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Neutron Stars in Scalar-tensor Theories: Universal Relations and Analytic Investigations

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Neutron stars are ideal astrophysical sources to probe general relativity due to their large compactnesses and strong gravitational fields. For example, binary pulsar and gravitational wave observations have placed stringent bounds on certain scalar-tensor theories in which a massless scalar field is coupled to the metric through matter. A remarkable phenomenon of neutron stars in such scalar-tensor theories is spontaneous scalarization, where a normalized scalar charge remains order unity even if the matter-scalar coupling vanishes asymptotically far from the neutron star. On the other hand, certain quasi-universal relations have been found for global quantities of neutron stars (such as the moment of inertia and quadrupole moment) that are insensitive to the underlying equations of state. We find a new quasi-universal relation in massless scalar-tensor theories between the scalar charge and stellar binding energy (related to stellar compactness). Although the above finding is based on numerical calculations, we give mathematical support for this universal relation by computing for the first time scalar charges analytically for both Tolman VII and constant density stars. Such analytic results provide ready-to-use expressions for scalar charges in massless scalar-tensor theories.

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