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Geometry, matter, quasi-normal modes and echoes in a family of ultrastatic wormholes

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We investigate a family of ultra-static, Lorentzian wormholes for which the wormhole shapes and sizes are controlled by two metric parameters −b_0 (the throat radius) and n (an even integer). The well-known Ellis-Bronnikov wormhole is a special case (n= 2) in this family. The n>2 spacetimes are however, distinctly different geometrically, a fact evident from their embedding features. As expected, we note that the required matter stress-energy violates all energy conditions. Interestingly, we find that the stress-energy (for all even n) can be split into a part due to a phantom scalar and another extra piece which satisfies the Averaged Null Energy Condition (ANEC) along radial null geodesics. For n= 2, the additional stress energy and therefore, the ANEC integral, vanishes. A stability analysis of this family of wormholes is then carried out by first looking at scalar perturbations. Using time domain profiles as well as other standard methods, we find the quasi-normal modes. The n>2 geometries have double barrier effective potentials (in the scalar perturbation equation) and hence harbour echoes arising due to multiple reflections. We show how the scalar quasi-normal modes can be used as a tool for distinguishing and identifying the small 'n' wormholes. For large 'n', characteristic echoes act as signatures. All wormholes of this family are found to be stable under scalar as well as axial gravitational perturbations. In summary, with additional future work (especially on metric perturbations) our family of wormholes could turn out to be viable templates for black hole mimickers in gravitational wave physics.
(1) Revisiting a family of wormholes: geometry, matter, scalar quasinormal modes and echoes; P. Dutta Roy, S. Aneesh and Sayan Kar, Eur. Phys. J. C 80:850 (2020).

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