

学 位 論 文 の 要 旨

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学位論文題目	Gravitational bending angle of light with finite-distance corrections in stationary axisymmetric spacetimes (定常軸対称時空における有限距離補正を伴った重力による光の曲がり角))		
学位論文要旨 <p>The gravitational bending of light by mass led to the first experimental confirmations of the theory of general relativity. In modern astronomy and cosmology, the gravitational lensing is widely used as one of the important tools for probing extrasolar planets, dark matter and dark energy. A lot of calculations of the gravitational bending of light have been done not only for black holes but also for other objects such as wormholes and gravitational monopoles. For example, S. V. Iyer and A. O. Petters (2007) investigate the strong-deflection by the gravitational lens, V. Perlick (2004) study the lensing by a Barriola-Vilenkin monopole and also that by an Ellis wormhole and T. Kitamura, K. Nakajima, and H. Asada (2013) study the gravitational lensing by a lens model whose gravitational potential depends on the inverse distance to the n-th power.</p> <p>In 2008, Gibbons and Werner proposed an alternative way of deriving the deflection angle of light. They used the Gauss-Bonnet theorem to a spatial domain described by the optical metric, where they assumed that the source and receiver are located at an asymptotic region. By using the Gauss-Bonnet theorem, the bending angle of light in a static, spherically symmetric and asymptotically flat spacetime has been recently discussed, especially by taking account of the finite distance from a lens object to a light source and a receiver [Ishihara, Suzuki, Ono, Asada, Phys. Rev. D 95, 044017 (2017)].</p> <p>We discuss a possible extension of the method of calculating the bending angle of light to stationary, axisymmetric and asymptotically flat spacetimes. To be more precise, we investigate the light rays on the equatorial plane in the axisymmetric spacetime. We introduce a spatial metric to define the bending angle of light in the finite-distance situation. We call this metric generalized optical metric. The price for using the generalized optical metric is that we have to take account of the geodesic curvature of the light ray in the optical geometry and have to do the path integral of the geodesic curvature. We note that the light ray is not necessarily geodesic in the optical geometry, though the light ray follows the null geodesic in a four-dimensional spacetime.</p>			

We show that the proposed bending angle of light is coordinate-invariant by using the Gauss-Bonnet theorem. The non-vanishing geodesic curvature of the photon orbit with the generalized optical metric is caused in gravitomagnetism, even though the light ray in the four-dimensional spacetime follows the null geodesic. We consider Kerr spacetime and rotating Teo wormhole as examples in order to examine how the bending angle of light is computed by the present method.

In Kerr case, the finite-distance correction to the gravitomagnetic deflection angle due to the Sun's spin is around a pico-arcsecond. The finite-distance corrections for SgrA* also are estimated to be very small. Therefore, the gravitomagnetic finite-distance corrections for these objects are unlikely to be observed with present technology.

The wormhole spacetime has a non-trivial structure. The metric for the rotating wormhole spacetime was found by E. Teo (1998). We obtain the deflection angle of light for an observer and source at finite distance from a rotating Teo wormhole. This results recover the asymptotic deflection angles by Jusufi and Ovgun (2018), if we take the far limit.

It might be interesting to examine the gravitomagnetic bending of light by using other axisymmetric spacetimes in general relativity or in a specific theory of modified gravity.