

Objects
Super-spinning Black Holes:
Motivations
and Observational Signatures

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References

- **C. Bambi and K. Freese, PRD 79 (2009) 043002**
- **R. Takahashi, C. Bambi, T. Harada, K. Freese and M. Honma, in preparation**

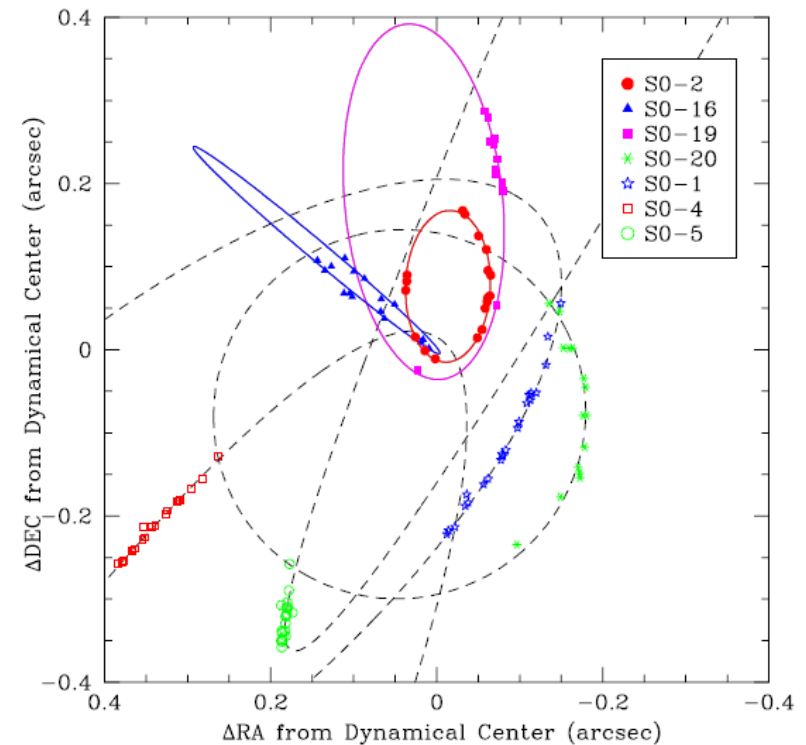
Observations

- **BH candidates: stellar mass BHs in X-ray binary systems (5 – 20 Solar masses), super-massive BHs in galactic nuclei (10^6 – 10^9 Solar masses), IMBHs in ULXSs (10^3 – 10^4 Solar masses?)**
- **Today we have reliable measurements of the mass of BH candidates**
- **There are currently many efforts to measure the spin of BH candidates**

The BH candidate in the Galaxy

- Study of the orbits of individual stars
- Mass about 4×10^6 Solar masses
- Radius < 45 AU ($600 R_{\text{Sch}}$)

The possibility that it is a cluster of some non-luminous bodies sounds very unlikely, because the cluster lifetime due to evaporation or physical collisions is too short (see e.g. Maoz, 1998)



Weak points of current evidences supporting the existence of BHs

- **The interpretation that these objects are BHs is just the most conservative possibility**
- **Note that, so far, GR has been tested in the weak field limit only: BHs may not exist or may be very different from the ones predicted by GR!**

Carter-Israel Conjecture

- **The end-state of the gravitational collapse of matter is a Kerr-Newman BH**
- **Kerr-Newman BH: 3 free parameters (mass M , Kerr parameter a , and electric charge Q)**
- **Condition for the existence of the horizon: $M^2 > a^2 + Q^2$**

Kerr metric with $|a| > M$

- If $M^2 < a^2 + Q^2$ there is no horizon \rightarrow Naked singularity!
- Closed time-like curves: we can violate causality
- Cosmic Censorship Conjecture: naked singularity are forbidden

Is the CCC really necessary?

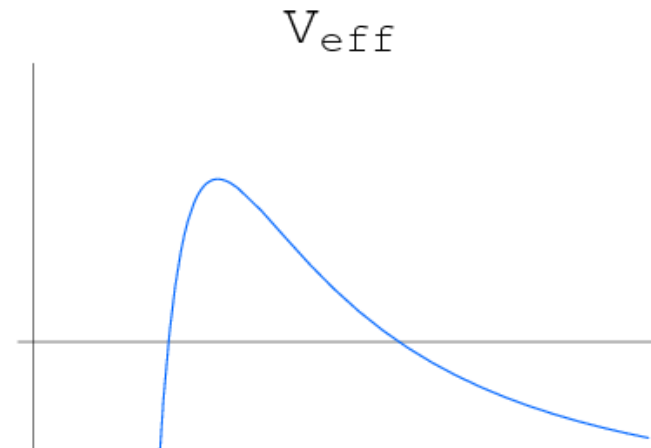
- **What is the “physical meaning” of the singularity at the center of BHs? It may be the symptom of the breakdown of classical GR and be solved at the quantum level/by a higher energy theory. In this case, there would be no reason to impose the bound $M > |a|$**
- **The possibility of violation of the Kerr Bound was first discussed in Horava & Gimon 2007 in the framework of string theories, but actually it may occur in any extension of GR**

Photon Orbits

- Geodesic equations for massless particles
- 3 constants of motion (Energy, component of the Angular Momentum parallel to the BH spin and Carter Constant). 2 constants determine the orbit

- **Effective potential:**

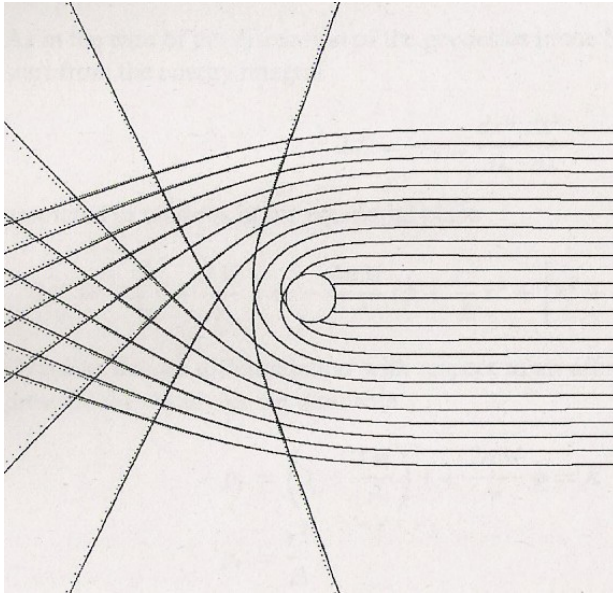
$$V_{eff}(r) = \frac{L^2}{2r^2} - \frac{mL^2}{r^3}$$



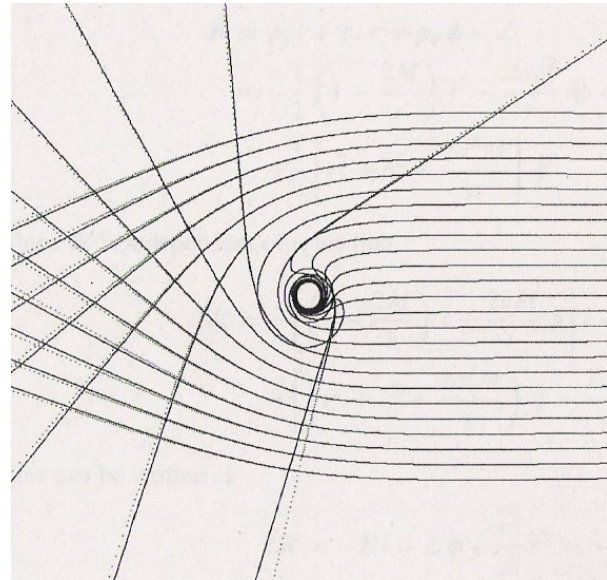
- 3 kinds of photon orbits: capture orbits, scattering orbits and unstable orbits of constant radius

Null geodesics

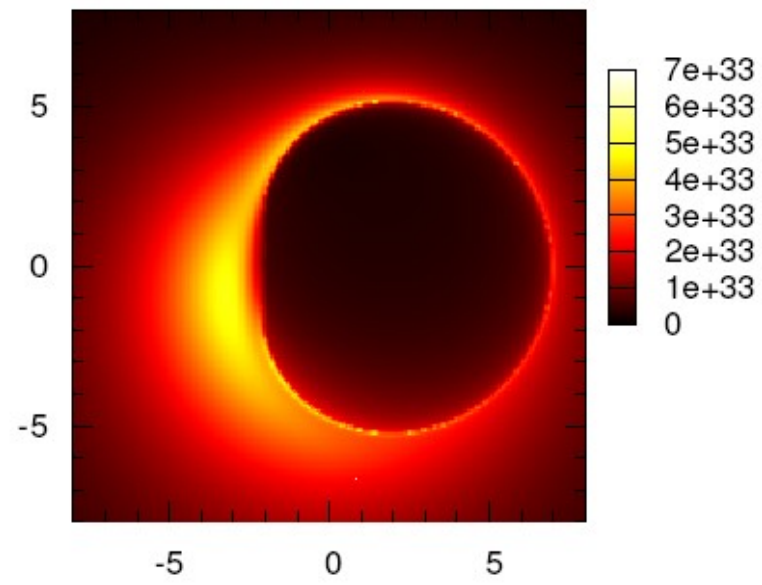
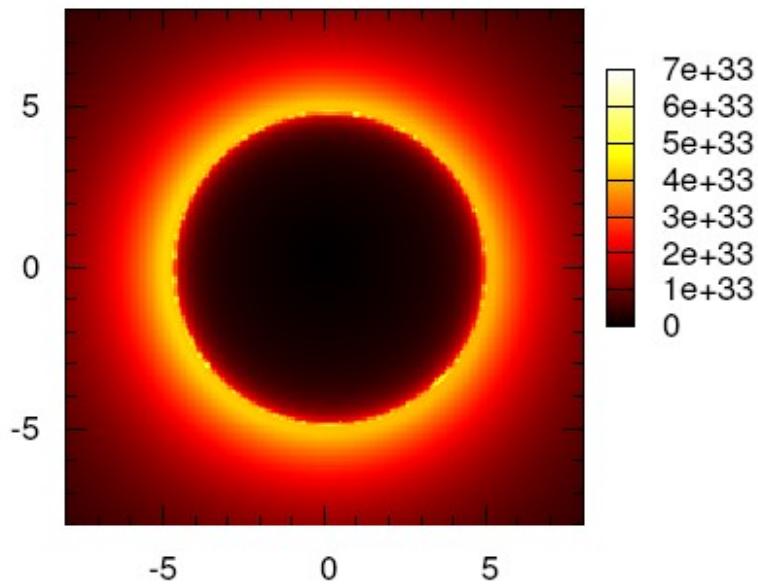
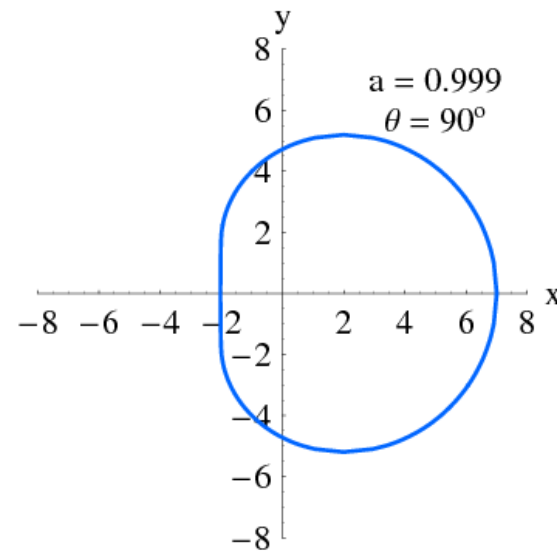
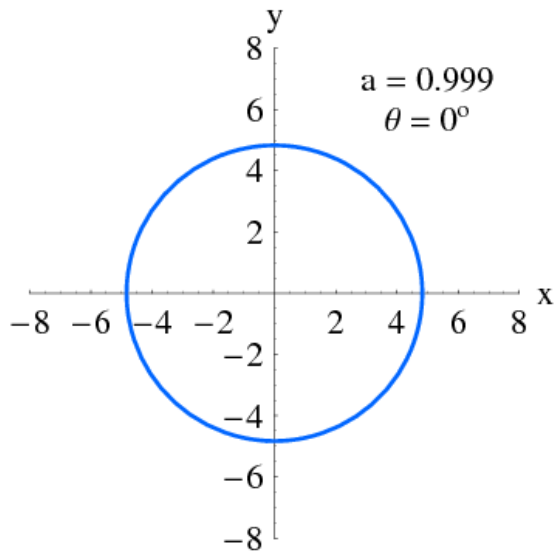
Schwarzschild



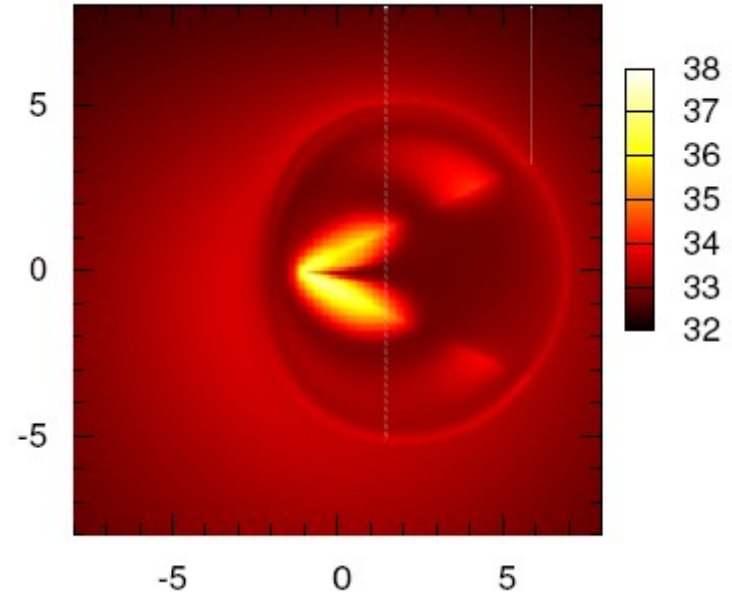
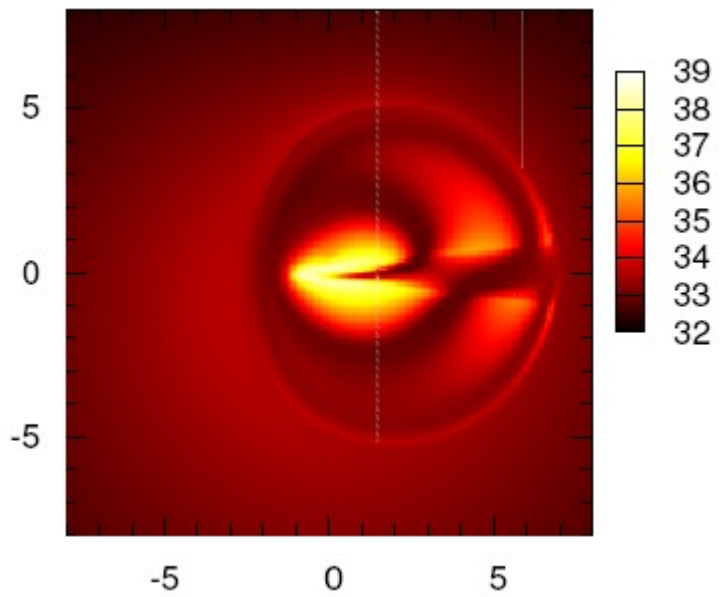
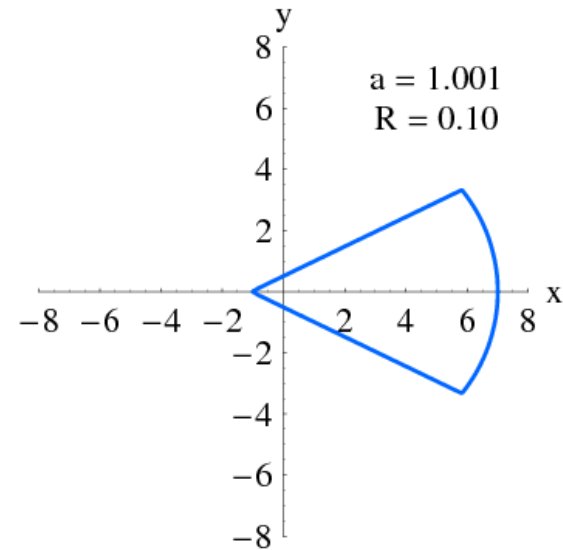
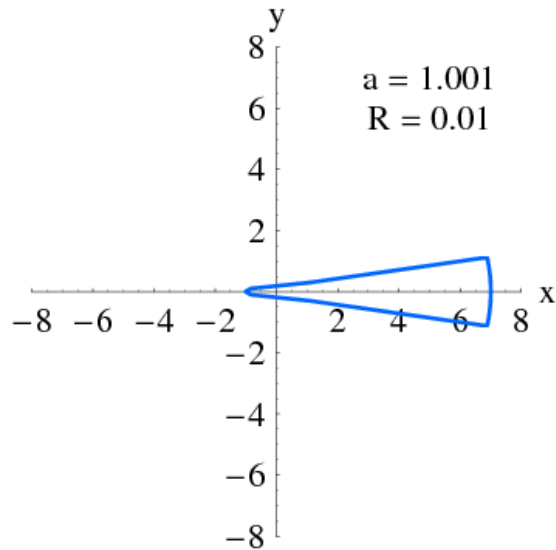
Kerr



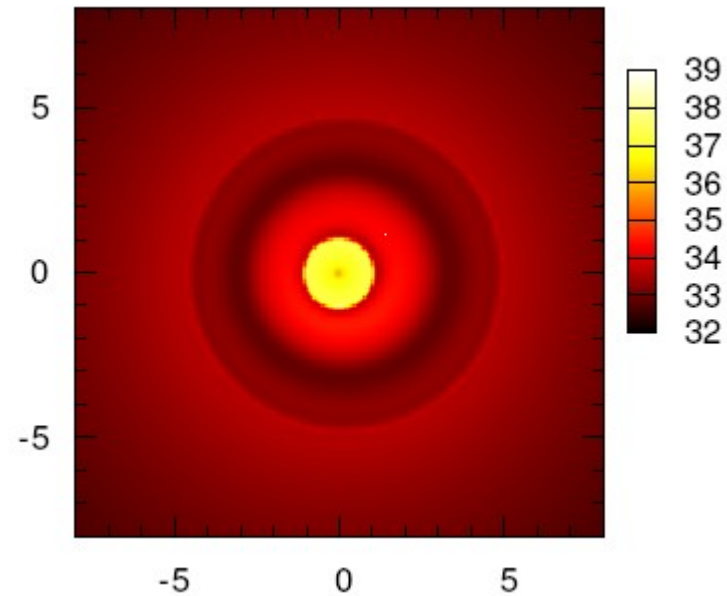
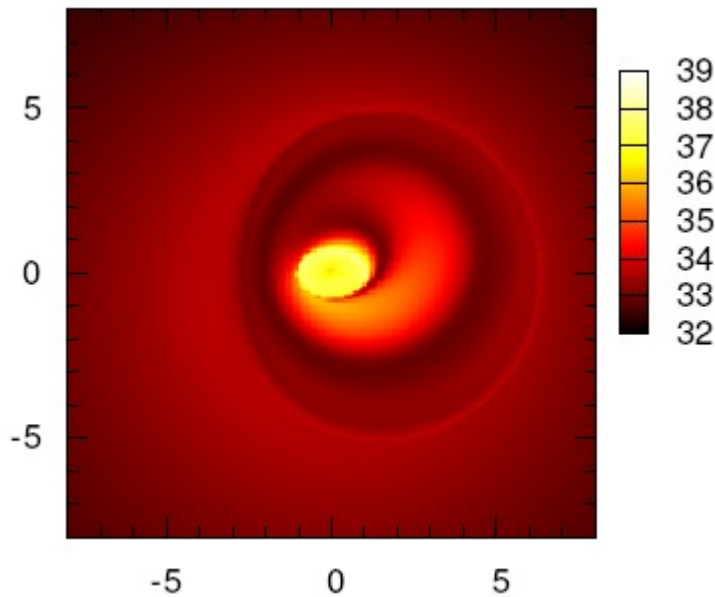
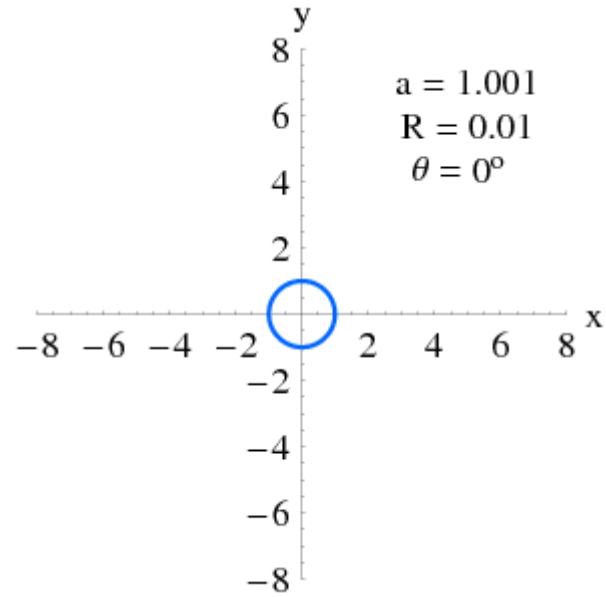
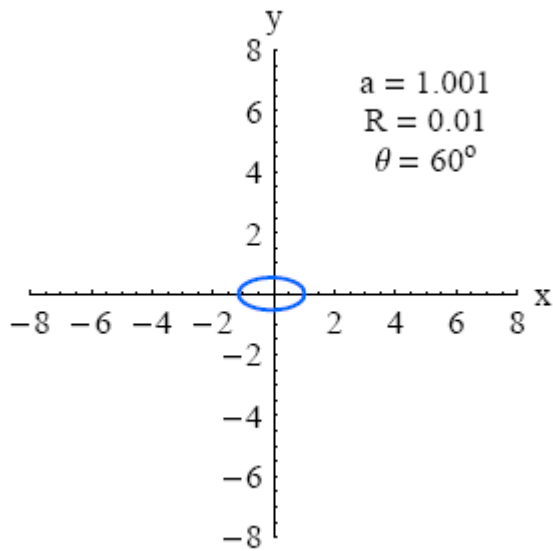
Direct Image ($M > |a|$)



Direct Image ($M < |a|$)



Direct Image ($M < |a|$)



Conclusions

- **The singularity at the center of BHs is likely unphysical. The bound $M > |a|$ may be violated**
- **The relation $M > |a|$ could be tested in the near future, by observing the shadow of the BH candidate in the Galactic Center**