Université Mohammed
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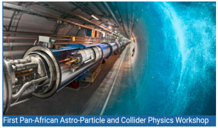
Equipe Sciences de la Matière et du Rayonnement



Deflection angle of light rays by accelerating black holes with cosmological constant

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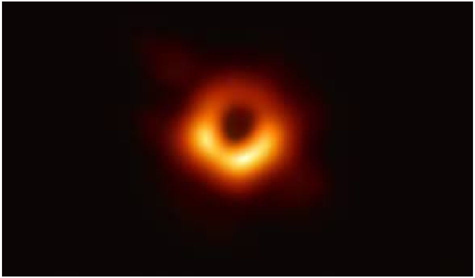
Plan

Introduction

K. Akiyama et al., First M87 Event Horizon Telescope Results. VI. Imaging the Central Supermassive Black Hole, Astrophys. J. L6(1)(2019)875.



Black hole properties from

- Thermodynamical study : state equation, phase transitions, critical points, stability...
- Optical study : shadow, deflection angle, photon ring ...

Accelerating black hole solutions with the cosmological constant contribution

The metric of the space time

$$ds^2 = \frac{1}{\Omega^2}\left[f(r)dt^2 - \frac{dr^2}{f(r)} - r^2\left(\frac{d\theta^2}{g(\theta)} + g(\theta)\sin^2\theta\frac{d\phi^2}{K^2}\right)\right] \tag{1}$$

$$\Omega = 1 + Ar\cos\theta \tag{2}$$

$$f(r) = (1 - A^2r^2)\left(1 - \frac{2m}{r}\right) - \frac{r^2\Lambda}{3} \tag{3}$$

$$g(\theta) = 1 + 2mA\cos\theta; \tag{4}$$

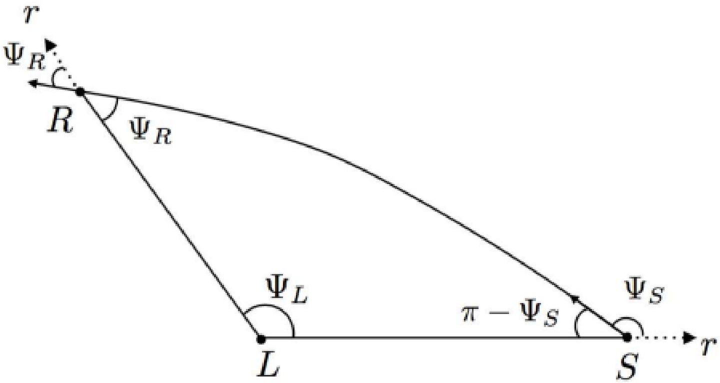
Tension of cosmic string in terms of the conical deficit of the spacetime

$$\mu = \frac{1}{4}\left(1 - \frac{g(\theta)}{K}\right). \tag{5}$$

Deflection angle formalisms from Gauss-Bonnet theorem

Placing the observer and the source at finite distance in the equatorial plane, the deflection angle can be derived from

$$\Theta = \Psi_R - \Psi_S + \phi_{SR}. \quad (6)$$



Fixing the time in the black hole metric, we get the optical metric

$$dl^2 \equiv \gamma_{ij} dx^i dx^j \tag{7}$$

The ψ angles expression is derived from

$$\cos \Psi \equiv \gamma_{ij} e^i R^j, \tag{8}$$

- e^i is the tangential vector along the light rays
- R^j is the radial vector of the light rays

Taking $u = \frac{1}{r}$, the ϕ_{RS} is defined as

$$\phi_{RS} = \int_S^R d\phi = \int_{u_0}^{u_S} \frac{d\phi}{du} du + \int_{u_0}^{u_R} \frac{d\phi}{du} du \tag{9}$$

The impact parameter of motion should be defined

$$b = \frac{E}{L} \qquad \frac{d\phi}{du} = 0 \Rightarrow b \simeq \frac{1}{u0} \tag{10}$$

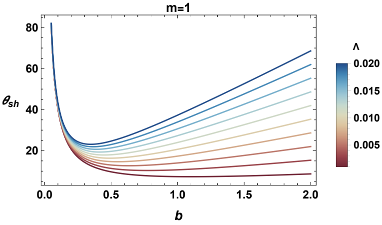
Deflection angle of accelerating black holes with cosmological constant

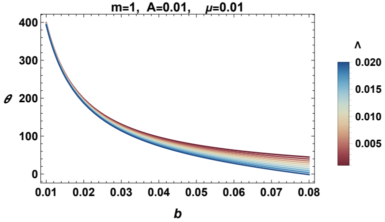
$$\Theta = \Theta_{sh} + \left(\frac{1}{u_R}+\frac{1}{u_S}\right)\frac{A^2 b}{2} + \frac{A^2 b\Lambda}{36}\left(\frac{1}{u_S^3}+\frac{1}{u_S^3}\right)) + 2b\Lambda\mu\left(\frac{1}{u_R}+\frac{1}{u_S}\right) + 2Ab\mu\left(\frac{1}{u_R}+\frac{1}{u_S}\right)$$
$$+\left(\frac{1}{u_S^2}+\frac{1}{u_S^2}\right)\left(\frac{7A^2 b\Lambda\mu m}{3}+\frac{A^2 b\Lambda m}{4}\right) + \frac{5A^2 b\Lambda\mu}{9}\left(\frac{1}{u_S^3}+\frac{1}{u_S^3}\right) - bA^2 m - 4A^2 b\mu m$$
$$+\frac{436 b\Lambda\mu m}{45}$$

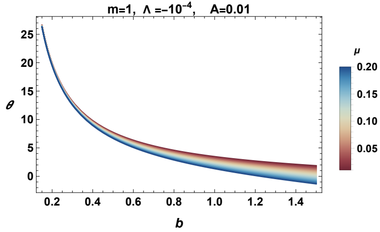
the Shwarzchild AdS deflection angle

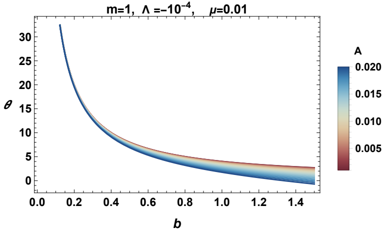
$$\Theta_{sh} = \frac{b\Lambda m}{3} + \frac{4m}{b} - \frac{b\Lambda}{6}\left(\frac{1}{u_R}+\frac{1}{u_S}\right) \tag{11}$$

Graphical analysis









Conclusion

The deflection angle of accelerating black hole decrease by increasing the magnitude acceleration and tension of the cosmic string and it become a decreases function of the cosmological constant without any minimum value compered to the Shwarzchild AdS deflection angle.

Thank you for your attention