Kelvin's theorem and Hamilton-Jacobi fluid dynamics in gravitational wave astrophysics

The motion of strongly gravitating fluid bodies is described by the Euler-Einstein system of partial differential equations. Centuries after their advent, the solution to these equations remains mathematically and computationally difficult, and the break-down of well-posedness on the boundary interface between fluid and vacuum remains a challenging open problem. The problem manifests itself in numerical simulations of binary neutron-star inspiral. This talk focuses on formulating and implementing well-posed, acoustical and canonical hydrodynamic schemes, suitable for inspiral simulations and gravitational-wave source modelling. The scheme uses a variational principle by Carter-Lichnerowicz stating that barotropic fluid motions are conformally geodesic, a corollary to Kelvin's theorem stating that initially irrotational flows remain irrotational, and Christodoulou's acoustic metric approach adopted to numerical relativity, in order to evolve the canonical momentum of a fluid element via Hamilton's equations. These mathematical theorems leave their fingerprints on inspiral waveforms from binary neutron stars observed by the LIGO-Virgo detectors.