LIGHT RINGS, LENSING, AND SHADOWS OF A SCHWARZSCHILD BLACK HOLE IMMERSED IN A SWIRLING UNIVERSE

Zeus S. Moreira[1], Carlos A. R. Herdeiro[2], and Luís C. B. Crispino[3]

1 Programa de Pós-Graduação em Física, UFPA

2 Departamento de Matemática da Universidade de Aveiro and CIDMA

Using the Ernst formalism, a novel solution of vacuum general relativity was recently obtained [Phys. Rev. D \textbf{106}, 064014 (2022)], describing a Schwarzschild black hole (BH) immersed in a nonasymptotically flat rotating background, dubbed swirling universe, with the peculiar property that north and south hemispheres spin in opposite directions. We investigate the null geodesic flow and, in particular, the existence of light rings in this vacuum geometry. By evaluating the total topological charge w, we show that there exists one unstable light ring ($w = −1$) for each rotation sense of the background. We observe that the swirling background drives the Schwarzschild BH light rings outside the equatorial plane, displaying counterrotating motion with respect to each other, while (both) corotating with respect to the swirling universe. Using backward ray-tracing, we obtain the shadow and gravitational lensing effects, revealing a novel feature for observers on the equatorial plane: the BH shadow displays and odd $\mathbb{Z}_2$ (north-south) symmetry, inherited from the same type of symmetry of the spacetime itself: a twisted shadow.