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Making the Heaviest Elemens in the Universe

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The origin of the heavy elements made by the rapid neutron-capture process ("r-process") is not fully understood, yet. Different sources have been proposed, e.g., core-collapse supernovae as well as neutron star mergers.

- We discuss the production of r-process elements in three of these suggested sites:
  1.the neutrino wind in core collapse supernovae, 2. jet ejecta from magneto-rotationally driven (MHD) supernovae, and 3. neutron star mergers, with respect to the predicted environment conditions and the uncertainties in nuclear input physics. This comes to the conclusion that regular core collapse supernovae cannot be the source of the heaviest r-process elements, there is a slight chance that minor contributions for medium-heavy r-process nuclei originate from them.
- In a second step we utilize Europium (Eu) in old metal-poor stars as the most indicative element to trace the r-process production in galactic evolution, since it is dominantly made by the r-process and relatively easy to observe compared to other heavy r-process elements. We test the most important parameters affecting the chemical evolution of our Galaxy as a function of metallicity ([Fe/H]) with an inhomogeneous (not automatically mixed) model. These are (a) for neutron star mergers the coalescence time scale of mergers and the probability to experience such a merger event after two supernova explosions occurred and formed a double neutron star system, and (b) for the sub-class of MHD-supernovae their occurrence rate compared to standard supernovae.
- The main results are the following: The observed [Eu/Fe] pattern in the Galaxy can be reproduced by a combination of neutron star mergers and MHD-supernovae as r-process sources. While neutron star mergers alone seem to set in at too high metallicities, MHD-SNe provide a cure for this deficiency at low metallicities. Furthermore, we confirm that local inhomogeneities can explain the observed large spread in the Eu abundances at low metallicities. We also predict the evolution of oxygen ([O/Fe]) as a function of metallicity, to test whether the spread in so-called α-elements for inhomogeneous models agrees with observations, and whether this provides either constraints on supernova explosion models and their nucleosynthesis or clues on mixing processes in the interstellar medium.

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