Testing the nature of black holes with gravitational waves

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ABSTRACT

Gravitational wave (GW) astronomy allows us for unprecedented tests of the nature of dark compact objects. In this context, I will discuss two signatures of new physics at the horizon scale: GW "echoes" in the postmerger ringdown phase of a binary coalescence, and finite-size effects of exotic compact objects that affect the inspiral premerger phase. In the first case, the ringdown waveform of exotic ultracompact objects is initially identical to that of a black hole, and putative corrections at the horizon scale appear only at later times as a modulated and distorted train of echoes of the modes of vibration associated with the photon sphere. As for the second case, I will discuss the tidal heating and tidal Love numbers of different families of boson stars, gravastars, wormholes, and other toy models for quantum corrections at the horizon scale. These corrections display a universal logarithmic dependence on the location of the surface in the black-hole limit. I will discuss the ability of present and future GW detectors to measure these effects. Both LIGO, ET and LISA can impose interesting constraints on boson stars, while LISA is able to probe even Planckian corrections. We argue that these effects provide a smoking gun of new physics at the horizon scale, and that future GW measurements of a binary coalescence provide a novel way to test black holes and general relativity in the strong-field regime.