Heavy-element Nucleosynthesis in Magnetohydrodynamical Jets from Collapsars

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Massive stars larger than 8 $M_\odot$ evolve to form the core composed of iron-group nuclei (Fe core). The core grows and eventually begins to collapse, which will lead to a supernova explosion. The origin of most elements heavier than carbon in the universe is attributed to the supernova explosions. The nucleosynthesis during the hydrostatic evolution of a massive star and its supernova explosion may involve s, p, r-process. Therefore, supernova explosions are important phenomena in both astrophysics and nuclear physics aspects.

We investigate the heavy-element nucleosynthesis of a massive star whose mass in the main sequence stage is $M_{\rm ms} = 70\ M_\odot$. Numerical calculations of the nucleosynthesis are performed during the stage of hydrostatic stellar evolution until the Fe core begins to collapse. As a supernova explosion model, a collapsar model is constructed whose jets are driven by magnetohydrodynamical effects of a differentially rotating core by two-dimensional magnetohydrodynamical simulations. The heavy-elevent nucleosynthesis inside the jet is followed along the trajectories of stream lines of the jet. We calculate the heavy-element nucleosynthesis by using a large nucelar reaction network which includes r-elements (about 4000 nuclei) and its involving reactions. We combine the results of both detailed hydrostatic and heavy-element nucleosyntheses to compare with the solar abundances. We also investigate the effects of different mass formulae on the produced abundance pattern.

As shown in Figure 1, neutron-rich elements of $70 < A < 160$ and weak s-elements of $70 < A < 90$ are highly overproduced to the solar abundances. Therefore, we conclude that this explosion model should correspond to rare events and other underproduced elements would be produced in different type supernova explosions.

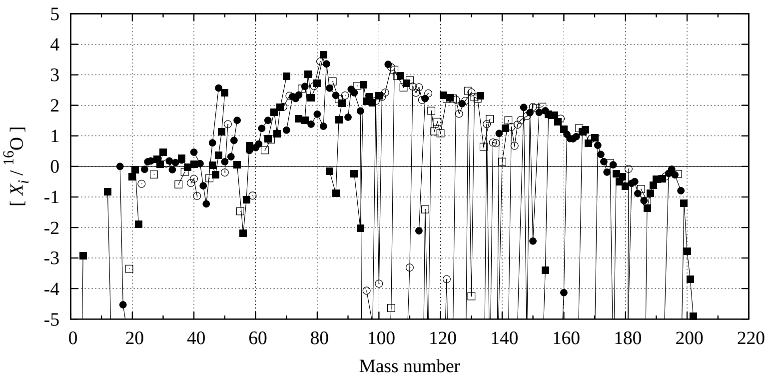

Figure 1: Normalized overproduction $[X_i/^{16}\mathrm{O}]$ against the mass number of nuclei ejected by the jet. $[X_i/^{16}\mathrm{O}] \equiv \log_{10}[(X(i)/X(^{16}\mathrm{O}))] - \log_{10}[(X(i)/X(^{16}\mathrm{O}))_\odot]$, where X and i denote the mass fraction and i th nuclei, respectively. Filled (open) symbols connected to each other indicate the isotopes with the even (odd) atomic numbers.