Demonstrating wormholes as black hole mimickers: A perturbation analysis

August 17, 2022

After almost 50 years of formulation, wormholes are still frowned upon as real astrophysical entities. Our work intends to change this picture by exploring various wormhole models with a detailed analysis of their energy-momentum tensor properties and gravitational wave signatures. We focus mainly on two classes of spacetimes: a) a two-parameter Lorentzian wormhole family, b) a generalized version of the Hayward metric with two different mass parameters in g_{tt} and g_{rr}, which interpolates between wormholes, regular and singular black holes depending on parameter choice. Firstly, we begin with the stability analysis of the Lorentzian wormhole family, which is supported by a phantom scalar field and an additional ANEC satisfying matter, under both scalar and axial gravitational perturbation. The corresponding quasi-normal modes of the member wormholes play a crucial role in distinguishing each geometry. Interestingly, our simple wormhole family supports a novel triple barrier potential along with their standard counterparts, single and double barriers, under axial perturbation. Such multi-peak potentials lead to a rich time-domain profile characterized by 'echoes.' The ringdown behavior and quasi-normal modes of the wormholes are compared with a classical black hole to get insight into their 'mimicking' properties.

Secondly, we analyze the stability of all the geometries arising from the generalized Hayward metric under scalar perturbations. Apart from giving rise to distinct spacetimes, the generalized metric provides the perfect ground for comparing the behavior and quasi-normal modes of different wormholes to that of both the regular and singular black holes. Thus our ultimate goal is to elevate wormholes, using their quasi-normal mode analysis, to where they will be recognized as possible objects that might be lurking in the universe and not simply mathematical solutions.