
# Sgr A*: super massive black hole or naked singularity?

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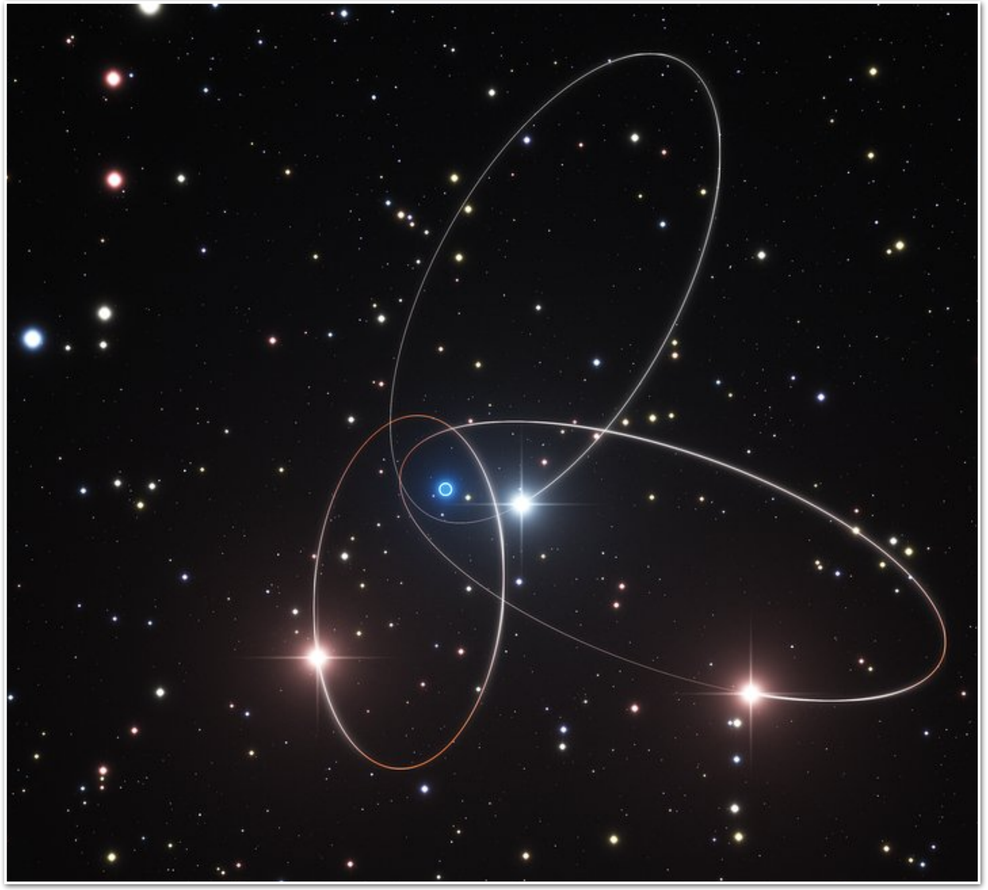
# Compact source Sgr A *

- Our galactic center has a compact source Sgr A * of mass $M \approx 4 \times 10^6 M_\odot$ with variable X-ray, radio and infrared emission.
- We infer more information about the source through different observations.

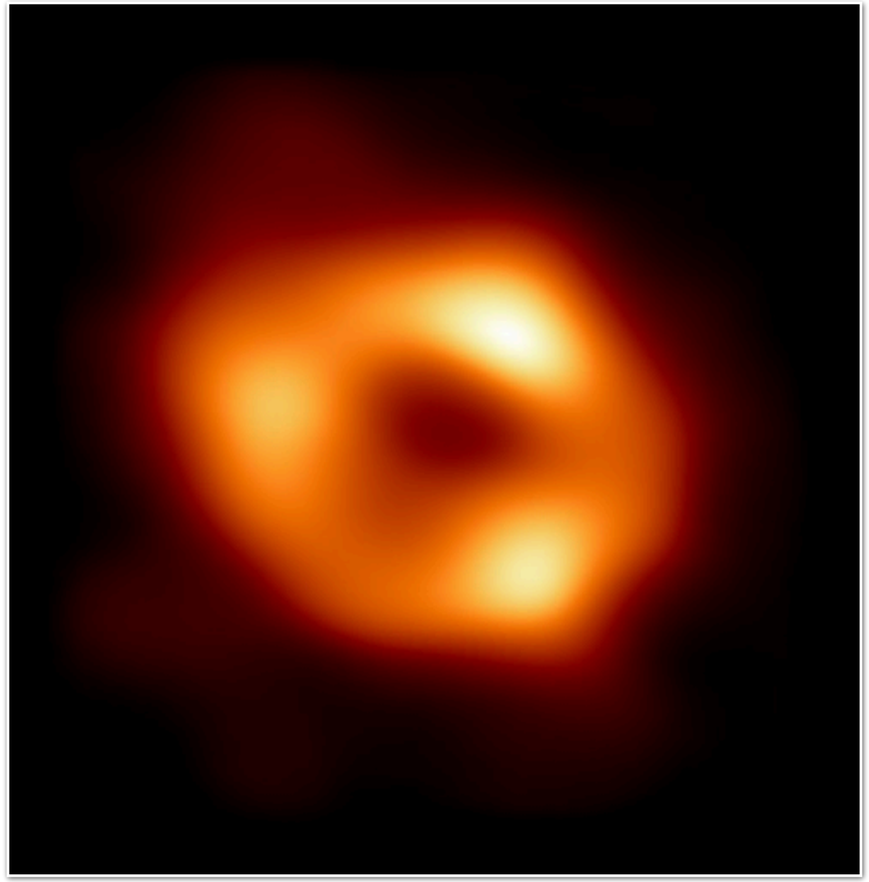
1. Monitoring the motion of the stars orbiting the galactic center one can reconstruct the gravitational potential far from the source.
2. Black hole shadow or silhouette has been resolved by Event Horizon Telescope (EHT) image for Sgr A* .



Motion of stars around Sgr A*

# Do the observations confirm the presence of a Kerr black hole ?

- The diameter of EHT image of Sgr A* is $51.8\mu$as, the distance of the source is $\approx$ 8kpc (from stellar orbits), the apparent size translates to 5.42 M $(G/c^2)$
- Many studies (Lara et al. 2021, Bauer et al. 2021, Wielgus 2021) addressed the question whether we can reconstruct the space-time metric from EHT images.
- Objects alternative to Kerr black hole could produce images similar to EHT (Vincent et al. 2021)
- **Sgr A * could be a naked singularity** : can not be ruled out from metric tests (Event Horizon Telescope Collaboration et al. 2022)



EHT Collaboration

# Reissner-Nordström metric

- In GR the gravitational field of a electrically charged, non-rotating spherically symmetric body is described by Reissner-Nordström (RN) metric.

$$ds^2 = -e^{2\Phi}dt^2 + e^{2\Lambda}dr^2 + r^2(d\theta^2 + \sin^2\theta d\varphi^2)$$

$$\Phi = \frac{1}{2}\log\left[1 - \frac{2M}{r} + \frac{Q^2}{r^2}\right] \qquad \Lambda = -\Phi$$

$\Phi$ - gravitational potential

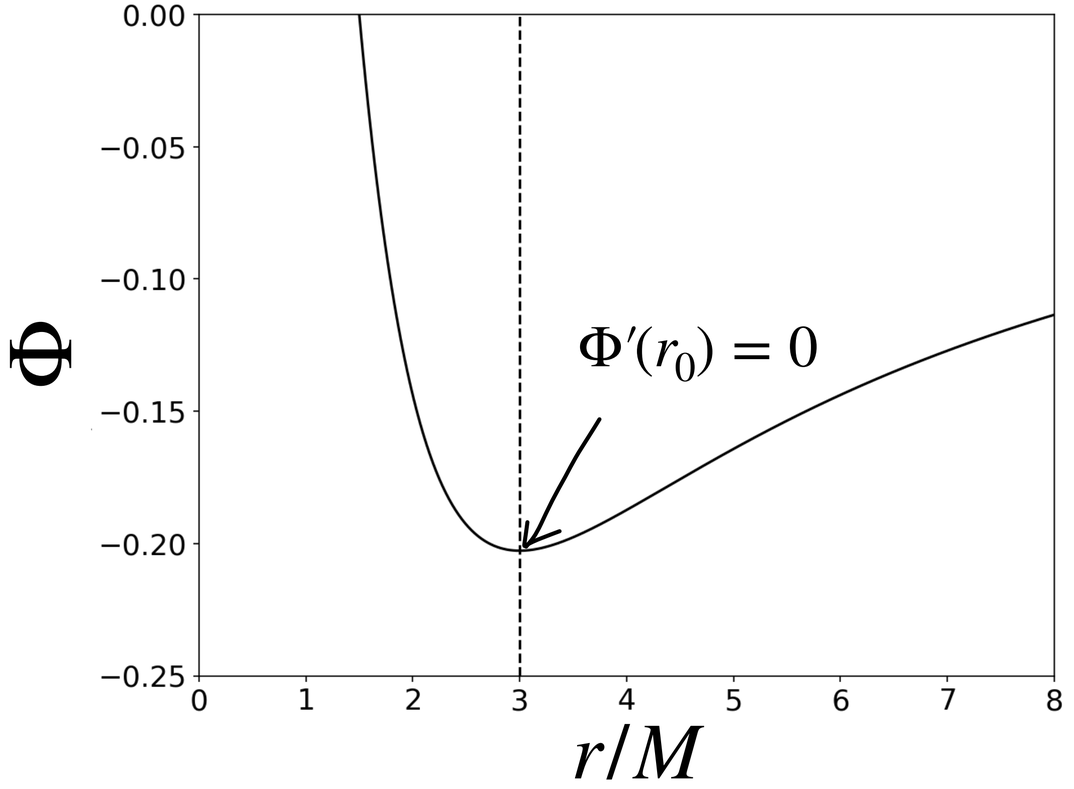
- For $Q > M$ we have a naked singularity. Naked singularities are hypothetical objects in space-time that are not dressed by an event horizon.

# Zero gravity sphere

- The 4-acceleration of a static observer is given by, $a_r = \dfrac{d\Phi}{dr} \equiv \Phi'(r)$
- There exists a $r_0$ at which $\Phi'(r_0) = 0$, $r_0$ is "zero-gravity radius" given by

$$\frac{r_0}{M} = \left(\frac{Q}{M}\right)^2$$

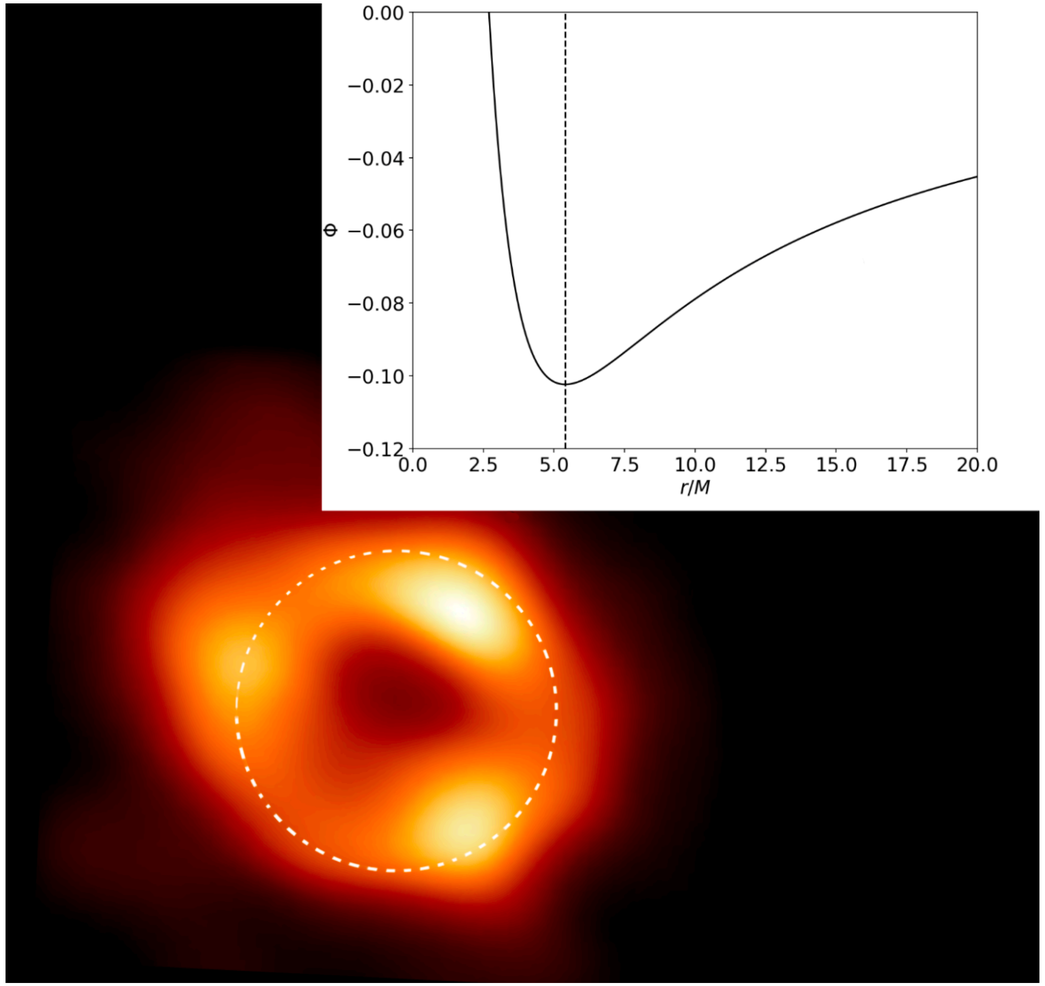
- Outside of it gravity is attractive and inside gravity is repulsive.
- At zero gravity radius a test particle remains at rest for an observer at infinity.




Here $\left(\frac{Q}{M}\right)^2 = 3$. $\Phi$ has minimum at the zero-gravity radius $r_0 = 3r/M$

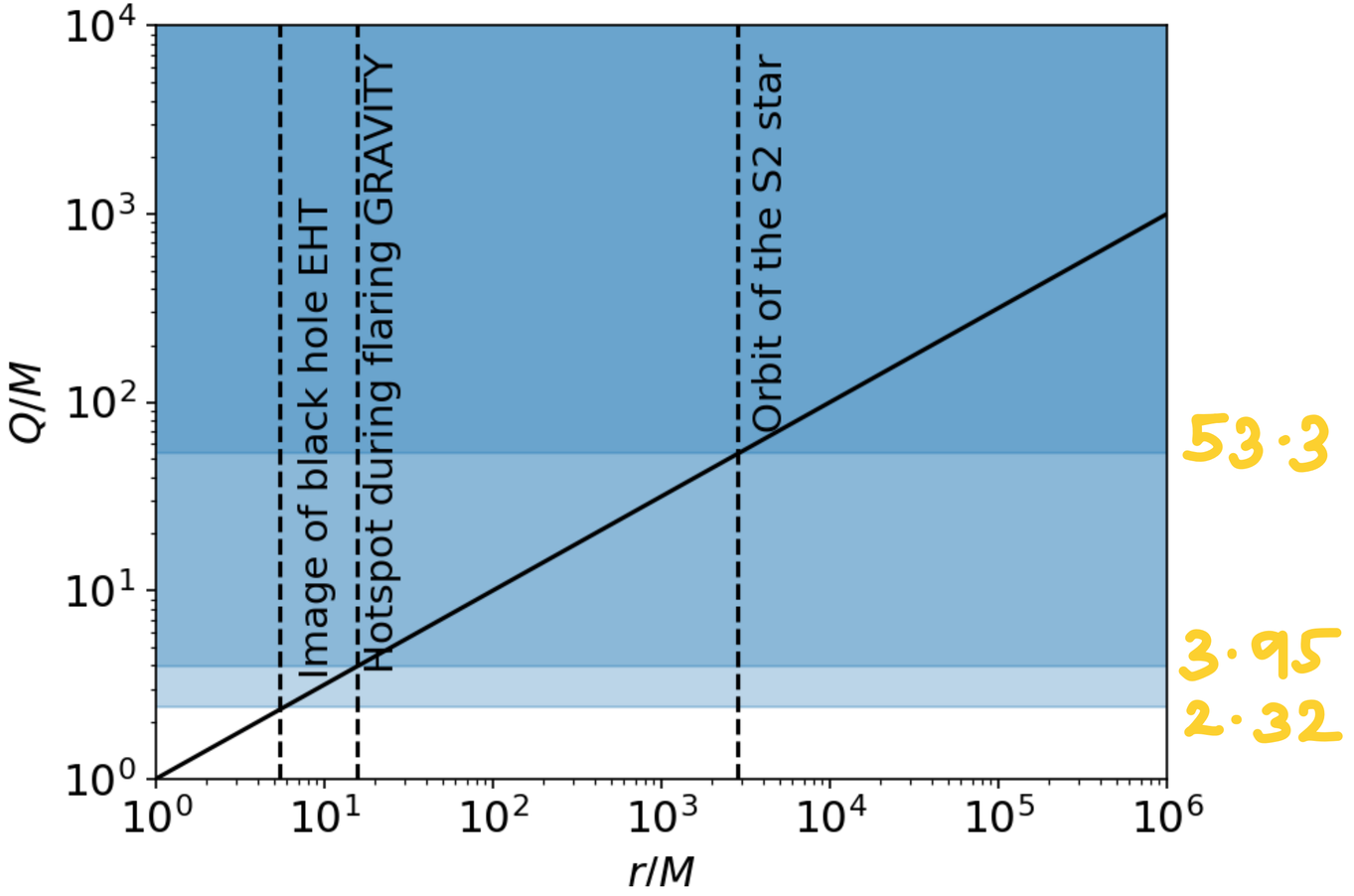
# Zero gravity sphere

- Circular geodesic motion can not occur inside the radius $r_0$ ( Pugliese et al. 2021 )
- No quasi stable structure can exist fully inside of the zero gravity sphere. So when we see any structure, a part of it must lie outside of the zero gravity sphere.

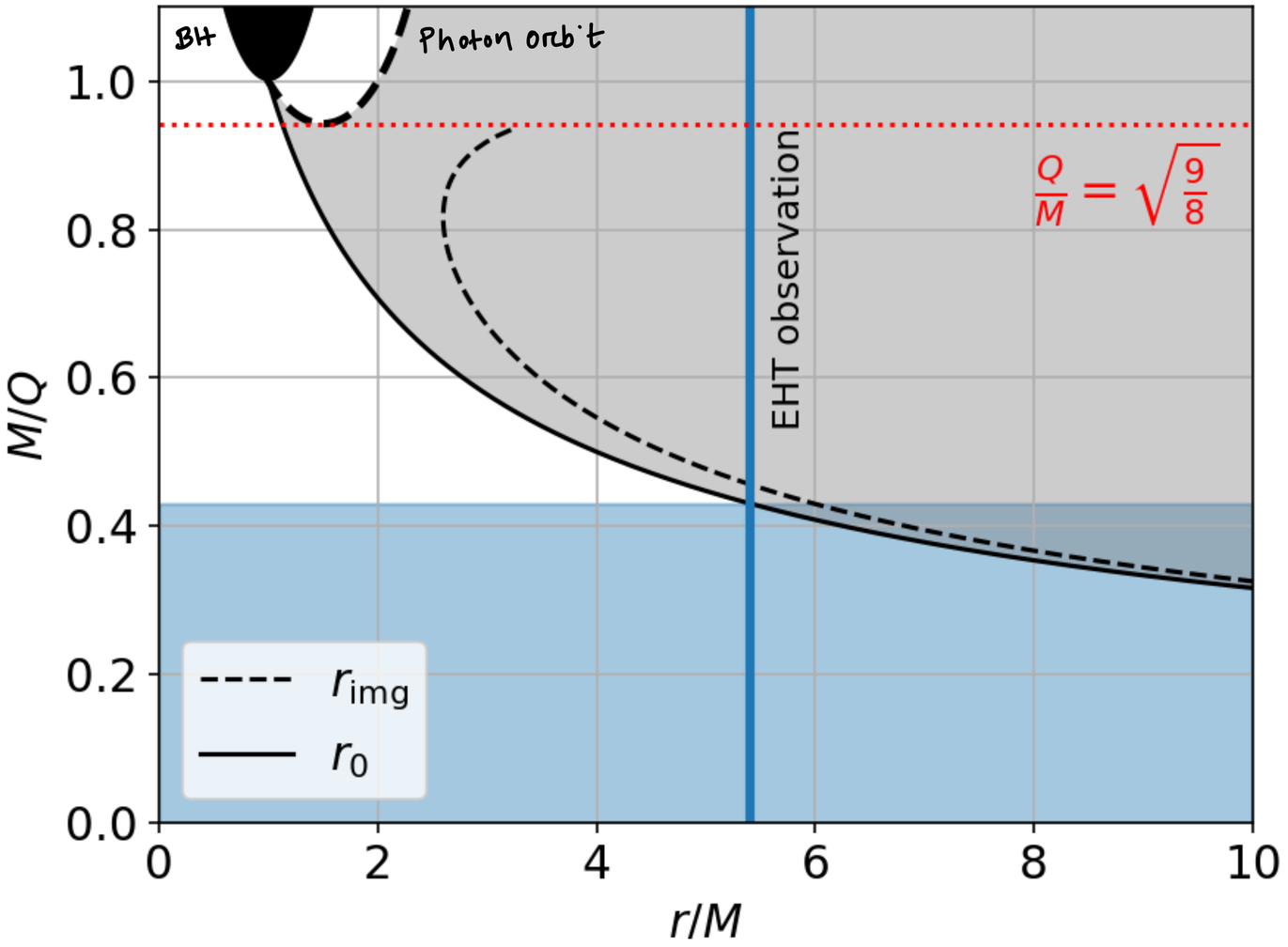


# Constraints on $Q/M$

- Using this property we can constrain $Q/M$ for Sgr A* based on different observations.
- We exclude a huge parameter space imposing constraints on the charge.



# Constraints on $Q/M$ from EHT observation




$$r_0/M = (Q/M)^2 < \frac{R_{\rm EHT}}{M} = 5.42$$

Apparent size of the zero gravity sphere

$$r_{\rm img} = \frac{r_0}{\sqrt{1 - \frac{M^2}{Q^2}}}$$

$$Q/M < \sqrt{\frac{R_{\rm EHT}}{M}} < 2.32$$

# Summary

- We consider the compact source Sgr A* at the galactic centre to be a naked singularity in RN space-time.
- The general property of RN metric imply that, there exists a zero-gravity radius, where a test particle remains at rest.
- There are no orbits inside of the zero-gravity radius .
- A part of any quasi stable structure must necessarily lie outside of the zero-gravity radius.
- EHT observations place stringent limits on charge : if Sgr A* were a naked singularity, its electric charge must be $Q < 2.3M$.

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# Thank you