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Timelike Circular Orbits and Efficiency of Compact Objects

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We prove the following result. For a stationary, axisymmetric, asymptotically flat, ultracompact object (*i.e.* an object with light-rings) with a $\mathbb{Z}_2$ symmetry fixing an equatorial plane, the possibility and stability of timelike circular orbits in the vicinity of the existing light-rings, for both rotation directions, depend exclusively on the stability of the light-ring itself. An unstable light-ring present, radially below it, no timelike circular orbits, and, radially above it, unstable timelike circular orbits. On the other hand, a stable light-ring presents, radially below it, stable timelike circular orbits, and, radially above it, no timelike circular orbits. Consequences of this theorem are presented for horizonless objects and black holes. The efficiency associated with converting gravitational energy into radiation by a material particle falling under an adiabatic sequence of timelike circular orbits is also studied for a variety of exotic star models and black holes. For most objects studied, it is possible to obtain efficiencies larger than the well-known maximal efficiency of Kerr black holes.

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