APR17-2016-000376
Abstract for an Invited Paper
for the APR17 Meeting of
the American Physical Society

Strangeness in nuclei and neutron stars[1]

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The presence of exotic particles in the core of neutron stars (NS) has been questioned for a long time. At present, it is still an unsolved problem that drives intense research efforts, both theoretical and experimental. The appearance of strange baryons in the inner regions of a NS, where the density can exceed several times the nuclear saturation density, is likely to happen due to energetic considerations. The onset of strange degrees of freedom is considered as an effective mechanism to soften the equation of state (EoS). This softening affects the entire structure of the star, reducing the pressure and therefore the maximum mass that the star can stably support. The observation of two very massive NS with masses of the order of $2M_\odot$ seems instead to rule out soft EoS, apparently excluding the possibility of hyperon formation in the core of the star. This inconsistency, usually referred to as the *hyperon puzzle*, is based on what we currently know about the interaction between strange particles and normal nucleons. The combination of a poor knowledge of the hypernuclear interactions and the difficulty of obtaining clear astrophysical evidence of the presence of hyperons in NS makes the understanding of the behavior of strange degrees of freedom in NS an intriguing theoretical challenge. We give our contribution to the discussion by studying the general problem of the hyperon-nucleon interaction. We attack this issue by employing a quantum Monte Carlo (QMC) technique, that has proven to be successful in the description of strongly correlated Fermion systems, to the study of finite size nuclear systems including strange degrees of freedom, i.e. hypernuclei. We show that many-body hypernuclear forces are fundamental to properly reproduce the ground state physics of Λ hypernuclei from light- to medium-heavy. However, the poor abundance of experimental data on strange nuclei leaves room for a good deal of indetermination in the construction of hypernuclear potential models. This lack of accuracy leads to uncertainties in the prediction of NS properties. We apply the same QMC algorithm and the same hypernuclear interactions to the study an infinite system of neutrons and Λ particles, deriving NS observables. We show how the appearance of hyperons in the inner core of NS is strongly dependent on the details of the underlying many-body hypernuclear interactions, that at present cannot be accurately derived from the scarce hypernuclear experimental data. Our results suggest that more experimental and/or observational constraints are needed to pin down the essential features of the hypernuclear forces and thus to draw conclusions on the role played by hyperons in NS.

[1]This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under the award DE-SC0013617 titled "FRIB Theory Center - A path for the science at FRIB" and under the NUCLEI SciDAC-3 grant.