Astrophysical and nuclear physics aspects of the r-process

ConferencePaper (Artikel, die in Tagungsbänden erschienen sind)

ID 110434
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Year 1998
Title Astrophysical and nuclear physics aspects of the r-process
Editor(s) Hamilton, JH and Ramayya, AV
Book title (Conference Proceedings) Fission and properties of neutron-rich nuclei
Place of Conference International Conference on Fission and Properties of Neutron-Rich Nuclei, SANIBEL ISL, FL, NOV 10-15, 1997
Publisher z
Place of Publication World Scientific Publishing Company
Pages S. 47-62
ISSN/ISBN 981-02-3537-2
The formation of elements as heavy as Th and U and beyond is due to the rapid neutron-capture process (r-process), which causes the production of highly unstable nuclei near the neutron drip-line and functions via neutron captures, (gamma, n)-photodisintegrations, beta(-)-decays and beta-delayed processes. Neutrino-induced reactions may also play a possible role. Observations of abundances in old (low metallicity) stars indicate that it operates very early in galactic evolution, and is thus related to massive star progenitors forming supernovae and/or neutron stars. The abundances, being in all individual observations identical to solar r-abundances (at least for 4<130), indicate a unique process and witness the interplay between nuclear structure far from beta-stability and the appropriate astrophysical environment. In previous studies we pursued a model-independent approach for the r-process as a function of neutron number densities n(n), temperatures T, and durations times tau. The present study follows the expansion of matter with an initial entropy S and an expansion timescales tau (more suited for astrophysical environments), which can also follow the freeze-out of reactions with declining temperatures and densities explicitely. We compare the similarities and differences between the two approaches. Special emphasis is given to constraints on nuclear properties far from stability, resulting from a comparison with solar r-process abundances in either approach. In particular the behavior of shell closures is examined. In addition, investigations are presented to test whether some features can also provide clear constraints on the permitted astrophysical conditions. We discuss supernova and neutron star merger scenarios with respect to these findings.
edoc-URL http://edoc.unibas.ch/dok/A5839336
Full Text on edoc No;
ISI-Number 000077363600003
Document type (ISI) inproceedings