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Study of correlations of nuclear saturation properties and neutron star f mode oscillations from a machine learning

We investigate the intricate relationships between the non-radial f mode oscillation frequencies of neutron stars (NS)s and the corresponding nuclear matter equation of state (EOS) using a machine learning (ML) approach within the ambit of the relativistic mean field (RMF) framework for nuclear matter. With two distinct parameterizations of the Walecka model, namely, (1) with non-linear self interactions of the scalar field (NL) and, (2) a density dependent Bayesian model (DDB), we perform a thorough examination of the f mode frequency in relation to various nuclear saturation properties. The correlations between the f mode frequencies and nuclear saturation properties reveal, through various analytical and ML methods, the complex nature of NSs and their potential as the cosmic laboratory for studying extreme states of matter. A principal component analysis (PCA) has been performed using mixed datasets from DDB and NL models to discriminate the relative importance of the different components of the EOS on the f mode frequencies. Additionally, a {\it Random forest feature importance} analysis also elucidates the distinct roles of these properties in determining the f mode frequency across a spectrum of NS masses. Our findings are further supported by symbolic regression searches, yielding high-accuracy relations with strong Pearson coefficients and minimal errors. These relations suggest new methodologies for probing NS core characteristics, such as energy density, pressure, and speed of sound from observations of non-radial f mode oscillations of NSs.

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