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Massive, magnetized compact stars: Theory and Simulation

Over the last few years, there has been considerable interest in massive compact stars, specifically neutron stars (NSs) and white dwarfs (WDs). Peculiar over-luminous type Ia supernovae (such as SNLS-03D3bb) and gravitational wave observations (such as GW190814) lend observational support to this idea. These massive compact stars are also prime candidates to fill in the observational mass gap that currently exists between the heaviest NSs and the lightest black holes. It is found that the magnetic field greatly contributes to the existence of these massive stars, both through classical and quantum effects. In this work, we explore both massive WDs and NSs formed as a result of the classical effects of the star's magnetic field. For WDs, this results in masses greater than the conventional Chandrasekhar limit, leading to super-Chandrasekhar WDs and new mass limit(s), depending on the magnetic field geometry. We explore the full evolution and stability of these objects from the main sequence stage through the one-dimensional stellar evolution codes STARS and MESA. There is however no consensus on a Chandrasekhar type maximum mass for a NS due to the high-density nuclear matter equation of state (EOS) still being unknown. As a result, the study of massive NSs ends up simultaneously becoming an exploration of strong interactions in highly dense, magnetized environments. Pulsar observations (PSR J1614-2230, PSR J0348+0432, PSR J0740+6620, PSR J0952–0607) indicate that NS's limiting mass, if there is any, could be well over $2M_{\odot}$. We do a semi-analytic exploration of massive NSs by employing various relativistic mean field EOSs along with magnetic field and a model anisotropy. We also explore additional implications like that of tidal deformability and universal relations. On the whole, our exploration shows that magnetic field can lead to significant increase in the masses of both NSs and WDs, violating their conventional limits.

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