HK 47: Nuclear Astrophysics I

Time: Thursday 14:00–15:45 Location: J-HS B

Group Report HK 47.1 Thu 14:00 J-HS B

Electron capture processes in intermediate-mass stars — •Dag F. Strömberg[1,2], Gabriel Martínez-Pinedo[2,1], and Karlheinz Langanke[2,1] — [1]Institut für Kernphysik (Theoriezentrum), Technische Universität Darmstadt, Schlossgartenstr. 2, 64289 Darmstadt, Germany — [2]Gesellschaft für Schwerionenforschung, Planckstr. 1, 64259 Darmstadt, Germany

Following carbon burning, intermediate-mass stars (initial mass $\sim 7-11$ solar masses) form degenerate cores composed primarily of ^{16}O and ^{20}Ne, with smaller amounts of ^{23}Na, ^{24}Mg and ^{25}Mg. When such cores grow massive enough electron capture reactions are triggered due to the high chemical potential of the electrons. Most notably, the double electron capture $^{20}\mathrm{Ne} \to {}^{20}\mathrm{F} \to {}^{20}\mathrm{O}$ releases enough heat to ignite runaway oxygen burning resulting in either a collapse to a neutron star or a thermonuclear explosion.

In this contribution we will discuss how details of the electron capture reactions can affect the conditions at oxygen ignition and thus the outcome of the runaway reaction. Due to the comparatively low temperatures ($T < 1$ GK) prior to oxygen ignition the electron capture rates are fully determined by a small number of transitions. Some of these are forbidden, such as the recently measured $0^+ \to 2^+$ transition between the ground states of ^{20}Ne and ^{20}F. We will examine the impact of such transitions and how this depends on the growth rate and composition of the core.

This work is supported by the Deutsche Forschungsgemeinschaft via contract SFB 1245 and the EU COST Action CA1611 (ChETEC).

HK 47.2 Thu 14:30 J-HS B

Towards a study of the ^{12}C$(\alpha,\gamma)^{16}$O reaction at the new underground lab Felsenkeller — •Felix Ludwig[1,2], Daniel Bemmerer[1], Tamás Szücs[1], Steffen Turkat[2], and Kai Zuber[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden — [2]Technische Universität Dresden

The reaction ^{12}C$(\alpha,\gamma)^{16}$O is of paramount importance for the nucleosynthesis of elements in stars. It takes place during helium burning and determines the ratio of the abundances of ^{12}C and ^{16}O.

Due to its low cross section, underground experiments are needed to measure this reaction at astrophysically relevant energies. On the way towards a comprehensive study of this reaction at the new underground laboratory Felsenkeller in Dresden, ^{12}C beam tests and γ background data have recently been reported [1].

The contribution will present initial ^{12}C$(\alpha,\gamma)^{16}$O data from Felsenkeller. In a first phase, ^{12}C beam and implanted solid ^{4}He targets are used to study this reaction. Additional tests using two sevenfold Cluster detectors in Felsenkeller will be reported, as well.

– Supported by GAMMAPOOL resources, and by the Helmholtz Association (ERC-RA 0016).

[1] T. Szücs *et al.*, Eur. Phys. J. A 55, 174 (2019)

HK 47.3 Thu 14:45 J-HS B

Equation of state effects in core-collapse supernovae — •Sabrina Schäfer[1,2], Hannah Yasin[1], Almudena Arcones[1,3], and Achim Schwenk[1,2,4] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH — [4]Max-Planck-Institut für Kernphysik, Heidelberg

We investigate the impact of different properties of the nuclear equation of state in core-collapse supernovae, with a focus on the proto-neutron-star contraction and its impact on the shock evolution. To this end, we introduce a range of equations of state that vary the nucleon effective mass, incompressibility, symmetry energy, and nuclear saturation point. This allows us to point to the different effects in changing these properties from the Lattimer and Swesty to the Shen et al. equations of state, the two most commonly used equations of state in simulations. In particular, we trace the contraction behavior to the effective mass, which determines the thermal nucleonic contributions to the equation of state. Larger effective masses lead to lower pressures at nuclear densities and a lower thermal index. This results in a more rapid contraction of the proto-neutron star and consequently higher neutrino energies, which aids the shock evolution to a faster explosion.

*This work was supported by the Deutsche Forschungsgemeinschaft (DFG) - Projektnummer 279384907 - SFB 1245 and the European Research Council Grant No. 677912 EUROPIUM.

HK 47.4 Thu 15:00 J-HS B

Neutron matter at finite temperature based on chiral effective field theory interactions — •Jonas Keller[1,2], Kai Hebeler[1,2], Corbinian Wellenhofer[1,2], and Achim Schwenk[1,2,3] — [1]Institut für Kernphysik, Technische Universität Darmstadt — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH — [3]Max-Planck-Institut für Kernphysik, Heidelberg

We study the equation of state of neutron matter at finite temperature based on two- and three-nucleon interactions from chiral effective field theory. The free energy, pressure, entropy and internal energy are expanded in many body pertubation theory around the self-consistent Hartree-Fock solution. All calculations are performed including three-nucleon contributions without employing normal-ordering approximations, and include theoretical uncertainty estimates.

*This work is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Projektnummer 279384907 – SFB 1245.

HK 47.5 Thu 15:15 J-HS B

A study of r-process nucleosynthesis in the aftermath of a binary neutron star merger — •Stylianos Nikas[1,2], Gabriel Martinez Pinedo[1,2], André Sieverding Sieverding[5], and Meng-Ru Wu[3,4] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [2]Institut für Kernphysik (Theoriezentrum), Technische Universität Darmstadt,Schlossgartenstraße 2, 64289 Darmstadt, Germany — [3]Institute of Physics, Academia Sinica, Taipei 11529, Taiwan — [4]Institute of Astronomy and Astrophysics, Academia Sinica, Taipei 10617, Taiwan — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA

The r-process is thought to create about half of elements heavier than Fe. The site of the r-process was unknown until recently. The detection of the electromagnetic radiation following the gravitational wave event GW170817 in addition to the detection of Sr in the electromagnetic spectrum established neutron star mergers as a site where heavy elements are created.

We perform a nucleosynthesis study for the creation of the first r-process peak elements determining the astrophysical conditions under which the peak is produced. Based on those conditions we determine the nuclear properties that affect the abundance pattern.

This work was supported by DFG through - Projektnummer 279384907 - SFB 1245 and HGS-HIRe

HK 47.6 Thu 15:30 J-HS B

The role of fission yields in the r-process — •Bowen Jiang[1,2], Gabriel Martínez-Pinedo[1,2], and Bastian Schütrumpf[1] — [1]GSI — [2]Technische Universität Darmstadt

The r-process nucleosynthesis in neutron star mergers may reach fissionable nuclei, which generates significant uncertainties in predicting of the final abundance of r-process materials. We demonstrate that in cases where fission happens, it will have an essential impact on the abundance pattern around the second r-process peak ($A \sim 130$) as well as the lanthanides regime ($A = 135 \sim 160$).

Our calculations also show that fission only accounts for modifying abundance ratios among materials in the first several seconds. Fission yields of the nuclei fissioning in this time span could impact the number of free neutrons in the environment as well.

We evaluate the impact of fission yields by using two versions of a semi-empirical fission model called GEF. Large uncertainties of the prediction provided by the GEF model on neutron-rich fissionable nuclei are shown. We also discuss how improvement could be made in the GEF model to cover physical effects in exodic nuclei, by new experimental data of fission yields on a single nuclei, i.e. ^{258}**Fm** and ^{252}**Cf**.