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

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It is well established that black holes satisfying some quite general set of assumptions are always surrounded by a light ring. These are a special set of bound null orbits. Such orbits are of particular relevance when entering the new era of precision test of General Relativity, as they leave imprints on both gravitational wave observations, and on the black hole shadows, the two main new observation channels. The intimate relation between light rings and black holes, together with their observational relevance serve to highlight the need for a more profound understanding of light rings. Namely, the existence of light rings around black hole foils, be it horizonless compact objects or wormholes, or black hole spacetimes violating the assumptions of the original theorem. This work focus on the latter. The original result established that $1 + 3$ dimensional asymptotically at, axisymmetric, stationary, and circular spacetimes containing a nonextremal topologically spherical event horizon admit, at least, one light ring outside the horizon, per rotation sense. In order to improve the strength of this theorem we dropped a few of these assumptions to check if the conclusions hold. Specically, the requirement that the event horizon is topologically spherical was dropped and toroidal black holes were considered, to verify if light rings could be used as a probe of the topology of the black hole. Furthermore, the robustness of the light rings was tested by considering spacetimes harbouring multiple black holes. The results indicate that toroidal black holes obey a similar theorem as the 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 indicates that light rings obey a kind of superposition principle.

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