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Evolving Gravity Beyond Einstein

Gravitational wave observations of black hole and other compact object mergers have provided an unparalleled way to test our understanding of gravity, and have already been used to constrain a number of possible deviations from general relativity. However, despite the success of these observations, for many theories that introduce modifications to the Einstein equations, there are limited or no results on the well-posedness of the resulting initial value problem. Thus it is unclear how to, or even if one can, obtain a full theoretical prediction of what happens, e.g., when two black holes merge. I will discuss some recent progress in this regard, in particular the introduction of the modified harmonic formulation of Horndeski theories of gravity, a general class of theories of a metric coupled to a scalar field that give second order equations of motion. Using numerical solutions in this formulation, and focusing on the particular case of Einstein-scalar-Gauss-Bonnet gravity as a first application, I will demonstrate its utility in evolving strong-field data, including black hole mergers, in a regime where the deviations from general relativity are significant. I will discuss some of the remaining challenges in understanding how to evolve modifications to general relativity.