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Probing Dissipative Dynamics of Hybrid Stars through r-mode Oscillations

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We study the damping of r-mode oscillations in hybrid stars, focusing on bulk viscosity as the dominant dissipative mechanism. In the hybrid star the mixed phase emerges due to a first-order phase transition between hadronic and quark matter at high baryon densities, and is treated as a distinct region with its own transport properties. Bulk viscosity is computed by incorporating non-equilibrium weak interaction processes (such as direct Urca) in both the hadronic and quark Phases. Our analysis reveals that the mixed phase exhibits resonant peaks in bulk viscosity at low temperatures in the range $\sim 1.5 \times 10^7$ K $- 3 \times 10^7$ K, whereas the peak shows at $T \sim 5 \times 10^7$ K for pure hadronic phase and at $T \sim 1 \times 10^7$ K for quark phase .The increase in bulk viscosity within the mixed phase raises the critical rotation frequency (Ω/Ω_0), particularly in the temperature range $T \sim 10^6 - 10^8$ K, where r-mode instabilities are usually active. The mixed phase bulk viscosity moderately shifts r-mode instability window towards lower temperature, which may have consequences for the spin evolution of neutron stars and gravitational wave.

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