Rp-process in X-ray Bursts May Produce Heavier Elements Faster

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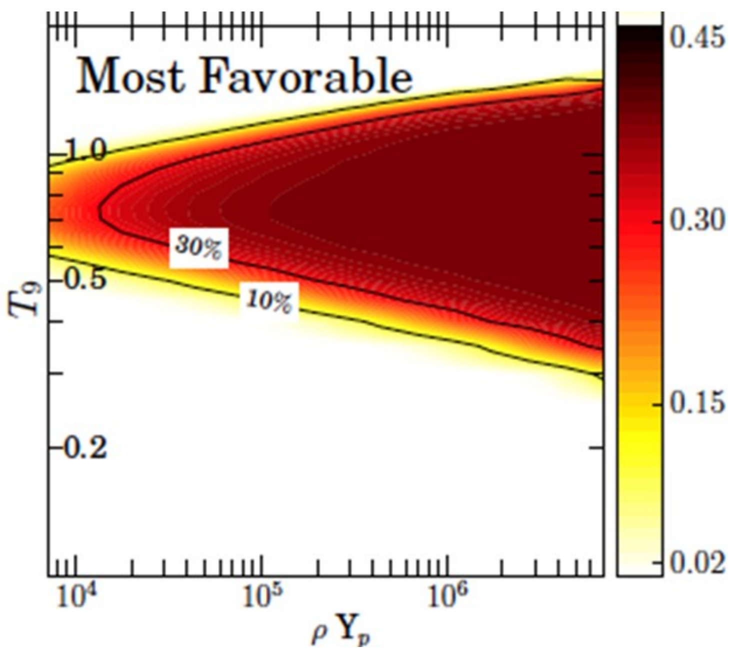
Thermonuclear explosions on the surface of accreting neutron stars are observed as X-ray bursts. The energy is thought to be produced by the synthesis of heavier elements out of hydrogen and helium via the rapid proton capture process (rp-process). The speed of the rp-process shapes the burst light curve and needs to be understood to match observations with models. A measurement of excited states in 56Cu using the GRETINA and S800 devices at Michigan State University's NSCL points to a possible way to accelerate the process.



Fraction of the rp-process bypassing 56Ni as functions of hydrogen density ρY_p (g/cm^3) and temperature T_9 (GK). Shown is an upper limit.

The isotope 56Ni is a major bottle-neck on the path of the rp-process. The decay time under stellar conditions is hours, much longer than the burst duration. At the same time, any proton capture is quickly reversed by the strong photodisintegration rate of the resulting 57Cu. However, proton capture on 55Ni may divert the reaction sequence before 56Ni is reached and may lead to a bypass of 56Ni.

Whether this is possible depends on the proton capture rate on 55Ni. An experiment at NSCL has now for the first time identified the relevant states in 56Cu that govern this reaction. A radioactive 55Ni beam was produced at NSCL and impinged on a deuterium target. A transfer of a proton from the deuterium on the 55Ni nucleus mimics the proton capture process and produces an excited 56Cu nucleus. Gamma rays from the de-excitation in flight were detected with the state of the art GRETINA gamma-ray array. Using the energies of the detected gamma-rays, states in 56Cu can be identified and the proton capture rate on 55Ni be calculated.

With the new rate it is found that indeed for a range of typical X-ray burst conditions up to 40% of the rp-process can bypass 56Ni. The work also identified a number of additional nuclear physics uncertainties that need to be addressed before final conclusions can be drawn. This work was led by JINA-CEE graduate student Wei Jia Ong at Michigan State University.

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Further Reading: Ong et al. accepted for publication in Phys. Rev. C (2016).