Dynamics of proto-neutron star neutrino wind and the r-process

I. V. Panov[1,2*], H.-Th. Janka[2]

[1]Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia

[2]Max-Planck-Institut für Astrophysik, Garching, Germany

The conditions for the r-process in a neutrino-driven wind and the extreme values of the entropy and dynamical timescale needed for a successful nucleosynthesis are numerically evaluated. A number of parametric calculations of the r-process nucleosynthesis for typical conditions in a neutrino wind of a hot proto-neutron star is made, and some critical conditions, to be achieved for a successful creation of the platinum peak during r-process, are determined. We confirm (see [1]) that the r-process is only possible, under the conditions of moderate entropy we are interested in, for a very short expansion timescale. The dependence of heavy element yields on the type of the asymptotic behavior of temperature and density is explored. Extreme cases of zero and constant velocity of the wind expansion are studied. It is shown that during the expansion with a constant velocity the sensitivity of the r-process calculation on initial parameters is much weaker than under constant boundary conditions.

Time-dependent asymptotic temperature and density behavior, as well as the model with reduced mass ejection rate [2], are more favorable for the r-process when the time-dependent asymptotic temperature T_9^f is based on the concept of steady expansion, instead of introducing constant boundary conditions [3, 4].

Variations in initial values of the asymptotic temperature $T_9^f(t_0)$ (and corresponding initial density $\rho^f(t_0)$) within the discussed limits ($0.1 < T_9^f(t_0) < 1.4$) significantly – up to three orders – affect the initial neutron density. However, because of a rapid temperature decline, the balance between (n,γ) and (γ,n)-processes is changed into the balance between (n,γ)-captures and beta-decays. Then the r-process transforms to the rβ-process (like in n-process of [5]) with the total number of captured neutrons being close for different initial $T_9^f(t_0)$ values.

The asymptotic temperature and density expansion, produced by the expansion of matter in winds with constant velocity, shows a weak sensitivity of the third peak formation to the initial values of $T_9^f(t_0)$ and $\rho^f(t_0)$. This fact probably gives evidence of the same robust r-process pattern for SN explosions with different characteristics.

References

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*E-mail: igor.panov@itep.ru