ROTATING CURZON-CHAZY METRIC

V.Khamidov
Republican scientific and methodological center for the development of education of the Republic of Uzbekistan
O. Yunusov
National University of Uzbekistan, Tashkent, Uzbekistan
H.Hoshimov
National University of Uzbekistan, Tashkent, Uzbekistan

It is well-known that obtaining an exact analytical solution for a rotating compact object is quite a challenging problem in general relativity and alternative theories of gravity. One of the simple analytical vacuum solutions to Einstein's field equations for a rotating black hole is described by the Kerr metric, which is a generalized form of the Schwarzschild metric.

The another simple vacuum solution of the Einstein field equations is the Curzon-Chazy metric described spacetime around a massive object of a mass M. In the spherical coordinates $x^{\alpha} = (t, r, \theta, \varphi)$, the explicit form of the Curzon-Chazy metric is given as[1]

$$ds^2 = -\exp(-\frac{2M}{r})dt^2 + \exp(-\frac{2M}{r})[\exp(-\frac{M^2 \sin^2\theta}{r^2})(dr^2 + r^2 d\theta^2) + r^2 \sin^2\theta d\phi^2], \quad (1)$$

which is static metric and asymptotically flat as $r \to \infty$, with a Schwarzschild mass M and this metric belongs to Weyl's class of solutions[3]. It is worth noting that the structure of the Curzon-Chazy metric is very similar to the Papapetrou metric. In Ref.[3], radial dependence of the curvature scalars in Papapetrou metric has been explicitly discussed. Also, the Curzon-Chazy metric is one of the particular cases of the Zipoy-Voorhees metric which is also known as γ-metric[4]. The simplified form of the rotating Curzon-Chazy metric as

$$ds^2 = -\exp(-\frac{2\sigma}{r})(dt - 2ad\phi)^2 + \exp(-\frac{2\sigma}{r})[\exp(-\frac{\sigma^2 \sin^2\theta}{r^2})(dr^2 + r^2 d\theta^2) + r^2 \sin^2\theta d\phi^2],$$

which is very similar to Curzon-Chazy static space time(1), where $\sigma = \sqrt{M^2 - a^2}$ and a- spin parameter of black hole. Interestingly, this metric can be recovered Minkowski spacetime if the compact object have maximum spin, $a/M \to 1$.

In this work we tested Curzon-Chazy spacetime through investigating test particle motion, weak gravitational lensing effect and properties of thin accretion disk surrounding spinning cenral object. Studying of particle motion in Curzon-Chazy spacetime has provided valuable insights into the behavior of particles in a unique gravitational environment. The curvature of Curzon-Chazy spacetime leads to presence of additional forces acting on particles, altering their trajectories and introducing intriguing effects. We have studied massive particle motion in rotating Curzon-Chazy spacetime. It is found that characteristic radii decrease for rotating object and for maximally rotating object they will be zero. We also seen that the deflection angle of the light rays decrease due to spin parameter a/M increase and if spin parameter of the compact object reaches maximum, this object do not influence light beams which is passing near the black hole. Additionally, in this spacetime observer can overlook three images of the source. However, two of them are the same each other. Also we have shown that total magnification decrease with spin parameter a and angle β is decreasing. We have conducted an analysis on the characteristics of the thin accretion disk surrounding a compact object governed by the rotating Curzon-Chazy spacetime. By employing the Novikov-Thorne model, we initially ascertained the rate at which energy is emitted from the surface of the disk, fig.(1) . Our findings indicate that the deformation of the spacetime has the potential to influence the emission in the high-frequency range originating from the thin accretion disk.

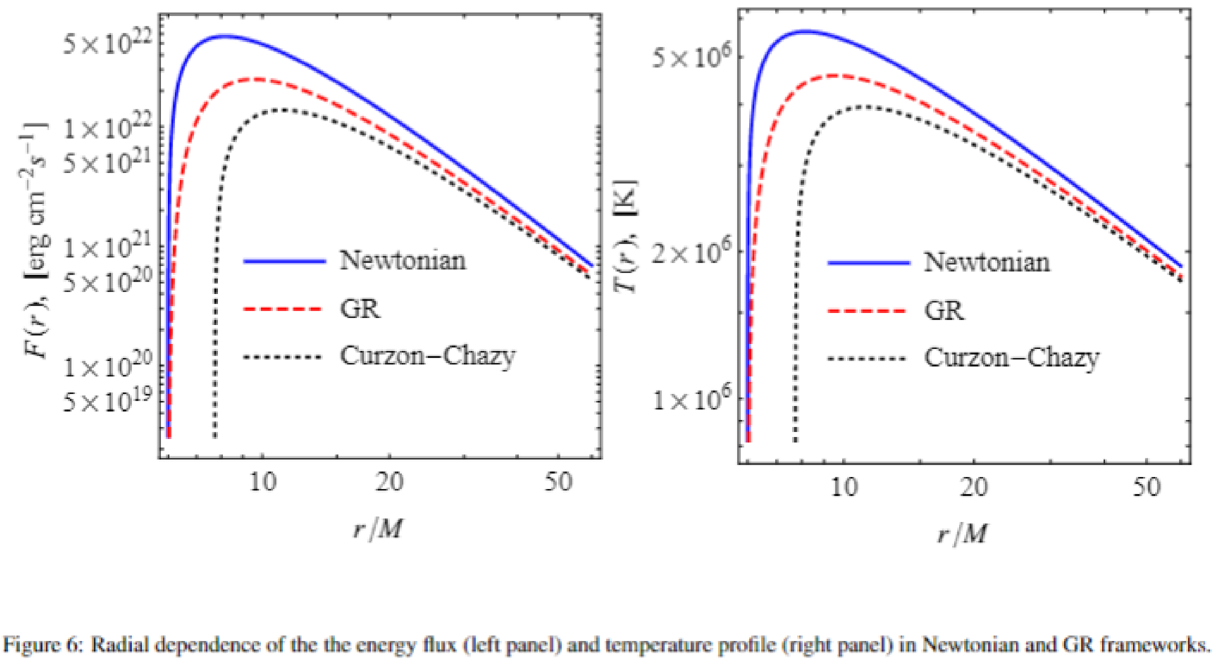

Figure 1: Radial dependence of the energy flux (left panel) and temperature (right panel) in Newtonian and GR frameworks.

REFERENCES:

[1] L. Polcar, O. Sv́ıtek, Phantom scalar field counterpart to Curzon–Chazy spacetime, Class. Quant. Grav. 39 (2022) 185002.

[2] H. Weyl, Bemerkung ̈uber die axialsymmetrischen L ̈osungen der Einsteinschen Gravitationsgleichungen, Annalen der Physik 364 (1919) 185–188.

[3] B. Turimov, Y. Turaev, B. Ahmedov, Z. Stuchl ́ık, Circular motion of test particles around wormhole represented by exponential metric, Physics of the Dark Universe 35 (2022) 100946.

[4] A. B. Abdikamalov, A. A. Abdujabbarov, D. Ayzenberg, D. Malafarina, C. Bambi, B. Ahmedov, Black hole mimicker hiding in the shadow: Optical properties of the γ metric, Phys. Rev. D 100 (2019) 024014