Chaotic dynamics around black holes

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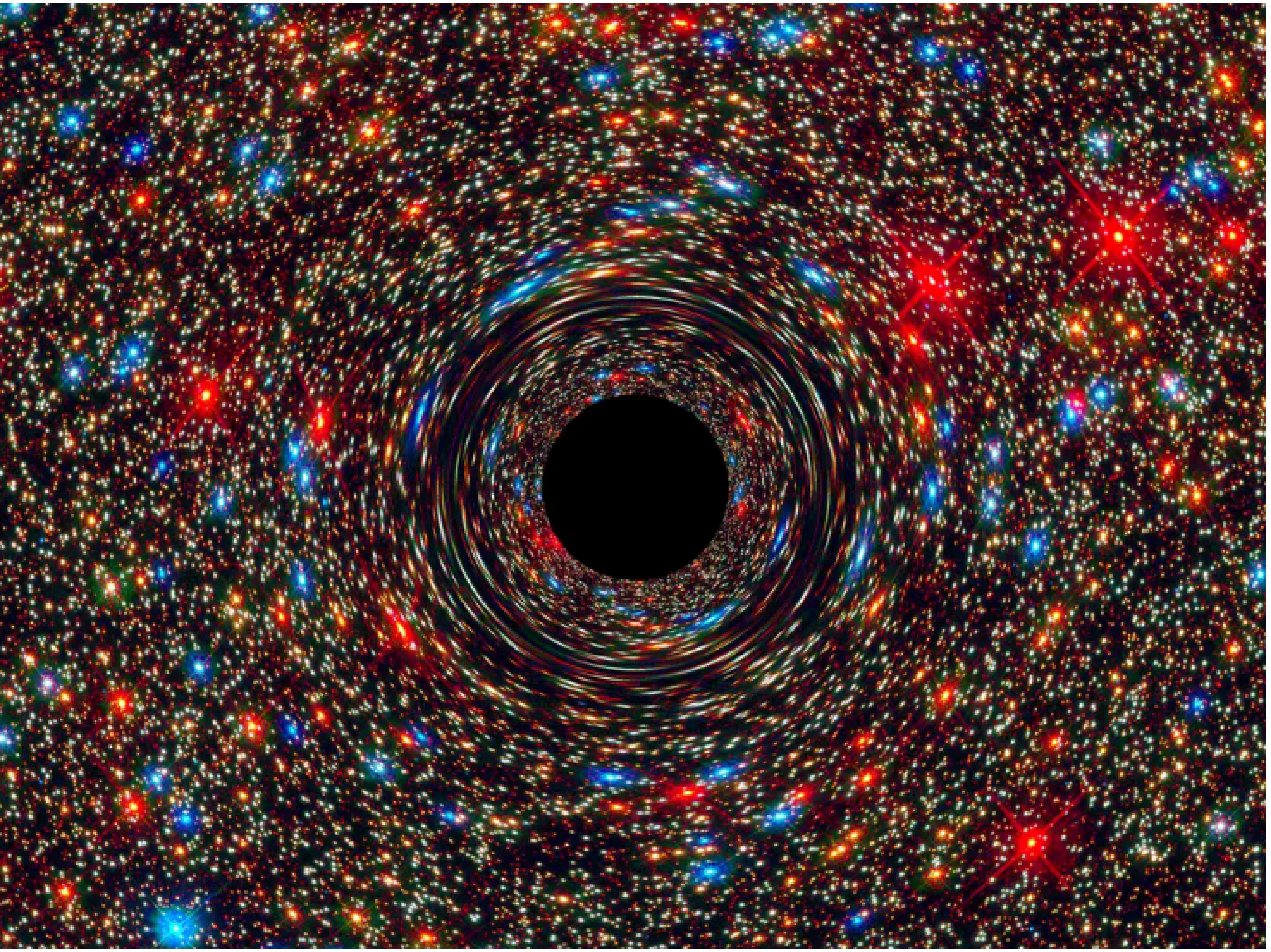
Motivation



NASA, ESA, and D. Coe, J. Anderson, and R. van der Marel (STScI)

- Influence of **black hole** mass and spin on dynamics
- Exploring **dynamics** around black holes
- Understanding the behavior of **extended objects**
- Revealing the role of **chaos** in astrophysical systems
- Investigating the effects of gravitational waves on motion
- Assessing the impact of chaotic dynamics on accretion and emissions

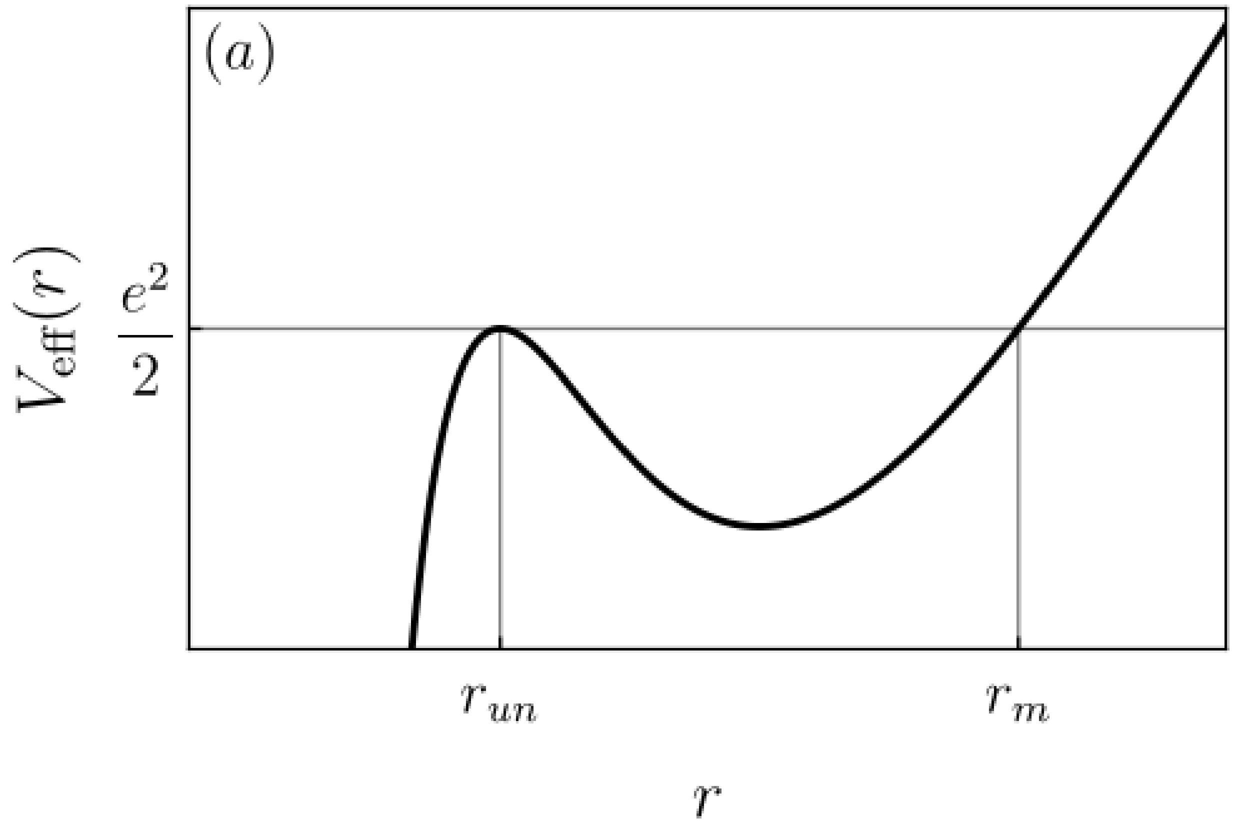
Motion around black holes

- Point particles follow geodesics;
  - in the presence of gravitational waves the movement can became chaotic;
    - this can affect the long time behavior of the particles around the black hole.

- The dynamics of extended objects is more complicate

$$\frac{Dp^{\mu}}{ds} = -\frac{1}{2} R^{\mu}{}_{\nu\alpha\beta} v^{\nu} S^{\alpha\beta} + F^{\mu},$$
$$\frac{DS^{\mu\nu}}{ds} = 2p^{[\mu} v^{\nu]} + N^{\mu\nu},$$

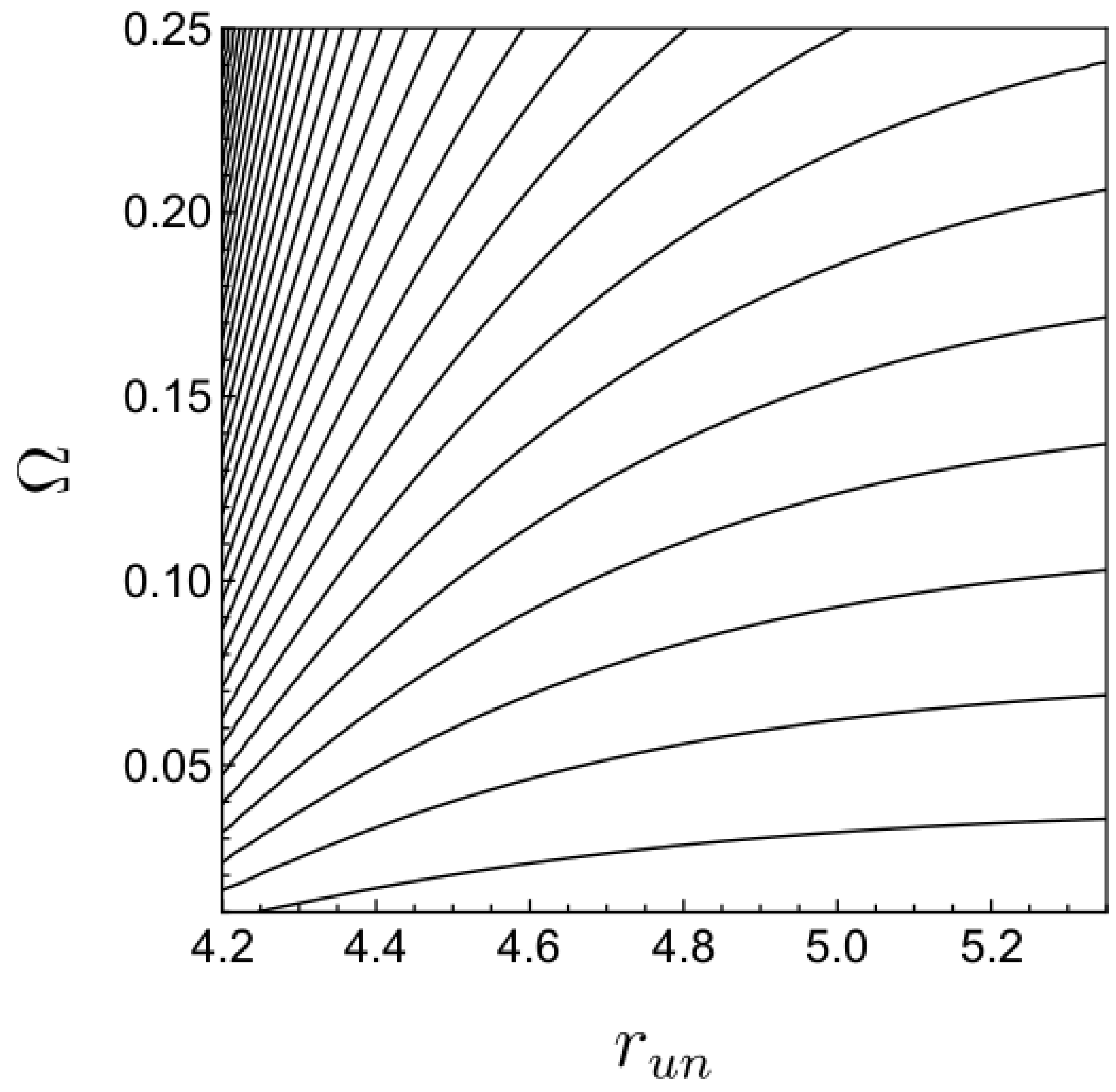
$$F^{\mu} = -\frac{1}{6} J^{\alpha\beta\gamma\delta} \nabla^{\mu} R_{\alpha\beta\gamma\delta},$$
$$N^{\mu\nu} = \frac{4}{3} J^{\alpha\beta\gamma[\mu} R^{\nu]}{}_{\gamma\alpha\beta},$$



- Different spacetime
- Different extended objects
- Melnikov function as a tool for chaos detection

$$M(\tau_0) = 2\cos(\Omega\tau_0)K(\Omega),$$

$$K(\Omega) = \int_{r_{un}}^{r_m} k(r)\sin[\Omega\,\tau(r)]dr,$$



[1] Mosna, R.A., Rodrigues, F.F., Vieira, R.S.S.: Chaotic dynamics of a spinless axisymmetric extended body around a schwarzschild black hole. Phys. Rev. D 106, 024016 (2022).
[2] Rodrigues, F.F., Mosna, R.A. and Vieira, R.S.S.: Chaotic dynamics of pulsating spheres orbiting black holes. Gen. Rel. Grav. 56:112 (2024).

Chaotic dynamics

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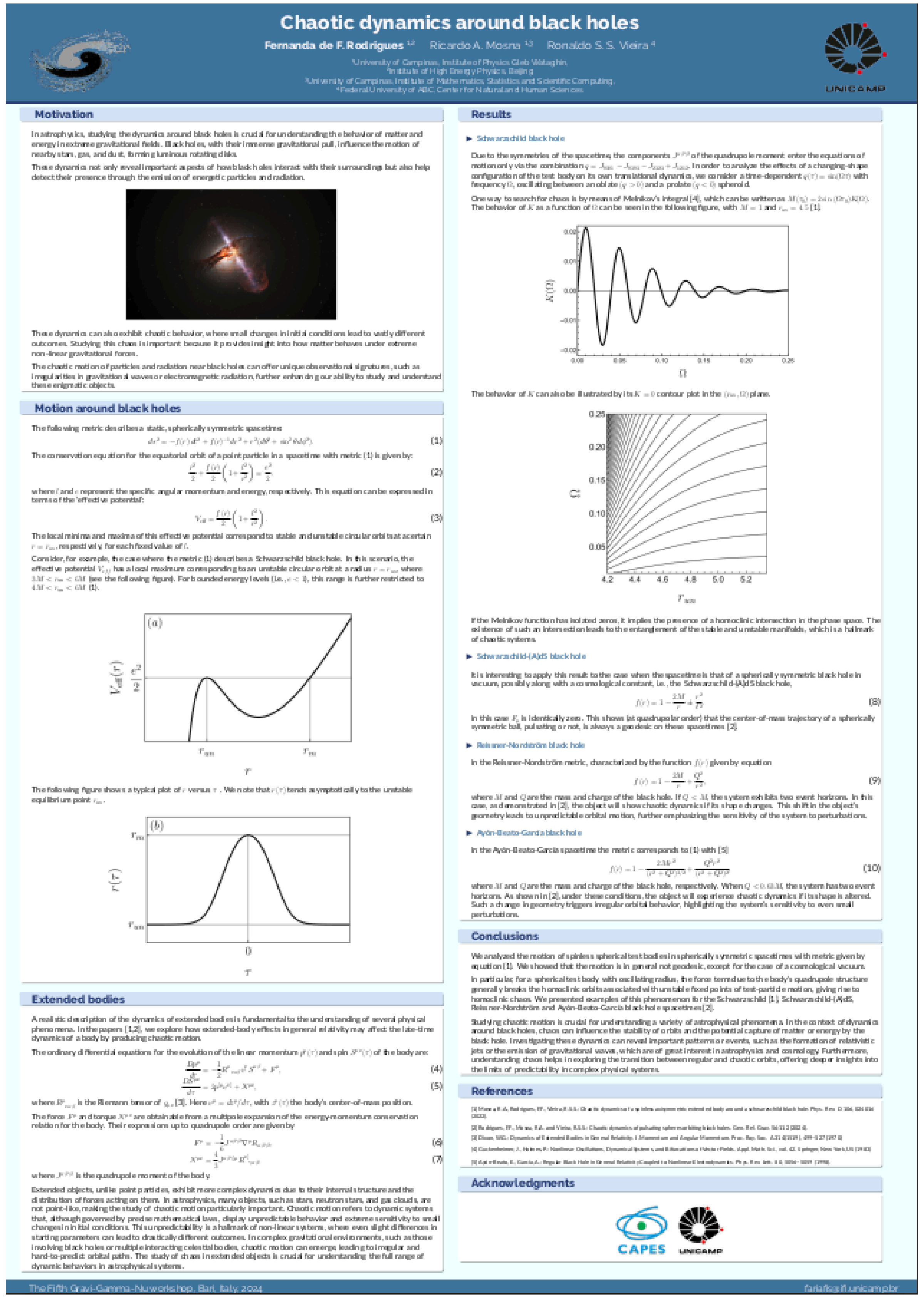


Thank you !
Grazie!