Destroying the Event Horizon of Regular Black Holes

Zilong Li and Cosimo Bambi

Center for Field Theory and Particle Physics & Department of Physics, Fudan University, 200433 Shanghai, China

Abstract

Recently, several authors have studied the possibility of overspinning or overcharging an existing black hole to destroy its event horizon and make the central singularity naked. When all the effects are properly taken into account, any attempt to destroy the black hole seems to be doomed to fail, in agreement with the weak cosmic censorship conjecture. In this poster, we study the possibility of destroying the event horizon of regular black holes[1], which have no central singularity and therefore they are not protected by the cosmic censorship hypothesis. Our results strongly support the conclusion that regular black holes can be destroyed.

Method

Here we consider two different methods to try to destroy the event horizon of black holes, one is a gedanken experiment (Test-Particle Approximation) and the other is a common astrophysical phenomenon like the thin disk accretion process.

1. Test-Particle Approximation (Fig.1)

One can imagine an experiment in which a black hole absorbs a small particle of energy E, angular momentum L, and electric charge q (here we assume that the small particle has no charge).

- Absorption condition:

$$E \geq \frac{q\left(A_\phi g_{t\phi} - A_t g_{\phi\phi}\right) - g_{t\phi} L}{g_{\phi\phi}} \, ;$$

- Destroying condition:

$$\Delta(r) = 0 \quad \text{has no solutions} \, .$$

Once these two conditions are satisfied, the test particle can be plunged into the black hole and destroy its event horizon.

2. Thin Disk Accretion Process (Fig.2)

In the case of a thin disk on the equatorial plane, the gas reaches the innermost stable circular orbit (ISCO) and it then plunges quickly onto the compact object[3], which changes its mass M and spin J by

$$M \to M + \epsilon_{\rm ISCO} \delta m \, , \quad J \to J + \lambda_{\rm ISCO} \delta m \, ,$$

$\epsilon_{\rm ISCO}$ and $\lambda_{\rm ISCO}$ are, respectively, the specific energy and the specific angular momentum of a test-particle at the ISCO, while δm is the gas rest-mass. Here we study the evolution of black holes as a consequence of the accretion process for an initially non-rotating object. We assume that the particles are neutral, so $Q \to Q$ or $g \to g$.

References

[1] Z. Li and C. Bambi, arXiv:1304.6592 [gr-qc].

[2] C. Bambi and L. Modesto, Phys. Lett. B **721**, 329 (2013).

[3] Z. Li and C. Bambi, JCAP **1303**, 031 (2013).

Background Spacetime

In Boyer-Lindquist coordinates, the non-vanishing spacetime metric coefficients are

$$g_{tt} = -\left(1 - \frac{2mr}{\Sigma}\right) , \quad g_{rr} = \frac{\Sigma}{\Delta} ,$$

$$g_{t\phi} = -\frac{2amr\sin^2\theta}{\Sigma} , \quad g_{\theta\theta} = \Sigma ,$$

$$g_{\phi\phi} = \left(r^2 + a^2 + \frac{2a^2 mr\sin^2\theta}{\Sigma}\right)\sin^2\theta ,$$

where $\Sigma = r^2 + a^2\cos^2\theta$, $\Delta = r^2 - 2mr + a^2$.

The event horizon of a black hole can be obtained by solving $\Delta = 0$.

Regular Black Holes

In the metric coefficients, m is given by[2]

$$m_{\rm KN} = M - \frac{Q^2}{2r} , \quad \text{Kerr-Newman Black Holes}$$

$$m_{\rm B} = \frac{Mr^3}{(r^2+g^2)^{3/2}} , \quad \text{Bardeen Black Holes}$$

$$m_{\rm H} = \frac{Mr^3}{r^3+g^3} , \quad \text{Hayward Black Holes}$$

Kerr-Newman black holes have central singularities, which are removed in the prototype of regular black holes, e.g. Bardeen and Hayward black holes.

Results

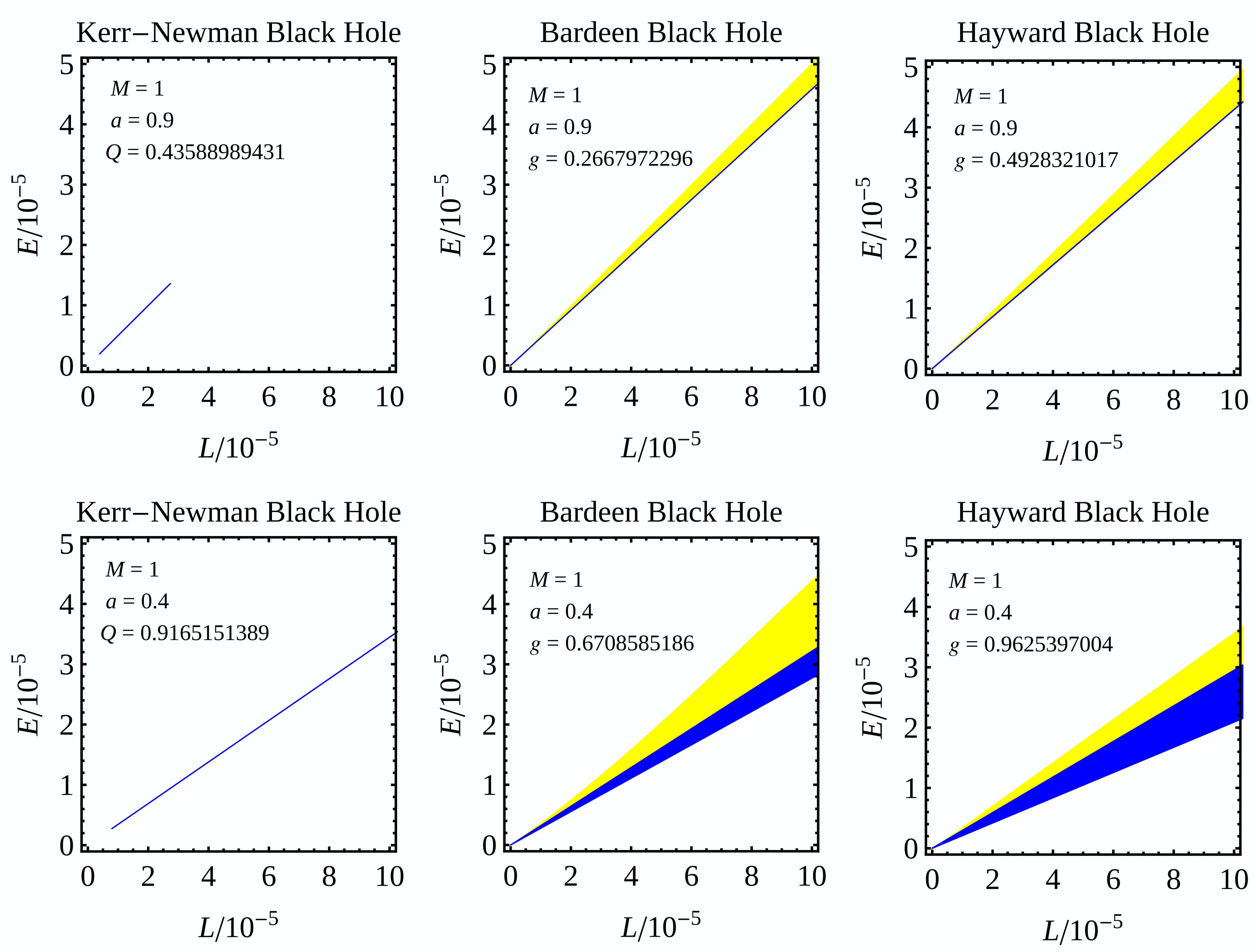
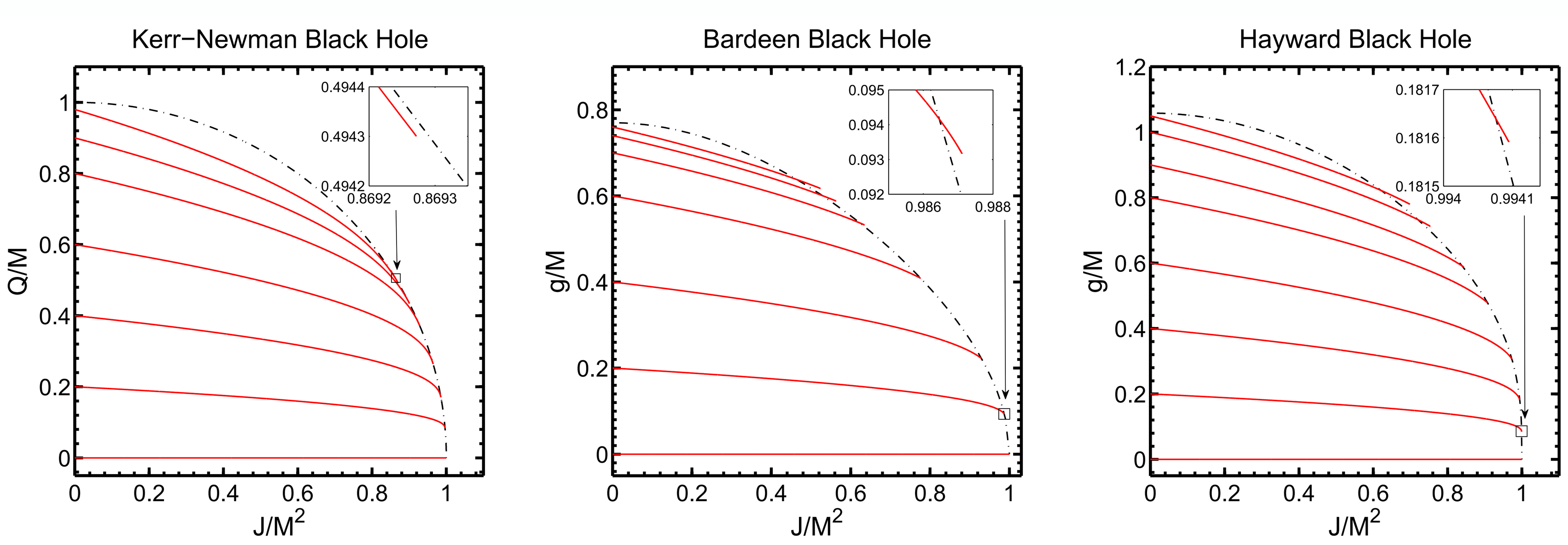


Fig.1 (Left) Values of the energy E and of the angular momentum L for which a test particle can destroy a near extremal (we take $Q = Q_{\rm extremal} - \varepsilon$ with $\varepsilon = 10^{-10}$, and the same with g) black hole. For regular black holes, the blue-dark region is for bound orbits, the yellow-light one is for unbound orbits.

Fig.2 (Right) Tracks of the evolution of black holes as a consequence of the accretion process from a thin disk of uncharged gas. The black dashed-dotted line is the boundary separating black holes and horizonless states.



Conclusions

We have presented two different examples strongly suggesting that regular black hole can be destroyed.

- The parameter region for which the test particle can destroy the regular black hole's event horizon is not narrow.
- The natural accretion process from a thin disk can destroy regular black holes.

A Future Direction

Naively, we may guess that a real astrophysical black hole has no central singularity, as the latter is more likely a pathological feature associated with classical general relativity, to be removed by (unknown) quantum gravity effects. If this guess is true somehow, we might have a chance to see the black hole's internal region and observe quantum gravity phenomena, e.g. from near future very long baseline interferometry (VLBI) observations.