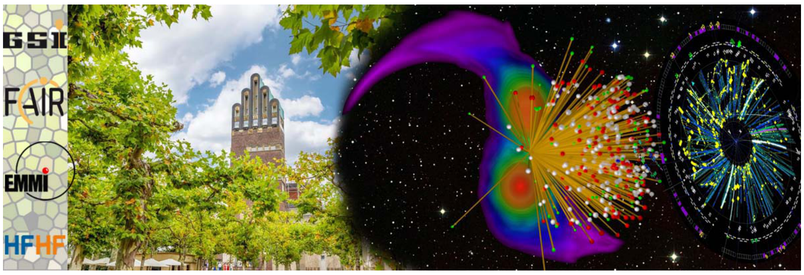

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Neutrino emission in (proto-)neutron star matter

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Neutrinos play a crucial role in neutron star physics, from their birth in a core-collapse supernovae where neutrinos dictate the dynamics of the explosion, to the merger by determining the matter composition in the ejecta for heavy element nucleosynthesis. They are also key actors of cooling in (proto-)neutron stars and of the thermal relaxation of accreting neutron stars. Identifying different efficient neutrino emission processes in neutron star matter, and providing an accurate calculation of neutrino emissivity is important to understand the astrophysical features of neutron stars, and to investigate highly dense matter.

After a quick overview of the various neutrino emission processes that can occur in neutron star matter, we propose to focus on Urca reactions. The so called direct Urca (dUrca) and modified Urca (mUrca) reactions operate via the charged current of the weak interaction. It is well known that dUrca reactions (very efficient neutrino emission process) observe a threshold that depend on the cinematic conditions and on the equation of state of dense matter. The mUrca reaction, which involves an additional baryon exchanging momentum via strong interaction, can lift the kinematic restrictions, but is less efficient. Although both processes were extensively studied in cold neutron star matter, and investigated in finite temperature dilute matter, calculations for the mUrca neutrino emission always implied limiting approximations.

We present new results for the mUrca neutrino emission in thermodynamic conditions which are relevant for supernovae, proto-neutron stars and mergers of neutron stars. We alleviated several of the usual approximations taken and compared our results to already established derivations. We find that there exists regimes of temperature and density in which the mUrca emission can be of the same order as the dUrca emission even when the latter is active. We show that those regimes can be anticipated from the thermodynamic quantities determined by the equation of state using a simple analytical derivation. These regimes are potentially relevant to determine beta-equilibrium conditions in binary neutron star merger or the late cooling of a proton neutron star.

Primary author: SULEIMAN, Lami (Nicholas and Lee Begovich Center for Gravitational Wave Physics and Astronomy, California State University Fullerton)

Co-authors: Dr OERTEL, Micaela (Laboratoire Univers et Theories, Observatoire de Paris); MANCINI, Marco (Laboratoire Univers et Theories, Observatoire de Paris)

Presenter: SULEIMAN, Lami (Nicholas and Lee Begovich Center for Gravitational Wave Physics and Astronomy, California State University Fullerton)

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