Int. Workshop “Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects”
ed. Nikolay Minkov, Heron Press, Sofia 2026

The Neutron Decay Puzzle in Nuclear Physics and its Implications for Neutron Star Properties

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Abstract

One of the unsolved mysteries in the particle physics is the ”neutron decay puzzle”. Discrepancies between the neutron lifetime measured in beam and bottle experiments suggest that exotic decay channels and/or the involvement of dark matter may be in play. Recent measurements of the compact star XTE J1814-338, with a mass of $M = 1.2^{+0.05}_{-0.05}\ M_{\odot}$ and a radius of $R = 7^{+0.4}_{-0.4}\ Km$ alongside those of HESS J1731-347, which has a mass of $M = 0.77^{+0.20}_{-0.17}\ M_{\odot}$ and a radius of $R = 10.4^{+0.86}_{-0.78}\ Km$, provide compelling evidence for the potential existence of exotic matter in neutron star cores. These observations offer important insights into the equation of state of dense nuclear matter. The proposed dark decay of the neutron may explain the existence of objects as a product of the mixing of neutron stars with dark matter, over a wide range that includes objects with small mass and radius as well as those in the mass gap region. This hypothesis can more generally explain other compact objects with both small masses and radii that are to the left and below the classical M-R diagrams. In particular we consider the case of neutron decay into a dark particle of mass $m_{\chi} = 939$ MeV according to the hypothesis formulated by Fornal and Grinstein. We consider this dark matter to interact both with itself and with neutrons thus defining the equation of state of the neutron and dark matter mixture. In this study we found that with the appropriate combination of interaction parameters both masses larger than 2 solar masses can be simultaneously predicted and at the same time the compact objects XTE J1814-338 and HESS J1731-347 can be reproduced in a self-consistent way. More information can be found at our work [1]

References

[1] M. Vikiaris, V. Petousis, M. Veselsky, Ch.C. Moustakidis, Neutron Dark Decay and Exotic Compact Objects, eprint arXiv:2602.04477