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Quasi-universality of the magnetic deformation of neutron stars in general relativity and beyond

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Neutron stars (NSs) harbour extremely powerful magnetic fields, leading to their shape being deformed. The magnetic deformation of NSs depends both on the geometry - and strength - of their internal magnetic field and on their composition, encoded by the equation of state (EoS). However, both the details of the internal magnetic structure and the EoS of the innermost part of NSs are mostly unkown. We performed a study of numerical models of magnetised, static, axisymmetric NSs in general relativity (GR) and in one of its most promising extensions, scalar-tensor theories (STTs). We did so by using several realistic EoSs currently allowed by observational and nuclear physics constraints, considering also EoSs for strange quark stars. We show that it is possible to find simple relations among the magnetic deformation of a NS, its Komar mass and its circumferential radius. These relations are quasi-universal, in the sense that they mostly do not depend on the EoS and only slightly depend on the magnetic field geometry. Our results, being formulated in terms of potentially observable quantities, could help to constrain the magnetic properties of NSs interiors and better assess the detectability of continuous gravitational waves by isolated neutron stars, without knowing their equation of state. In the case of STTs, these relations depend also on the scalar charge of the NS, thus potentially providing a new way to set constraints on the theory of gravitation.

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