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## Photon regions and umbilic conditions in stationary axisymmetric spacetimes

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A photon region in the black holes gravitational field is defined as a compact region where photons can travel endlessly without going to infinity or disappearing at the event horizon. In the Schwarzschild metric, the photon region degenerates to the photon sphere which is a three-dimensional umbilic hypersurface in spacetime (its second quadratic form is proportional to the induced metric). In the Kerr metric, the spherical photon orbits with constant Boyer-Lindquist coordinate  $r$  also exist and filling some spheres. However, these spheres do not correspond to umbilic hypersurfaces and underlying geometric structure was not fully identified so far. We suggest a new geometric description of the photon region in generic stationary axisymmetric spacetimes, showing that the photon region can be foliated by partially umbilic hypersurfaces, such that the umbilic condition holds for classes of null orbits defined by the foliation parameter [1]. The new formalism provides novel methods of description of photon regions and shadows in stationary axisymmetric spacetimes with non-separable geodesic equations.

[1] Kobialko, K.V., Gal'tsov, D.V. Photon regions and umbilic conditions in stationary axisymmetric spacetimes. *Eur. Phys. J. C* 80, 527 (2020).

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