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Harmonic coordinates in binary black hole mergers

Harmonic coordinates are often used in analytical calculations of the general relativistic binary problem, since they simplify Einstein's equations to a set of quasilinear wave equations. However, numerical relativity simulations of merging binary black holes are commonly performed in different gauges. In this article, we develop a technique to construct harmonic coordinates for binary black hole spacetimes in numerical simulations. We investigate the existence of harmonic coordinates in highly dynamical spacetimes of merging black holes, with the aim of capturing binary kinematics from numerical relativity in this coordinate gauge that holds special utility in analytical relativity. We find that harmonic coordinates exist throughout the inspiral and plunge of merging binary black holes. However, in a time-window lasting several BH light-crossing times around merger, we find that (a) harmonic coordinates may become singular, and (b) harmonic time slices become timelike. After merger, harmonic coordinates are well behaved everywhere in our computational domain, and can thus represent the evolution of the perturbed merged black hole into a stationary Kerr black hole.

Using our new techniques to construct harmonic coordinates, we investigate the inspiral trajectories of the black holes in harmonic coordinates. We compare these harmonic trajectories to post-Newtonian results in the same gauge and find good agreement. *This enables gauge-dependent comparisons of two-body kinematics between numerical relativity and post-Newtonian theory results, allowing for better understanding of general relativistic models for binary black hole dynamics.*

Email

prayush@icts.res.in

Affiliation

ICTS-TIFR, Bengaluru, India

Author: Dr KUMAR, Prayush (ICTS-TIFR)

Co-author: Prof. PFEIFFER, Harald (AEI Potsdam, Germany)

Presenter: Dr KUMAR, Prayush (ICTS-TIFR)

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