Nucleosynthesis of elements between Sr and Ag in neutron- and proton-rich neutrino-driven winds

J. Bliss[1] *and A. Arcones*[1,2]
[1]Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany; [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

Neutrino-driven winds that follow core collapse supernovae were thought to be the site where half of the heavy elements are produced by the r-process. Although recent hydrodynamic simulations show that the conditions in the wind are not neutron-rich enough for the r-process (see e.g. [7]), lighter heavy elements like Sr, Y and Zr can be produced [1, 8, 4]. However, it is still not clear whether the conditions in the wind are slighly neutron-rich or proton-rich. In Ref. [1], we have studied the formation of lighter heavy elements in slighly neutron-rich ($Y_e < 0.5$) and proton-rich ($Y_e > 0.5$) winds. We have systematically explored the impact of the wind parameters (see e.g. [9, 6]): entropy, expansion time scale and electron fraction Y_e. The wind parameters have been varied within typical conditions values found in wind simulations [2, 3].

An overview of the dependency of the Sr abundances on the wind parameters is shown in Fig. 1. Similar features and trends are obtained for other lighter heavy elements (see [1]).

In neutron-rich winds (upper panel) the abundances of Sr oscillate and exhibit several minima and maxima when the wind parameters are varied. In proton-rich winds (lower panel) we find two main differences. First, the abundances vary smoothly when varying the wind parameters. Depending on the wind parameters the heaviest element that can be produced changes. The overall abundance pattern remains similar for Sr, Y, Zr and Ag. Thus, if neutrino-driven winds are responsible for the observed abundances in very old stars, neutron-rich conditions would not provide the robustness observed in the abundance pattern. Second, most of the ejected matter consists of protons and alpha particles in proton-rich winds, while the amount of heavy nuclei is small ($Y_{\mathrm{seed}} \lesssim 10^{-4}$). In neutron-rich winds alpha particles also dominate the composition but heavy nuclei are more abundant ($Y_{\mathrm{seed}} > 10^{-3}$) than in proton-rich conditions. Hence, if every wind stays neutron-rich for several seconds there would be an overproduction around A=90 [5, 10]. Therefore, not every wind can be only neutron-rich.

Combining nucleosynthesis studies, like the one here, with new and future experimental data and observations, it will give rise to new insights about the supernova neutrinos and explosions.

This work was funded by the Helmholtz-University Young Investigator grant No. VH-NG-825.

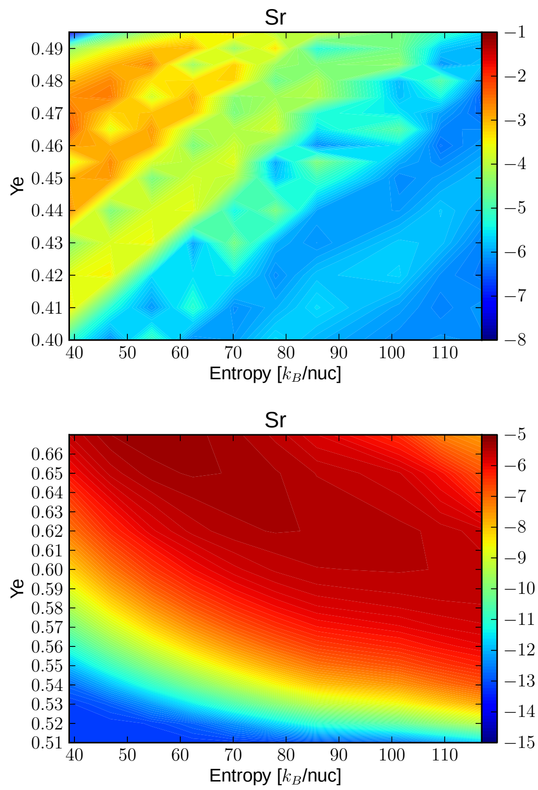

Figure 1: Color contours show the abundance in log scale of Sr for different entropies and Y_e in neutron-rich (upper panel) and proton-rich (lower panel) winds.

References

[1] A. Arcones and J. Bliss, *J. Phys. G*, 41:044005, 2014.

[2] A. Arcones and H.-T. Janka. *A&A*, 526:A160, 2011.

[3] A. Arcones, H.-T. Janka, and L. Scheck. *A&A*, 467:1227–1248, 2007.

[4] A. Arcones and F. Montes. *ApJ*, 731:5, 2011.

[5] R. D. Hoffman, S. E. Woosley, G. M. Fuller, and B. S. Meyer. *ApJ*, 460:478–488, 1996.

[6] R. D. Hoffman, S. E. Woosley, and Y.-Z. Qian. *ApJ*, 482:951–962, 1997.

[7] L. Hüdepohl, B. Müller, H.-T. Janka, A. Marek, and G. G. Raffelt. *Phys. Rev. Lett.*, 104(25):251101, 2010.

[8] Y.-Z. Qian and G. J. Wasserburg. *Phys. Rep.*, 442:237–268, 2007.

[9] Y.-Z. Qian and S. E. Woosley. *ApJ*, 471:331–351, 1996.

[10] S. E. Woosley and R. D. Hoffman. *ApJ*, 395:202–239, 1992.

DOI:10.15120/GR-2015-1-MU-THEORY-08