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Galactic wormholes: Geometry, stability, and echoes

In this work, we present the environmental effects on wormhole geometries residing in a galaxy through a fully relativistic analysis. In particular, we consider two wormhole spacetimes classes: the Damour-Solodukhin wormhole and the braneworld wormhole. While there is no classical matter model for the Damour-Solodukhin wormhole, the braneworld wormhole, on the other hand, is supported by a scalar-tensor theory on the four-dimensional brane. Intriguingly, it turns out that the presence of a dark matter halo surrounding these wormholes can tame the violations of energy conditions present in generic wormhole spacetimes. Our results also demonstrate that the galactic Damour-Solodukhin wormhole is more stable than its isolated counterpart, whereas we obtain the opposite behavior for the braneworld wormhole. The perturbation of these wormholes leads to echoes in the ringdown waveform, which are sensitive to the properties of the dark matter halo. To be precise, the time delay between two echoes is affected by the galactic matter environment, and it appears to be a generic effect present for any exotic compact object living in a galaxy. This allows us to identify the galactic parameters, independently from the gravitational wave measurements, if echoes are observed in future generations of gravitational wave detectors. For completeness, we have also analyzed the impact of the galactic environment on the photon sphere, the innermost stable circular orbits, and the shadow radius. It turns out that the dark matter halo indeed affects these locations, with implications for shadow and accretion physics.

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