CAPTURE OF MASSLESS PARTICLES BY PARAMETERIZED BLACK HOLES

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Abstract

General relativity is considered as the most satisfactory theory of gravitation due to its conceptual and structural elegance as well as its reasonable agreement with experimental and astronomical observations [1]. The following three observational classical tests are called experimental verification of the Einstein theory in weak field and slow motion regime: the perihelion precession of the orbit of the planet Mercury, deflection of the light ray as it passes close to the sun, and the gravitational redshift of light. Consequently, these all three tests verify the correctness of general relativity in weak gravitational field regime. This fact has served as a base for development of the new alternative theories of gravity that perfectly match with general relativity in the weak field regime but in the strong field regime the main differences could be risen.

The best laboratory to test the theory in strong gravitational field is black hole (and neutron star) close environment. Thanks to the development of new modern technologies in recent years we have obtained several observational breakthrough events such as detected gravitational waves from the coalescence of two mass black holes or neutron stars in close binaries by LIGO and Virgo scientific collaborations (for example, see [2–6]) and discovery of the first image of the supermassive black hole at the center of the elliptic galaxy M87 by the Event Horizon Telescope (EHT) collaboration [7] that gave us initial possibility to check general relativity in the strong field regime. However, there is still room for the alternative theories of gravity [8] as current sensitivity of the technologies is not enough to fully exclude them by testing the no-hair theorem and general relativity. With the further development of detectors and obtained new observational data in the near future we hopefully be able to check validity of all theories one by one in strong field regime.

However, there is much compact method in which all black hole geometries are written in the generic, model independent form. The generic spacetime geometry could be chosen in such a way that can be used to measure deviations from general relativity via the expansion parameters [9, 10] and depending on the data from observation, one can find the constrains for the appropriate parameters.

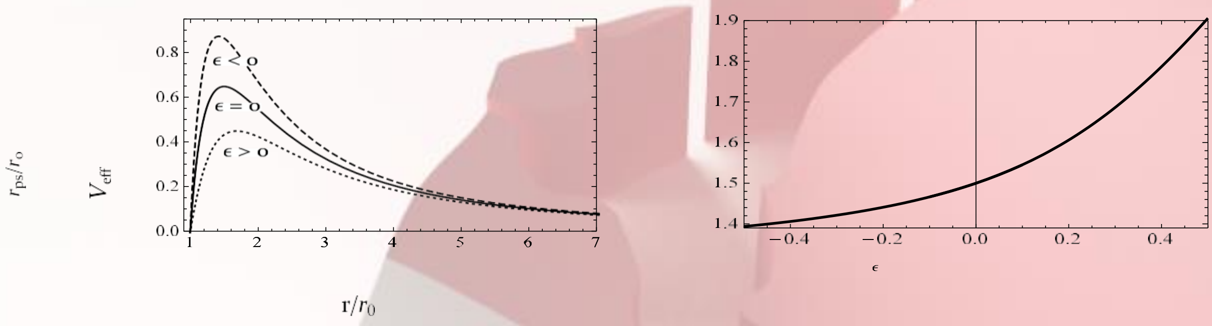

FIG. 1. Left panel: qualitative picture of radial dependence of the effective potential of photon for the different signs of the parameter g. Right panel: a location of maximum of the effective potential as a function of g.

In this section we explore motion of the photon and its capture by black hole whose line element is given by equation. In both studies determination of the impact parameter, b, that defines the closest approach distance of photon to black hole that castill pass through is very crucial. It is well-known fact that the photon passing through the black hole spacetime can approach the black hole until photonsphere, beyond it move along the photonsphere or is captured by the black hole. Therefore, the photonsphere is a boundary between capture and escape cases.

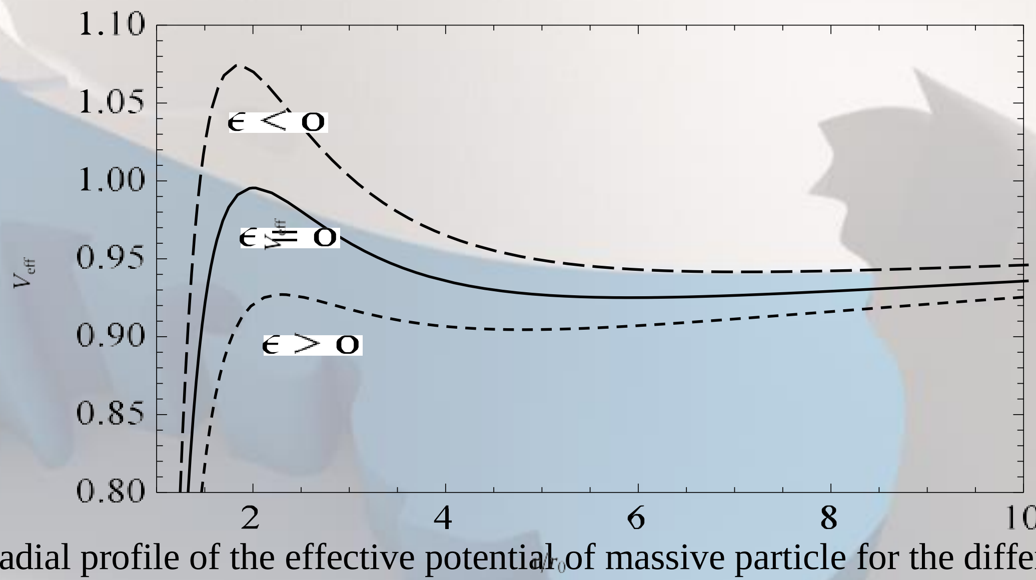

FIG. 3. Radial profile of the effective potential of massive particle for the different signs of the parameter g.

In this paper we have studied the capture of massless and massive particles by the generic spherically symmetric black hole whose line element is described by the Rezzolla- Zhidenko parameterization [10]. We have shown that negative (positive) values of _ decreases (increases) radius of characteristic circular orbits and consequently, increases (decreases) the energy and decreases (increases) the angular momentum of the particle moving along these orbits. Moreover, we have calculated and compared the capture cross section of the massive particle in relativistic and non-relativistic limits. It has been shown that in the case of small deviation from general relativity the capture cross section for the relativistic and nonrelativistic particle has additional term being linear in small dimensionless deviation parameter. We underline that dependence of spherically symmetric black hole cross sections on the dimensionless deviation parameter can be suggested as a powerful tool to determine the valid theory of gravity in the strong field regime using observational data on the highly energetic processes in black hole close environment.

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