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A Hamiltonian approach to relativistic fluid dynamics and binary inspiral

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Gravitational waves from neutron-star and black-hole binaries carry valuable information on their physical properties and probe physics inaccessible to the laboratory. Neutron stars can be well-modelled as simple barotropic fluids during the part of binary inspiral most relevant to gravitational wave astronomy, but the crucial geometric and mathematical consequences of this simplification have remained computationally unexploited. In particular, Carter and Lichnerowicz have described barotropic fluid motion via classical variational principles as conformally geodesic. Moreover, Kelvin's circulation theorem implies that initially irrotational flows remain irrotational. Applied to numerical relativity, these concepts lead to novel Hamiltonian or Hamilton-Jacobi schemes for evolving relativistic fluid flows. Hamiltonian methods can conserve not only flux, but also circulation and symplecticity, and moreover do not require addition of an artificial atmosphere typically required by standard conservative methods. These properties can allow production of high-precision gravitational waveforms at low computational cost.

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