Light rings in stationary axisymmetric spacetimes: Blind to the horizon's topology and able to coexist

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Abstract

A light ring is a closed null geodesic around a central compact object. When this central object is a black hole the study of light rings assumes significant importance in astrophysical observations due to their profound implications. The imprints of a light ring influence many observable phenomena such as gravitational lensing, black hole shadows, and the emission of gravitational waves in the ringdown. By examining these effects, researchers gain invaluable insights into the fundamental nature of black holes, as well as their surrounding environments. Therefore, it is fundamental to study the appearance of light rings to determine how general they are and what their existence can tell us about the spacetime. In this sense, it was shown

that for spacetimes satisfying some sensible assumptions every asymptotically flat, axisymmetric, stationary, and circular spacetime containing a nonextremal topologically spherical event horizon admits, at least, one light ring outside the horizon, per rotation sense. In this work we dropped some of the assumptions to see if the general result still holds. Namely the requirement that the event horizon is topologically spherical was dropped and toroidal black holes were considered. Furthermore, the robustness of the original light ring result was tested on more generic grounds by. The results indicate that toroidal black holes obey a similar theorem as the topologically spherical ones, and that in a spacetime with an arbitrary number of (spherical and toroidal) black holes each black hole contributes with at least one light, per rotation sense. This suggests that light rings obey a kind of superposition principle.

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