Neutrinos: from the discovery of the diffuse supernova background to entanglement

Neutrinos are elementary massive particles with mixings. They can change flavor while propagating. Weakly interacting, neutrinos tell us about the primordial Universe and dense environments, such as exploding stars (core-collapse supernovae) or binary compact objects (neutron star-neutron star, black hole-neutron star). Such neutrinos undergo unexpected flavor phenomena and can be unique probes for new physics.

The PhD Thesis will be focused on theoretical neutrino physics and astrophysics and involves both theoretical and phenomenological aspects. Unexpected novel phenomena occur in dense environments (e.g. core-collapse supernovae, binary neutron star mergers), due e.g. to neutrino-neutrino interactions that make neutrino flavor evolution a non-linear many-problem. In particular the role of many-body correlations and entanglement is being investigated which could completely change our understanding of flavor evolution in dense media. These can impact e.g. supernova explosions, r-process nucleosynthesis in core-collapse supernovae and kilonovae, and future observations of supernova neutrinos.

Moreover, neutrino emission from dense environments is tightly linked to non-standard neutrino properties and the search for dark matter. On the observational side, predictions of the neutrino spectra are essential in particular for the upcoming discovery of the diffuse supernova neutrino background by the running Super-Kamiokande+Gd and the upcoming JUNO and Hyper-Kamiokande, and the long-term DUNE experiments.

The Thesis will involve theoretical and phenomenological aspects, concerning e.g. unknown neutrino properties, the role of flavor evolution and entanglement, non-standard emission in dense environments, and their implications in particular for the upcoming measurement of the diffuse supernova neutrino background.

An M2 internship on the topic is also possible.

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