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Tidal properties of neutron stars in scalar-tensor theories of gravity

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A major science goal of gravitational-wave (GW) observations is to probe the nature of gravity and constrain modifications to General Relativity. An established class of modified gravity theories are scalar-tensor models, which introduce an extra scalar degree of freedom. This affects the internal structure of neutron stars (NSs), as well as their dynamics and GWs in binary systems, where distinct novel features can arise from the appearance of scalar condensates in parts of the parameter space. To improve the robustness of the analyses of such GW events requires advances in modeling internal-structure-dependent phenomena in scalar-tensor theories. We develop an effective description of potentially scalarized NSs on large scales, where information about the interior is encoded in characteristic Love numbers or equivalently tidal deformabilities. We demonstrate that three independent tidal deformabilities are needed to characterize the configurations: a scalar, tensor, and a novel 'mixed' parameter, and develop the general methodology to compute these quantities. We also present case studies for different NS equations of state and scalar properties and provide the mapping between the deformabilities in different frames often used for calculations. Our results have direct applications for future GW tests of gravity and studies of potential degeneracies with other uncertain physics such as the equation of state or presence of dark matter in NS binary systems.

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