

**Michael Jasiulek**

Albert-Einstein-Institute Potsdam, Am Muehlenberg 1, 14476 Potsdam, Germany

**Novel geometric methods for quasi-local mass and spin via  
isometric embeddings and curvature invariants**

Authors: M. Jasiulek and M. Korzynski

Quasi-local mass and angular momentum of bounded regions in numerical binary black hole (BBH) simulations provide necessary information to assemble complete waveforms of BBH inspirals, since the system parameters of the post-Newtonian part and the fully relativistic part of the waveform have to agree.

Meaningful definitions of quasi-local mass and spin are typically based on non-linear elliptic conditions on the geometry and location of closed 2-surfaces in an ambient spatial 3-slice, in order to fix certain gauge freedoms.

To access quasi-local mass of arbitrary bounded regions in numerical relativistic simulation we introduce a novel geometric method to find the isometric embedding of a 2-surface in Euclidean three space through linearised embedding flow which is necessary to determine the Liu-Yau or Brown-York masses.

To access quasi-local mass and angular momentum of axial black hole horizons we introduce a method to read off angular momentum and higher multipole moments through invariant curvature averages. The method does not require a solution of the Killing equation and yields well-defined generalised axial multipole moments for perturbed axial 2-metrics by averaging the contained axial information.