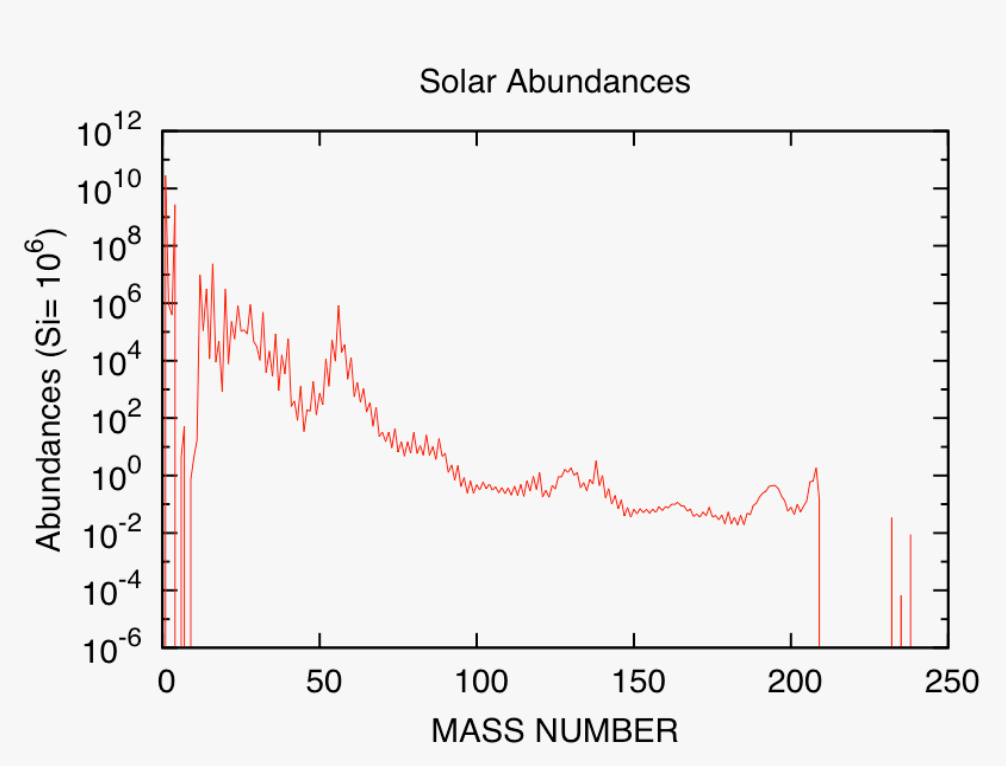
Origin of r-process elements

Kaori Otsuki
University of Chicago ~ May 31
NSCL(MSU) Jun.1 ~ Aug. 31
GSI Sept. 1~

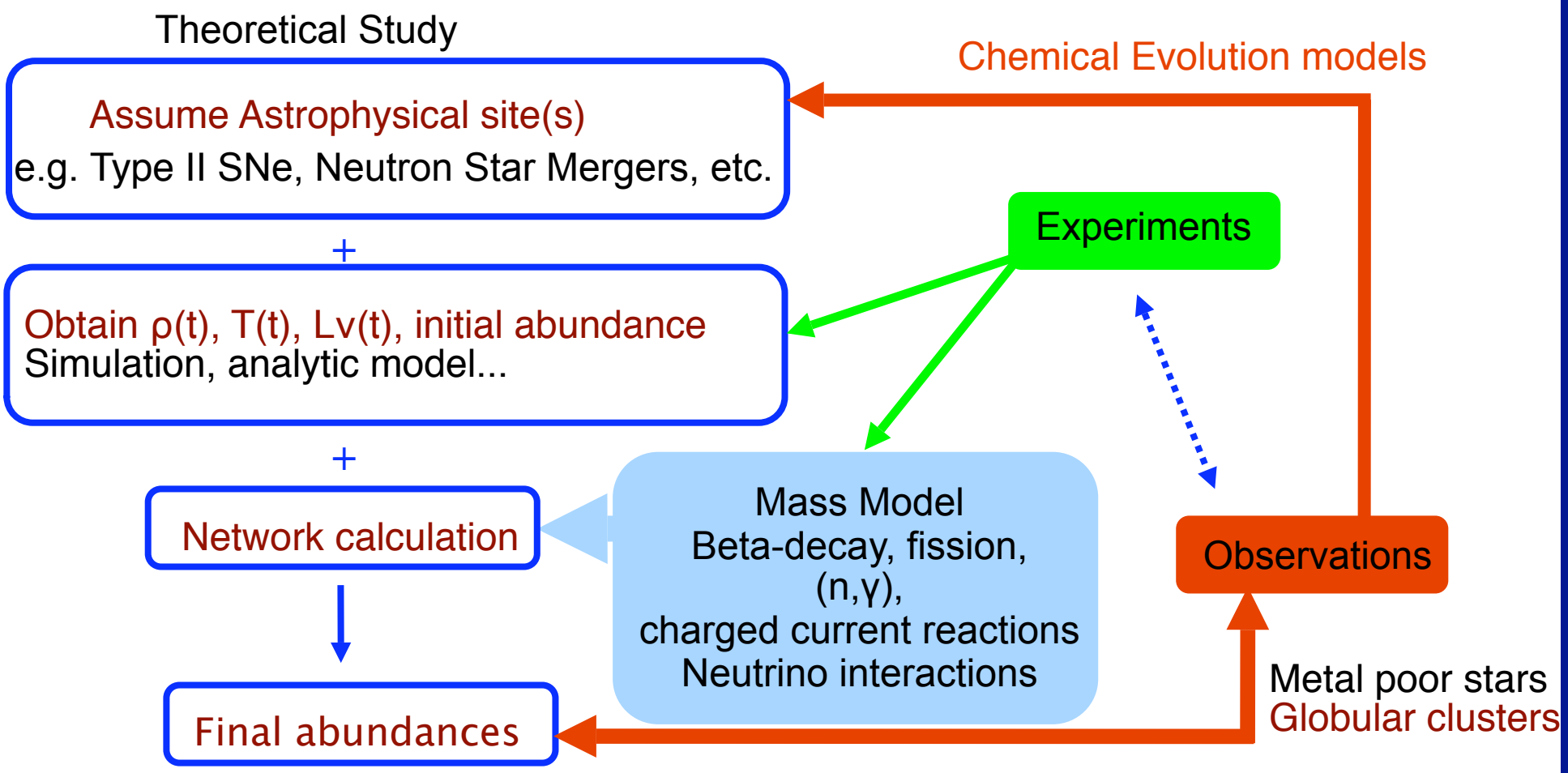


I would like to know

When, Where, How
they have been formed.

Map of enrichment history of our galaxy

R-process study



Network code

- Full dynamical network code
  - based on Meyer et al. 1994, modified by Terasawa, Orito, & Otsuki (1997, 2001, 2003)
  - differential equations for more than 4000 nuclide
  - start from free n&p
    - solve seed production and r-process at the same time
    - include neutron-capture of light elements (Sasaqui et al. 2005)
- Nuclear data
  - MASS---Hilf, HFB9, FRDM03, FRDM95
  - Beta-decay---Klapdor, FRDM03
  - (n,γ)---HFB9, Hilf, FRDM95(up to Bi)

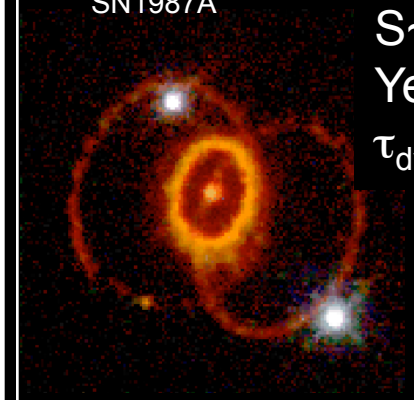
No Consistent data set is archived yet!

Astrophysical site for the ‘main’ r-process

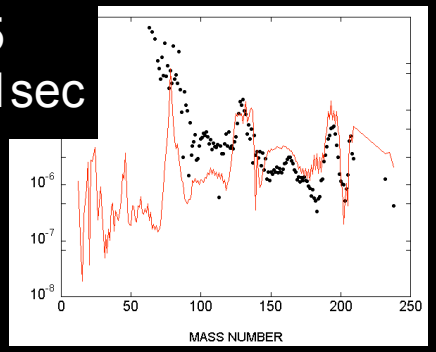
Dominant Candidate

Neutrino-driven wind in SNe II

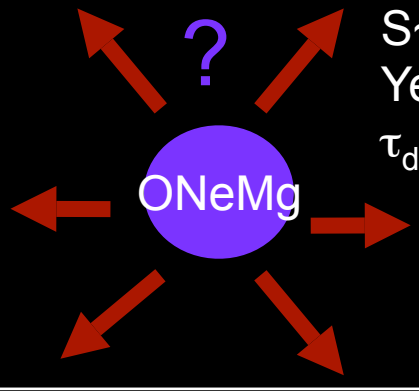
SN1987A



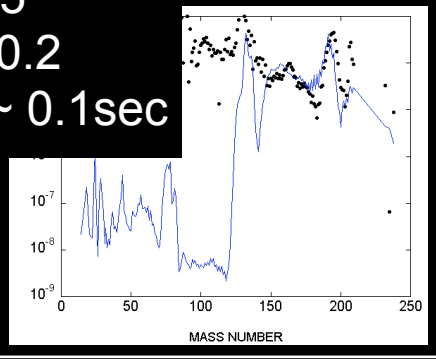
S~400
Ye~0.45
τ_{dyn}~ 0.1sec



Prompt explosion of low mass supernovae

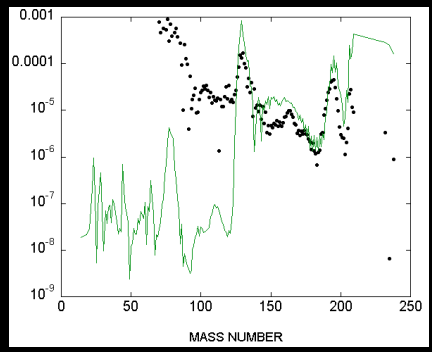


S~15
Ye~0.2
τ_{dyn}~ 0.1sec



Neutron star mergers

Simulation of NS mergers
(from Hayden planetarium)



S<4
Ye<0.2

gamma-ray burst
collapsar
quark novae
…

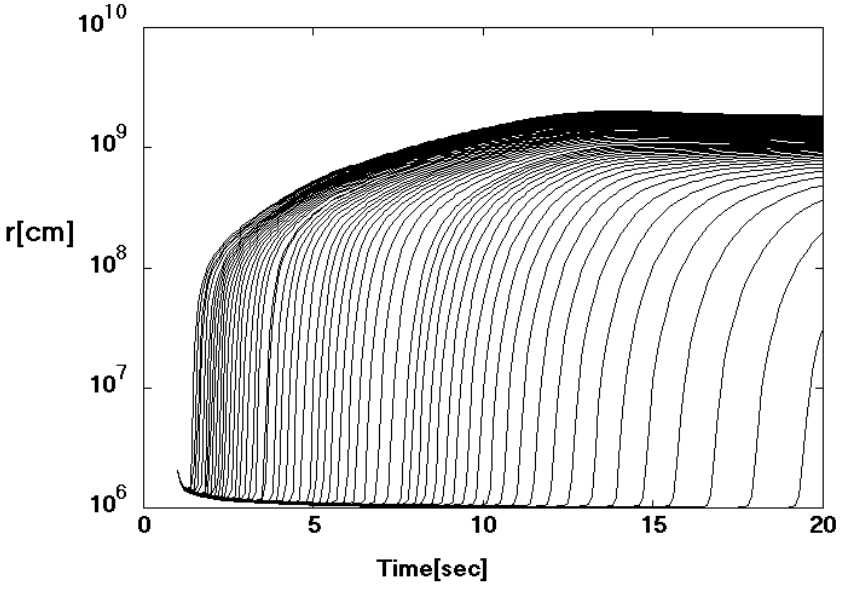
r-process abundance patterns from different environments are distinguishable.
If nuclear physics uncertainties are reduced, we could identify astrophysical site via observations.

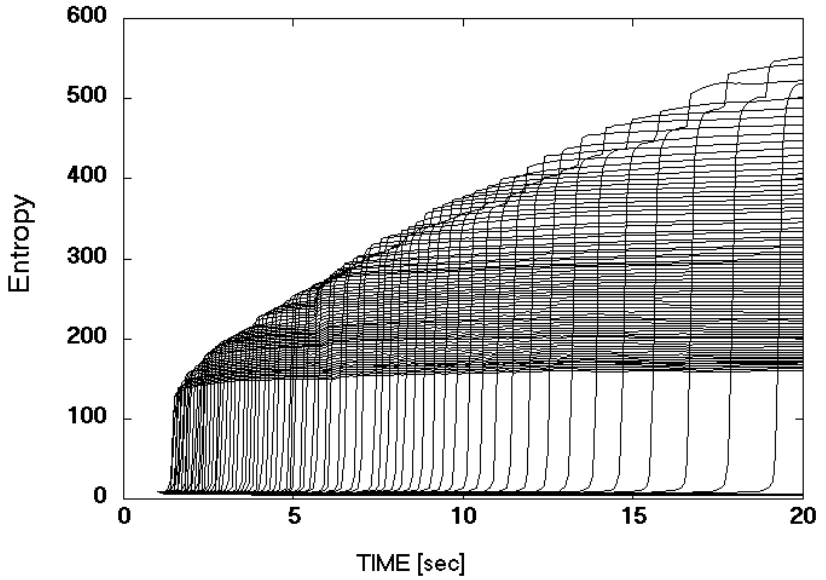
Theoretical calculation II (Wilson et al. 2006)

Wilson's new simulation(2006)

- M=20$M_{\odot}$ progenitor mass
- Improved EOS
- Improved numerical method

Entropy~500k
timescale ~0.1sec



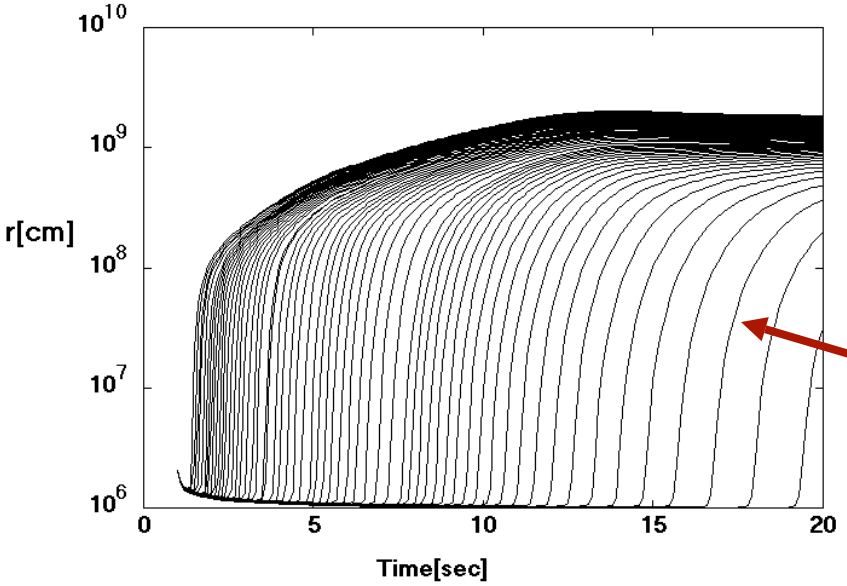


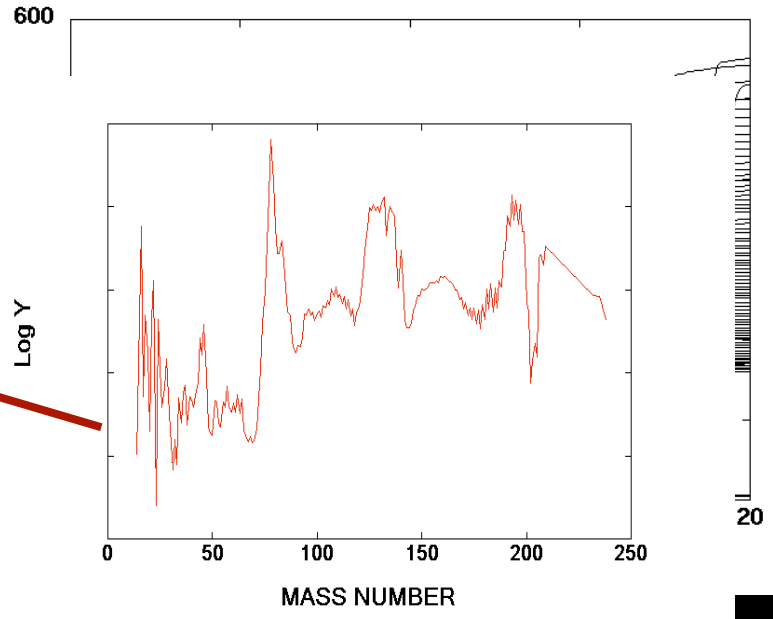
Theoretical calculation II (Wilson et al. 2006)

Wilson's new simulation(2006)

- M=20$M_{\odot}$ progenitor mass
- Improved EOS
- Improved numerical method

Entropy~500k
timescale ~0.1sec



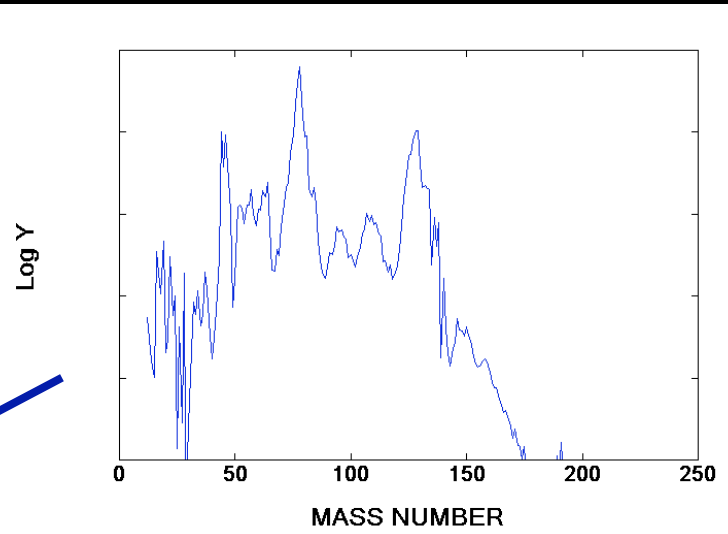


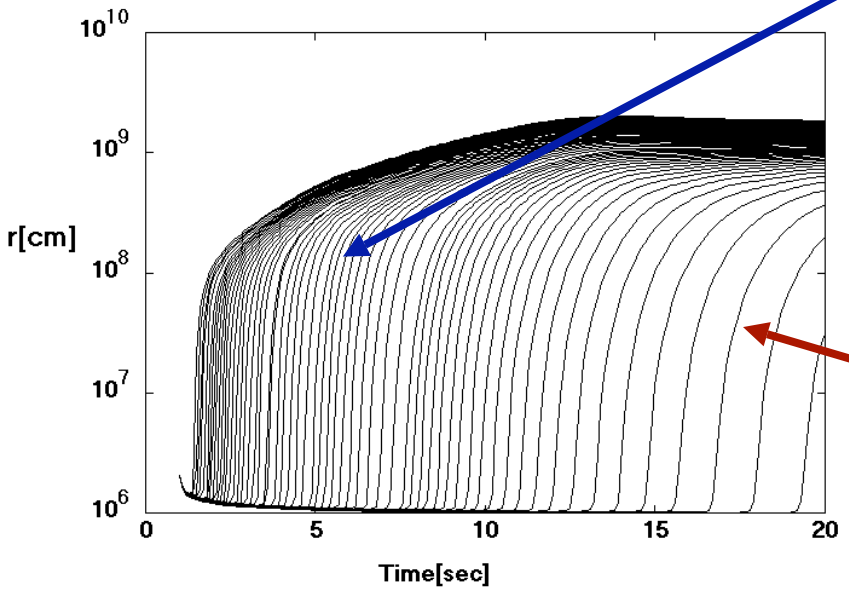
Theoretical calculation II (Wilson et al. 2006)

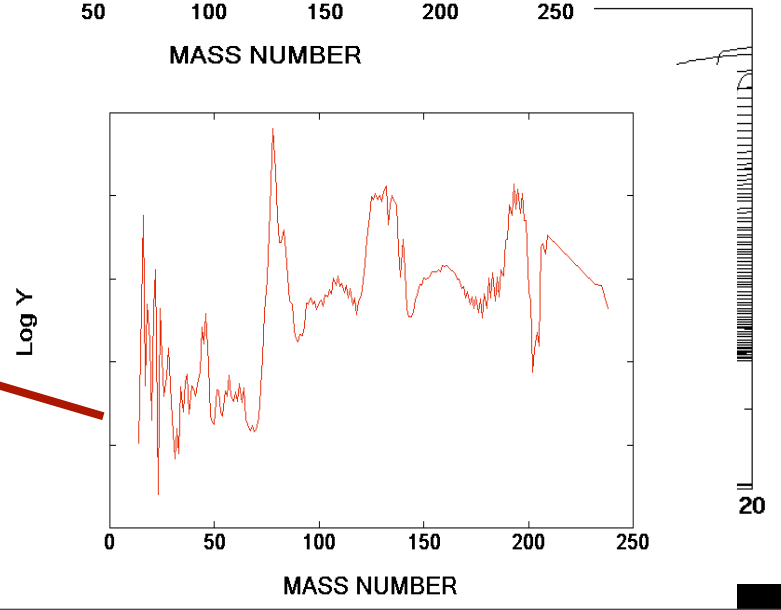
Wilson's new simulation(2006)

- $M=20M_{\odot}$ progenito
- Improved EOS
- Improved numerical

y~500k
e ~0.1sec



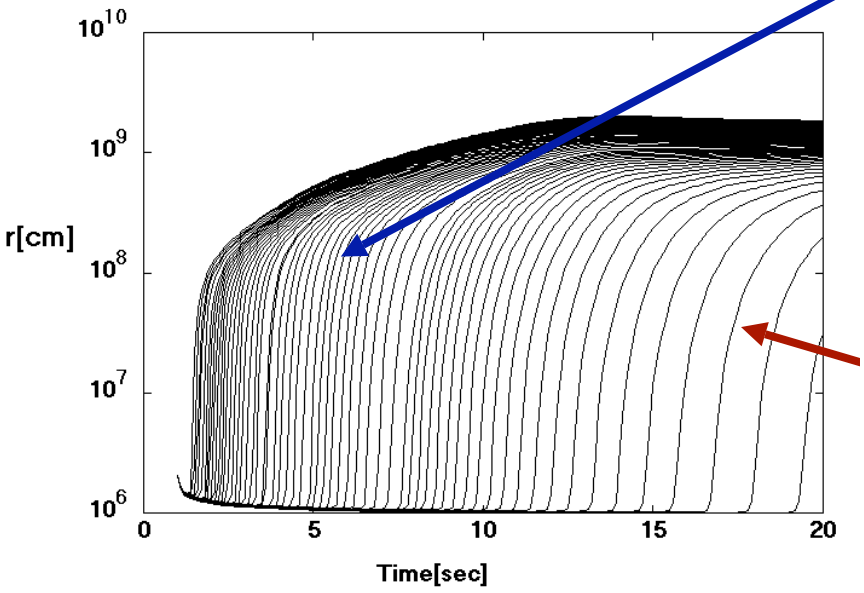


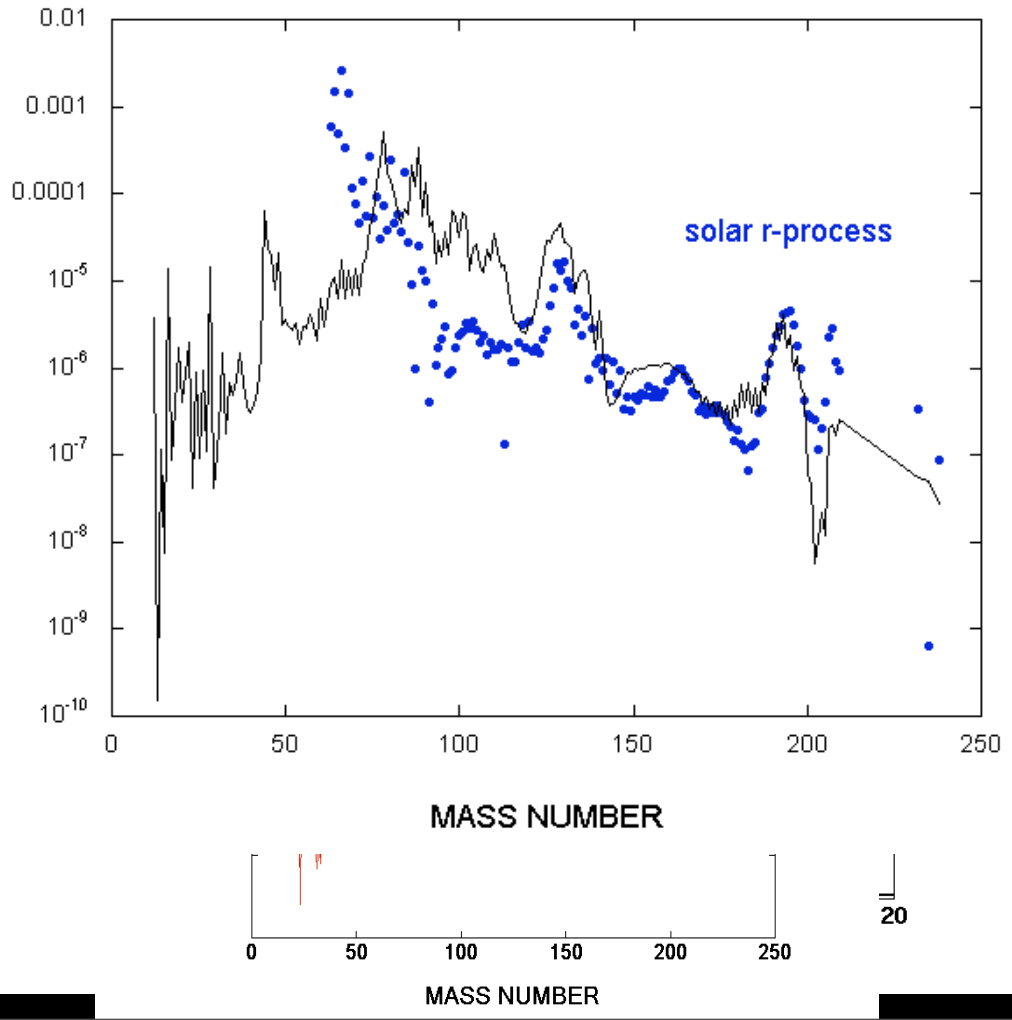


Theoretical calculation II (Wilson et al. 2006)

Wilson's new simulation(2006)

- M=20M$_\odot$ progenitor
- Improved EOS
- Improved numerical

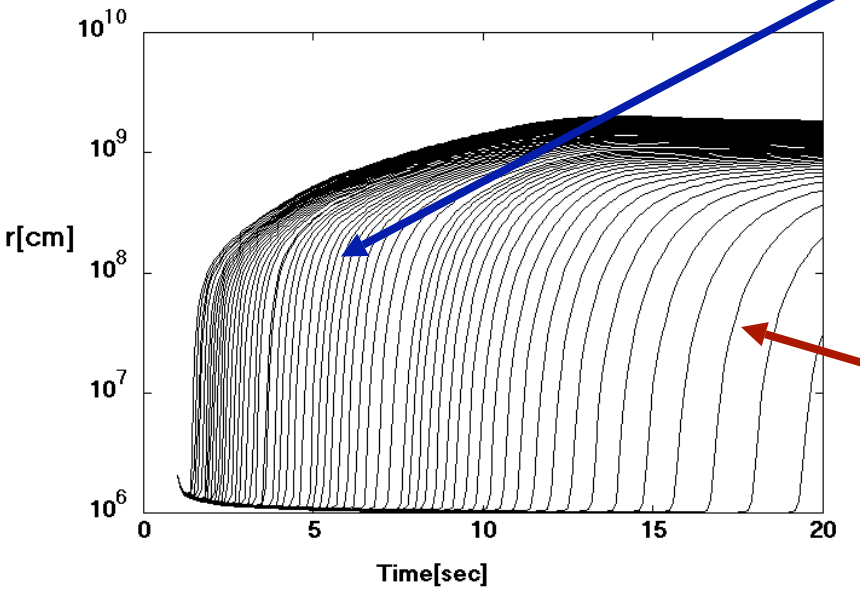


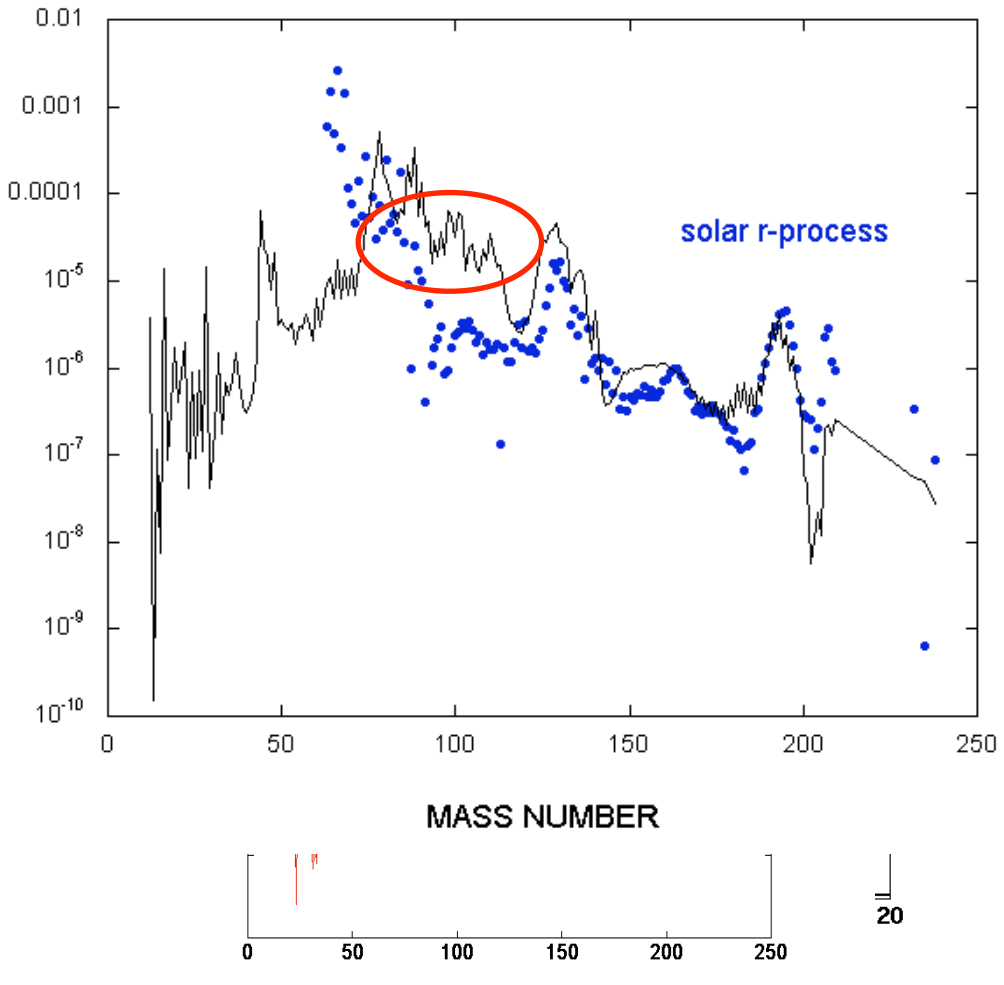


Theoretical calculation II (Wilson et al. 2006)

Wilson's new simulation(2006)

- M=20M$_\odot$ progenitor
- Improved EOS
- Improved numerical

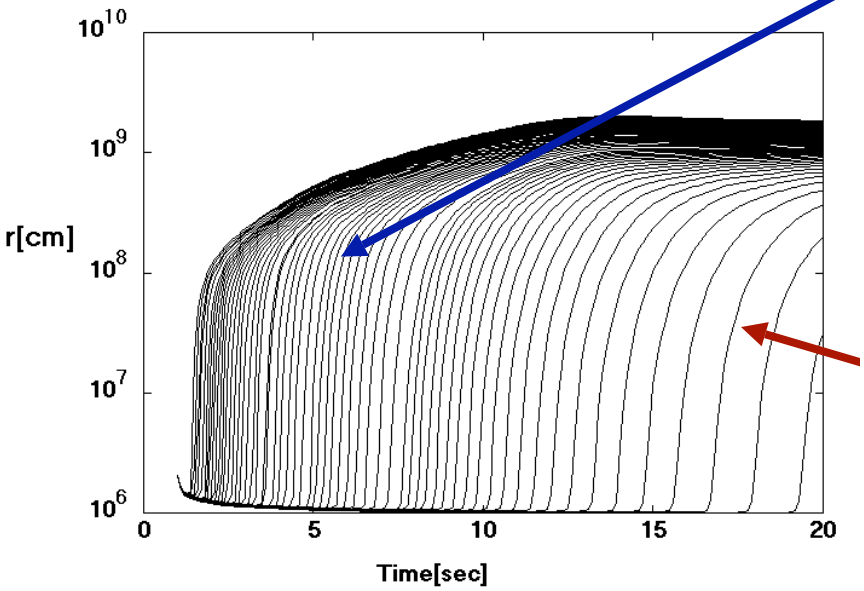


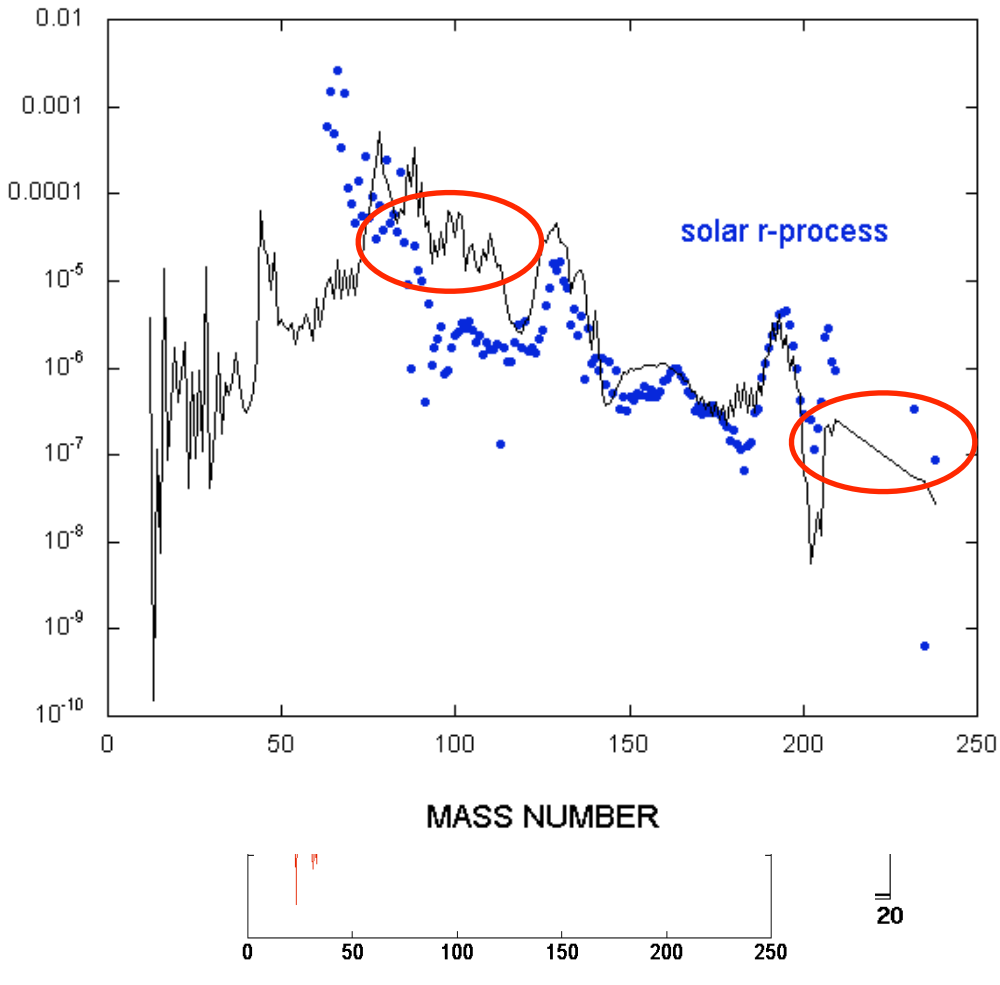


Theoretical calculation II (Wilson et al. 2006)

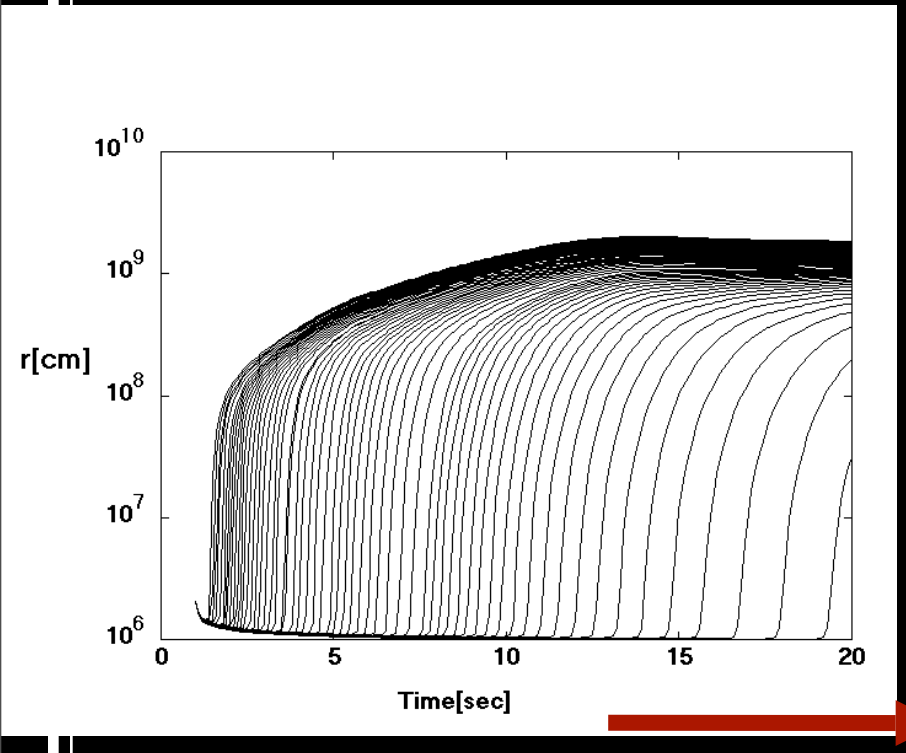
Wilson's new simulation(2006)

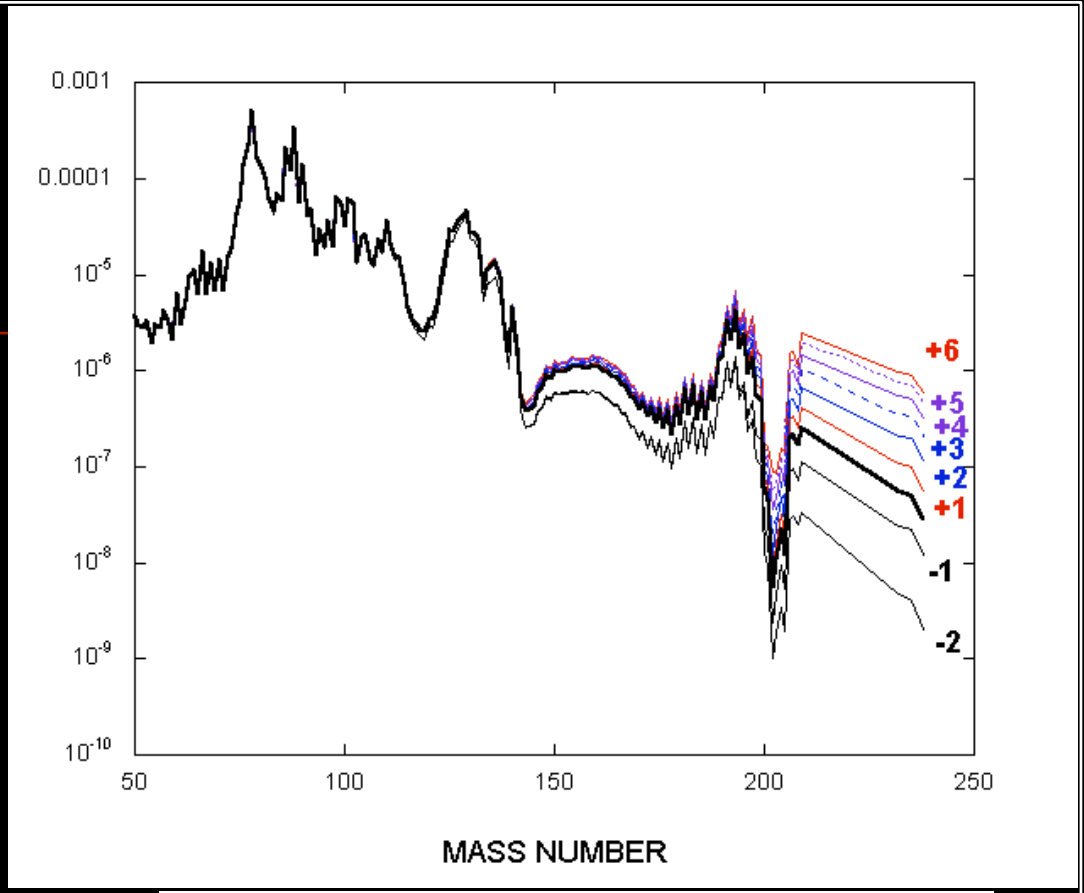
- M=20M$_\odot$ progenitor
- Improved EOS
- Improved numerical

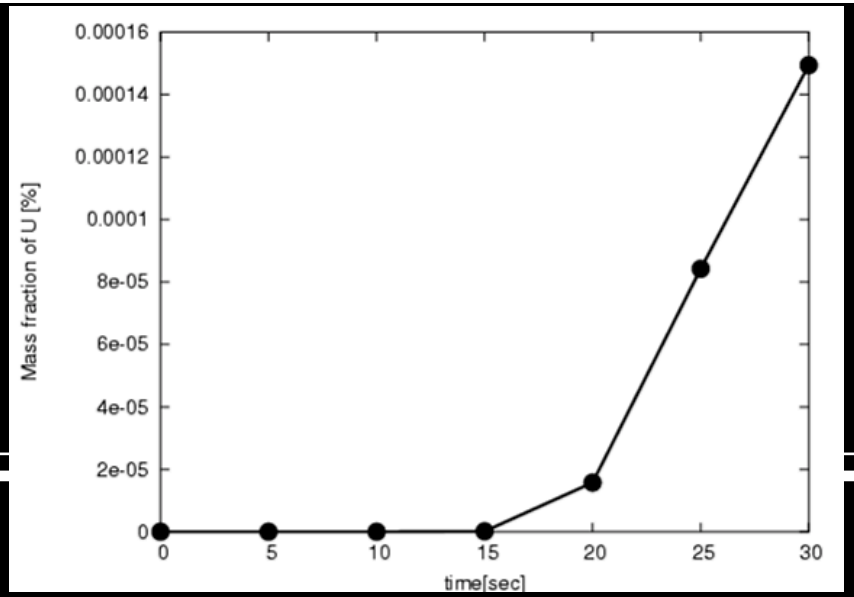




Heavy elements are formed at the later stage of wind.







Current & near future works

- Weak r-process in neutrino-winds
  - Can we reproduce HD122563 pattern?
- Role of Fission recycling in main r-process
  - Does it explain an universal abundance pattern?
- Suitable environment for the main r-process
  - Conditions to reproduce observed Th/Eu & Y,Zr/Eu
- Other collaborations
  - R-process in Type II SNe (based on Simulation data)
  - New reaction rates from experiments
  - Observation of neutron-capture elements in GCs
  - fission mass fragment
  - neutrino absorption in r-process