Neutron captures and the r-process

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In order to study neutron captures in the freeze-out it is necessary to perform dynamical r-process simulations. As an example, we performed calculations in the model of an adiabatically expanding hot bubble with temperature-dependent rates, including the theoretical rates of [1].
In this model of primary r-process, a blob of matter at high temperature ($T_9 \approx 9$) expands and cools [2]. For the calculation here we choose an expansion time scale of 35 ms which corresponds to an expansion speed of the hot bubble of around 7500 km/s.
The charged-particle reactions, in particular the α-captures, cease at around $T_9 \approx 3$. Below that temperature we used a full network, including (n,γ), (γ,n), and β-decays. The seed abundances for this r-process network are given by the α-rich freeze-out abundances of the charged particle network.
Fig. 1 shows an example of a an arbitrary chosen paramter combination which can reproduce the A=130-peak.

Since the uncertainties in the neutron capture rates

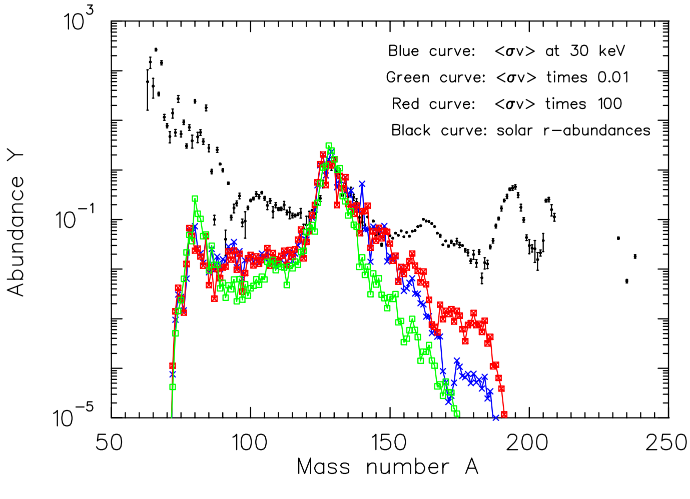

Figure 1: Decayed final abundances of the S=196-entropy sequence. The neutron rates are changed in a range of 4 orders of magnitude.

might be large, we scaled the standard neutron capture rates up and down by a factor 100. A very large perturbation of the neutron capture rates, as we see in Fig. 1, does not effect the finale abundance of the second r-process peak.
Fig. 2 shows the neutron number density as a function of time in also three cases.

Components with high entropy freeze out slower

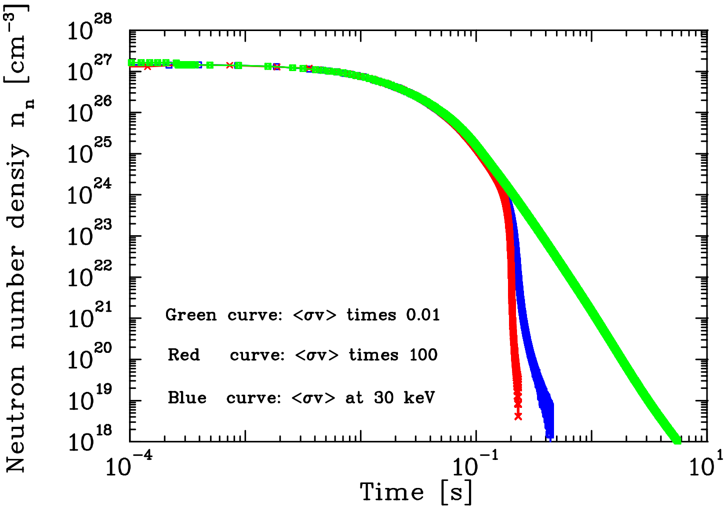

Figure 2: Time evolution of the neutron number density.

and late-time neutron captures can modify the final abundance distribution mainly in the region $A > 140$ (see fig. 3). Therefore, emphasis has to be put on improving the prediction of nuclear cross sections and astrophysical reaction rates in that mass region.

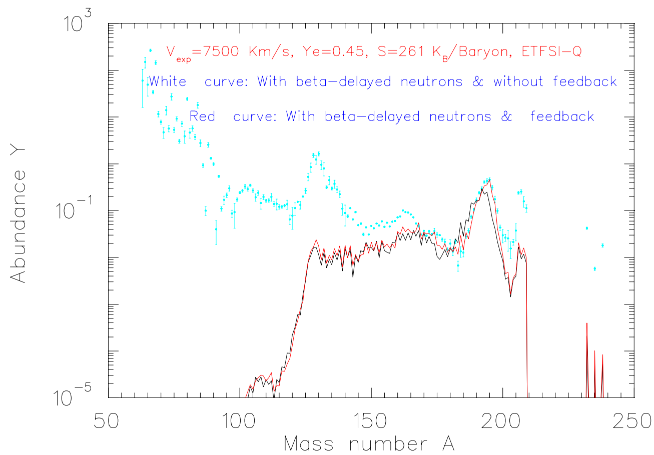

Figure 3: The effect of the β-delayed neutrons on the final abundance after the freeze-out.

References

[1] Rauscher, T. & Thielemann, F.-K., Atomic data Nucl. Data Tables 75, 1 (2000)

[2] Freiburghaus, C., et al., Ap. J. 516, 381 (1999)