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Modeling binary black hole systems using a spacetime with helical symmetry

Binary black hole systems can be approximated as a single circular orbit at fixed separation, from large distances down to the innermost stable circular orbit (ISCO), where the gravitational energy lost through gravitational waves is exactly compensated by an incoming flux of gravitational waves from infinity. In this approximation, one looks for a spacetime that is stationary in a corotating frame and admits a helical Killing vector, capturing the idea of an orbit that is “frozen”when viewed from a frame rotating with the binary. The Ernst formalism with respect to this Killing field reduces the study of a four-dimensional spacetime to the study of a three-dimensional quotient space. Within this framework, bispherical coordinates appear as a natural choice: they are well adapted to geometries with two spherical objects and offer the possibility to represent each black hole horizon as a surface {η= const.}, which is exactly what is needed to impose boundary conditions on two separate horizons. The strategy is to start from a simpler “toy model”, the double Schwarzschild metric describing two non-rotating black holes in equilibrium, held apart by a massless strut, originally expressed in Weyl coordinates. The main challenge is to find a suitable gauge, i.e. a bispherical coordinate system that captures all the symmetries and simplifies the metric as much as possible. In such a gauge, the double Schwarzschild solution would help to explore how bispherical coordinates can be used to describe the situation with helical symmetry and might provide insight into the different numerical issues that may be encountered, particularly near the horizons and at spatial infinity.