ID de Contribution: **16** Type: **Non spécifié**

Simulations of rotating neutron star oscillations with Roxas

mercredi 17 septembre 2025 14:00 (40 minutes)

Relativistic hydrodynamics has undergone major development over the past three decades, notably through high-resolution shock-capturing schemes enabled by conservative formulations of the relativistic fluid equations.
Simultaneously, advances in Numerical Relativity have allowed fully relativistic simulations of compact binary systems, particularly binary neutron stars, up to merger.
The GW170817 event marked a turning point, demonstrating the scientific potential of multi-messenger observations.
Post-merger remnants are expected to emit gravitational waves in the kHz band before collapsing into black holes, offering an additional probe of the dense-matter equation of state.

We developed ROXAS, a numerical code to evolve fast rotating isolated neutron stars and extract their oscillation modes.
A new hydrodynamic formalism was introduced, based on primitive rather than conserved variables, avoiding costly recovery procedures.
We employed multi-domain pseudospectral methods along with filters to mitigate aliasing.
The framework was validated on the scalar wave equation, then extended to self-gravitating configurations in both Newtonian and relativistic regimes.
A key feature is accurate stellar surface tracking. We extracted radial and non-axisymmetric modes of polytropic rapidly rotating stars.
More recently, the code was extended to differentially rotating configurations, a crucial step towards a realistic description of post-merger remnants.

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Classification de Session: Compact Objects WG (GdR on Gravitational Waves)