Nuclear Theory Seminar

Probing the Microphysics of Neutron Stars: Impact of Dark Matter and Modified Nuclear Interactions on Global and Oscillation Properties

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Science Hall #327, Department of Physics

In this talk, I will present my recent works on understanding how dark matter and modified nuclear interactions influence the internal structure and observable features of neutron stars.
I begin with a two-fluid formalism to model fermionic dark matter admixed with baryonic matter, examining how such configurations alter macroscopic properties like mass, radius, and tidal deformability. To assess the potential for observational discrimination, I employ machine learning techniques—specifically, Random Forest classifiers—to analyze over 30,000 simulated neutron star configurations. These results suggest that neutron stars with dark matter admixture exhibit measurable deviations, particularly in radius at extreme masses.
I then shift focus to a Bayesian model selection framework, where I compare three different equations of state: standard nuclear matter (NL), a stiffened variant using the σ-cut potential (NL-σ), and a dark matter-admixed EOS (NL-DM). Incorporating recent constraints from NICER, LIGO/Virgo, and other astrophysical observations, I find that the σ-cut EOS is currently the most favored, while models with dark matter are statistically less consistent with the combined data.
Finally, I explore how these EOSs affect the radial and non-radial oscillation modes of neutron stars, including f- and p-modes, calculated in full general relativity. I demonstrate that the mode frequencies and damping times carry clear signatures of the underlying microphysics, offering a path forward for distinguishing between competing models using future gravitational wave detections and asteroseismology. In a complementary study, I investigate the thermal evolution of dark matter-admixed proto-neutron stars using a two-fluid formalism with mirror dark matter at finite temperature. Even small dark matter fractions (1–5%) significantly impact temperature profiles, hyperon production, and isospin asymmetry, altering mass, radius, and tidal deformability. These thermal effects may leave detectable signatures in future gravitational wave and multi-messenger observations.

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