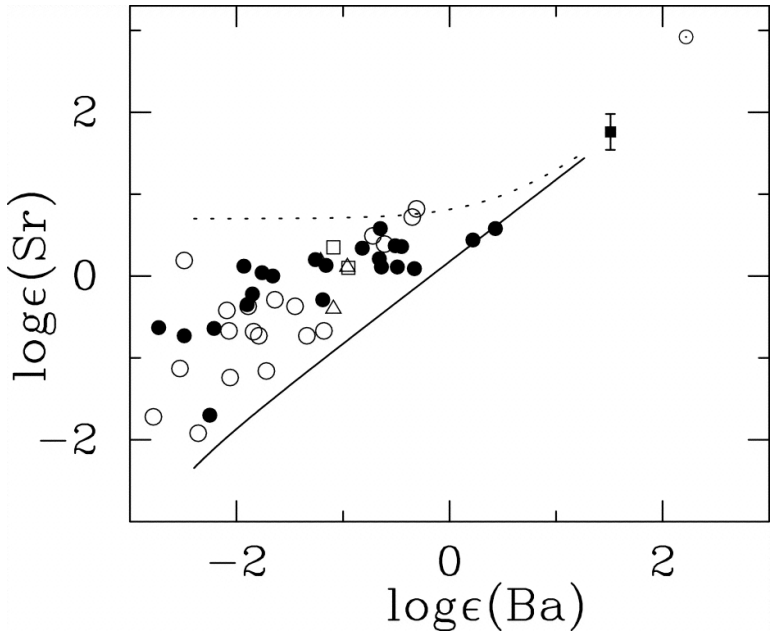
Astrophysical site for the weak r-process

K. Otsuki (NSCL)
J. Truran (U of Chicago),
S. Honda (Gunma Obs.),
W. Aoki (NAOJ)
G. Mathews (ND)

Two r-Processes in Field Stars

Honda et al. 2004





Two different processes enriched Sr,Y,Zr

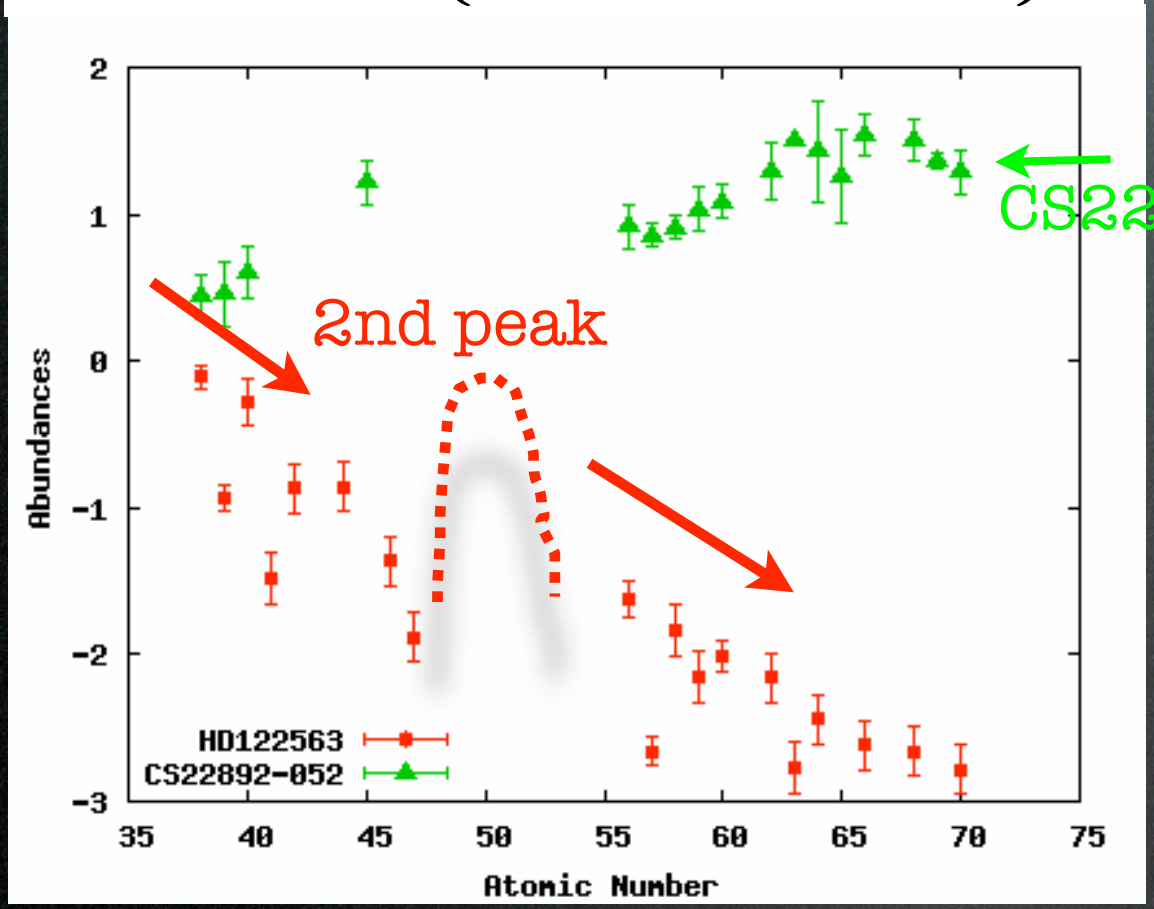
Main r-process: enrich all elements (Sr,Y,Zr.....Th,U)

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)

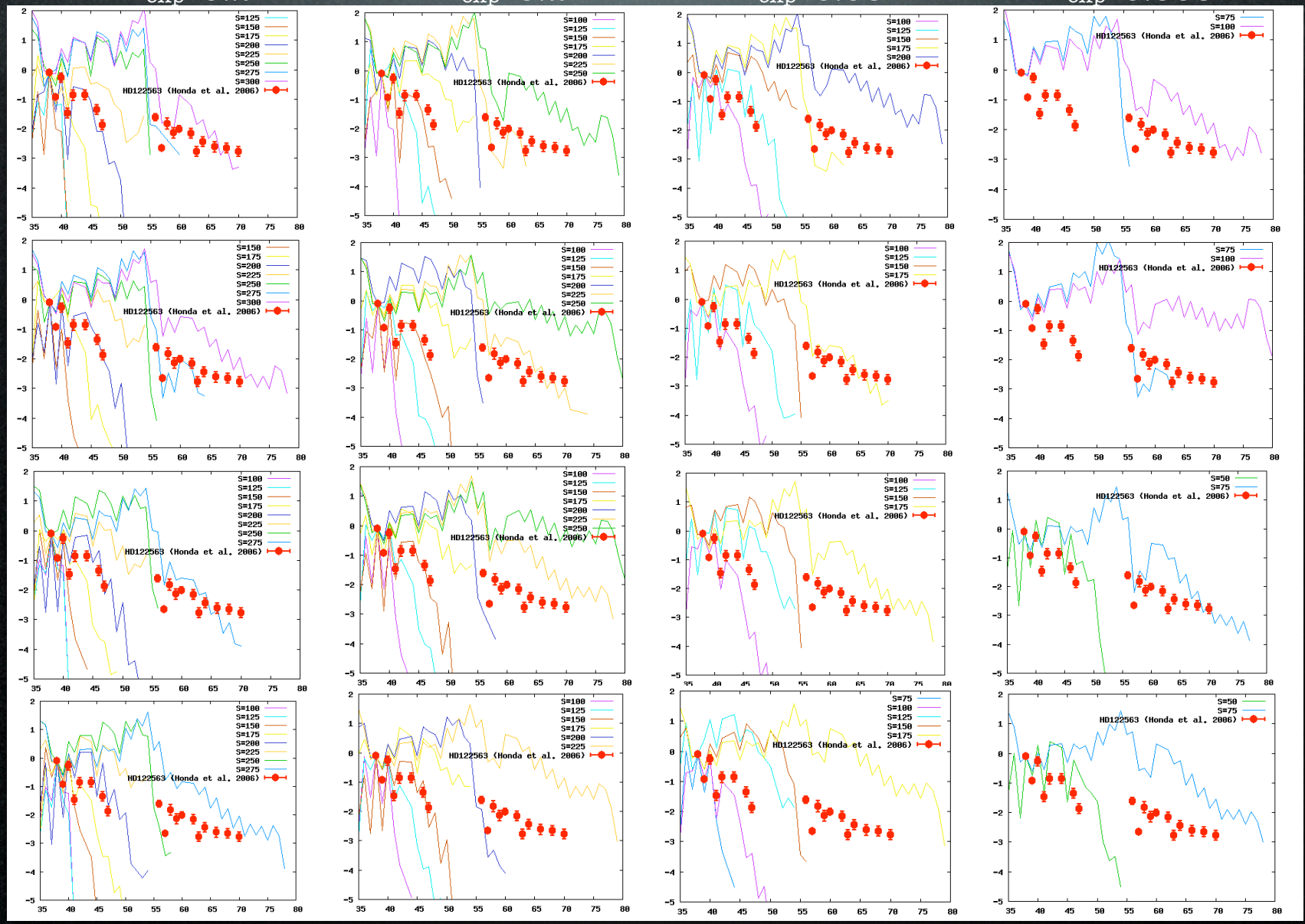


Can we reproduce this abundance pattern with r-process?

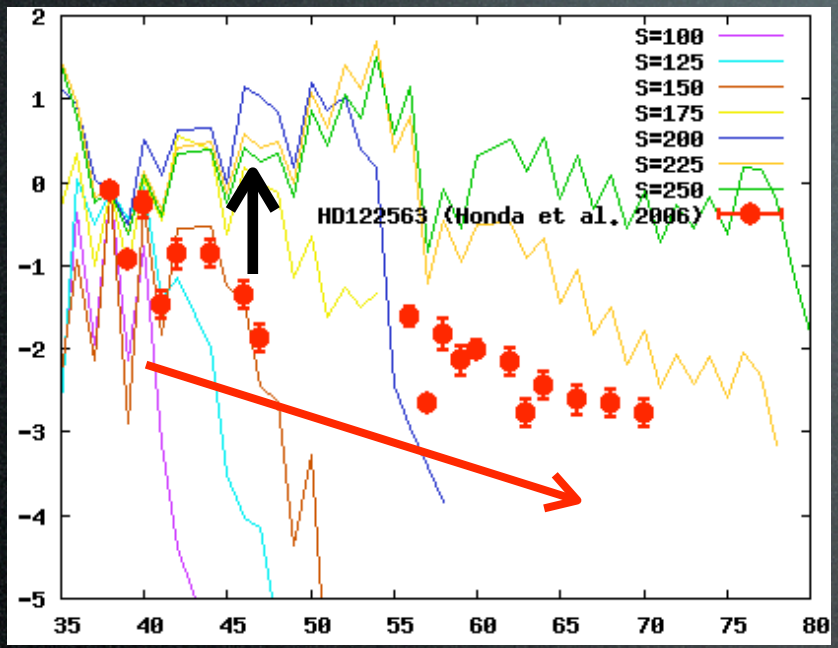
Theoretical Calculation

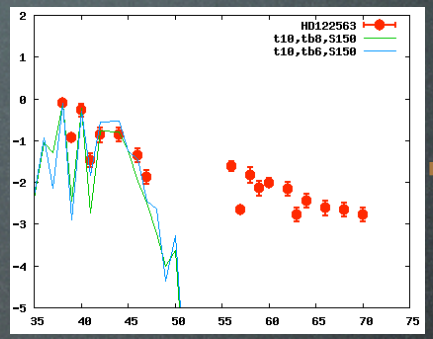
- Model
  - Adiabatic expansion (High entropy scenario)
    - $\rho(t)=9.0\ \exp(-t/\tau_{exp})+T_b$; $S \propto \rho/T^3$; $Y_e=0.45$
    - τ_{exp}=0.2,0.1,0.05,0.005 sec; S=75~300; T_b=0.4,0.6,0.8.1.0 GK
- Network Code
  - Full dynamical network code
    - based on Meyer et al. 2004, modified Orito, 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

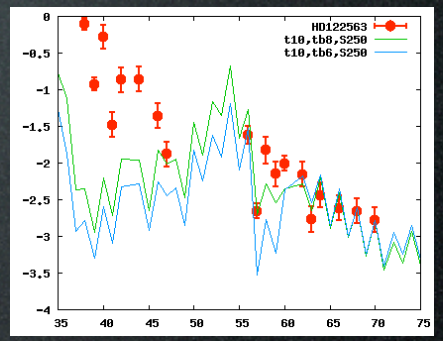


Conditions for the Weak r-process





+

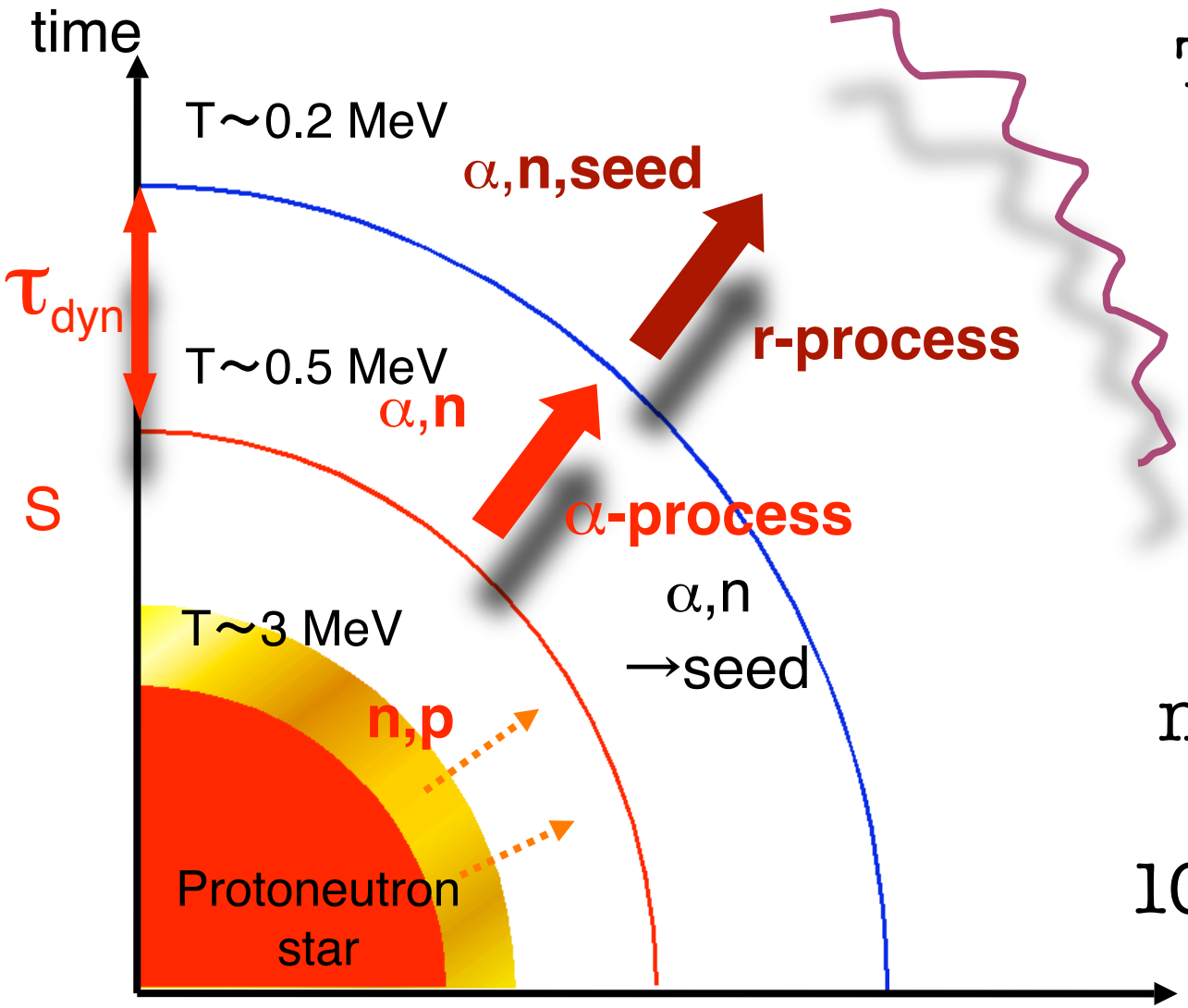


+ ....

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

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

Weak r-process in Neutrino Driven wind



Too low n/seed for main r-process

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

Spherical steady-state wind model (Otsuki et al. 2000)

$$\dot{M} = 4\pi r^2 \rho_b \upsilon$$

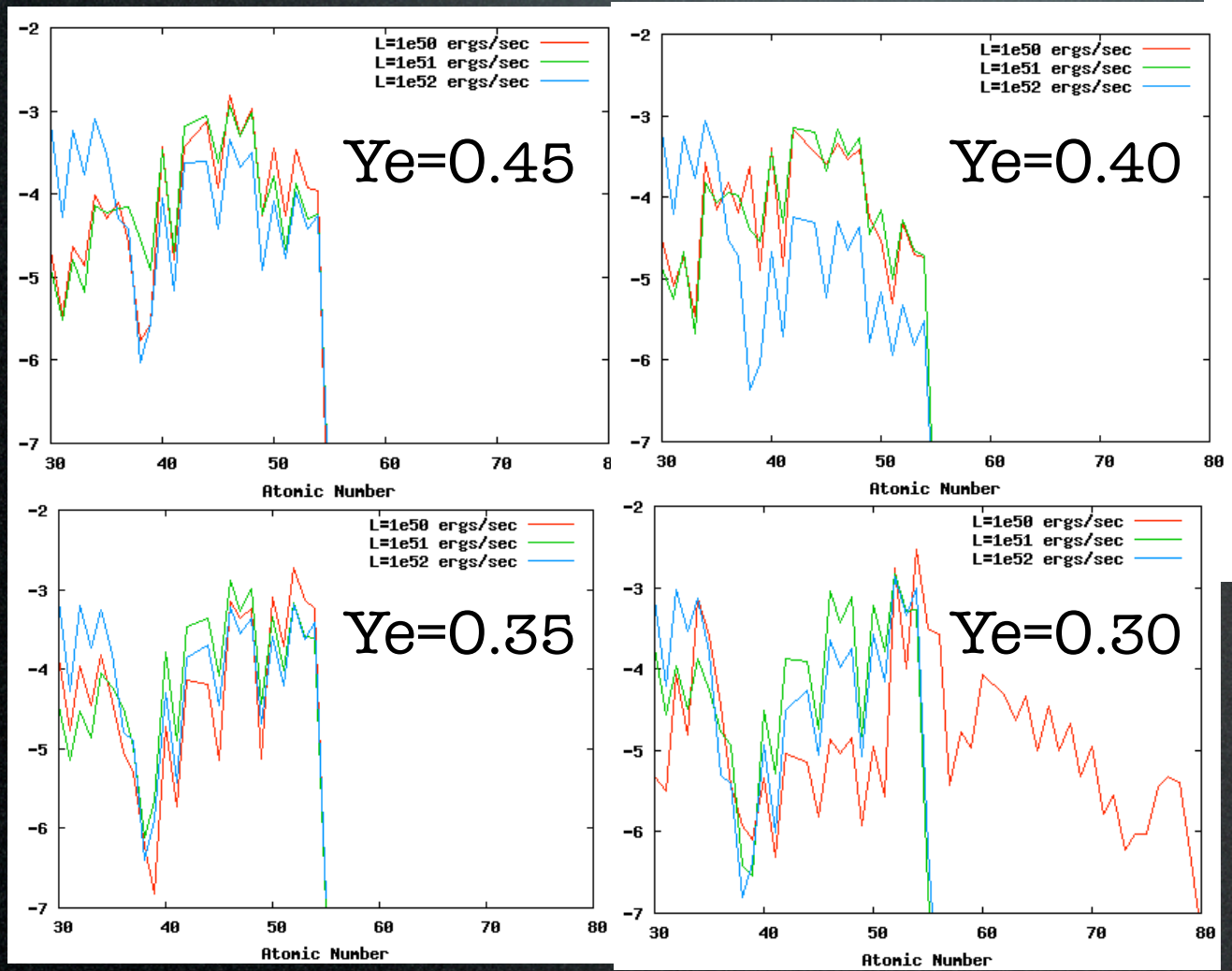
$$\upsilon \frac{d\upsilon}{dr} = \frac{1}{\rho_b + P} \frac{dP}{dr} \left(1 + \upsilon^2 - \frac{2M}{r}\right) - \frac{M}{r^2}$$

$$\dot{q} = \upsilon \left(\frac{d\epsilon}{dr} - \frac{P}{\rho_b^2} \frac{d\rho_b}{dr}\right)$$

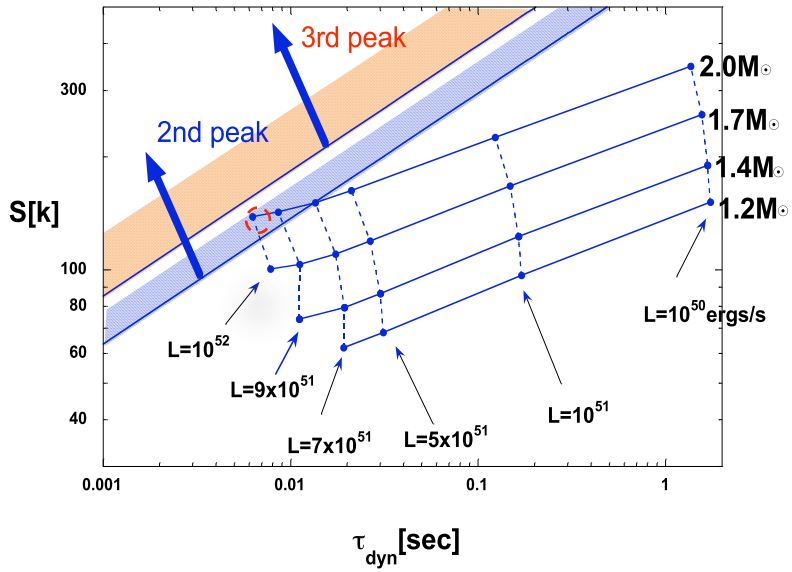
$$\nu + p \rightleftarrows n + e^+, \quad n + \nu \rightleftarrows p + e^-$$

$$\nu + e \rightarrow \nu + e, \quad \nu + \nu \rightleftarrows e^+ + e^-$$

Weak r-process in Neutrino Driven wind



Ye=0.45(Otsuki et al. 2000)



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

Summary

- We studied r-process calculation in various environment to find suitable condition for weak r-process.
  - It is difficult to reproduce the observed weak r-process pattern with a single nucleosynthesis condition.
- We studied r-process in Neutrino-Driven Wind using spherical steady-state flow model.
  - r-process in Neutrino-Driven wind around a 1.4 solar mass neutron star cannot reproduce 2nd peak tail.
    - ✓ Ye<0.3 or heavier neutron-star?
    - ✓ Shock reheat? (Acornes et al. 2007)