Comparison of Accretion Disks Modeled with Different Pseudo-Newtonian Potentials

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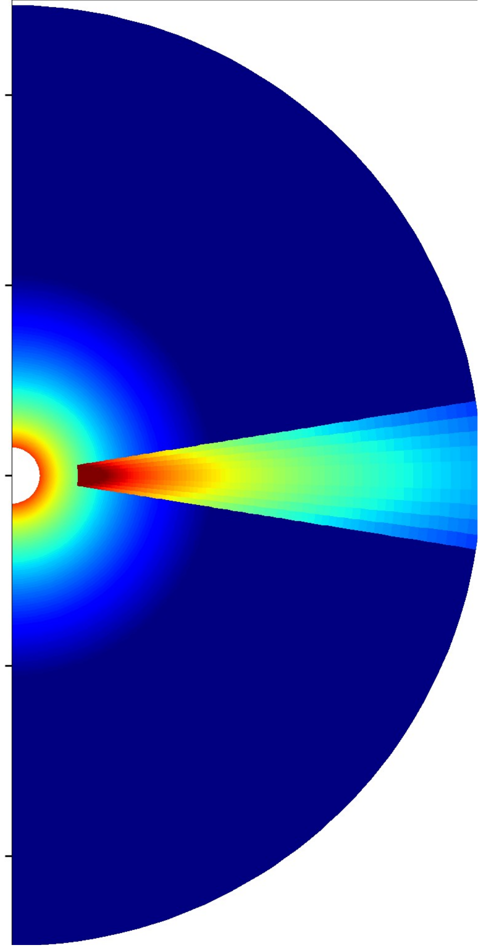
We performed **hydrodynamic simulations** with the PLUTO code (*Mignone et al. 2007*) of a thin accretion disk around two types of compact objects:

- **A Schwarzschild black hole**
- **A Reissner–Nordström naked singularity**



General relativistic effects were approximated using **pseudo-Newtonian potentials**:

- **The Paczyński–Wiita potential** (*Paczyński & Wiita 1980*)
- **The Kluźniak–Lee potential** (*Kluźniak & Lee 2002*)
- Our novel **potential for the Reissner–Nordström metric** (*Čemeljić et al. 2025*)

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Paczyński–Wiita potential (BH)

$$V_{PW} = -\frac{GM}{r - r_s}$$

Reproduces:

- The Schwarzschild Keplerian angular momentum

$$L(r) = \sqrt{\frac{GMr^3}{(r - r_s)^2}}$$

r_s = 2GM/c²

Kluźniak–Lee potential (BH)

$$V_{KL} = \frac{GM}{3r_s}\left(1 - e^{3r_s/r}\right)$$

Reproduces:

- The Schwarzschild ratio of the radial epicyclic frequency to the orbital frequency

$$\kappa/\Omega = \sqrt{1 - 3r_s/r}$$

Potential for the Reissner–Nordström metric (NkS)

$$V_{RN} = -\frac{GM}{r} + \frac{Q^2}{2r^2}$$

Reproduces:

- The orbital frequency

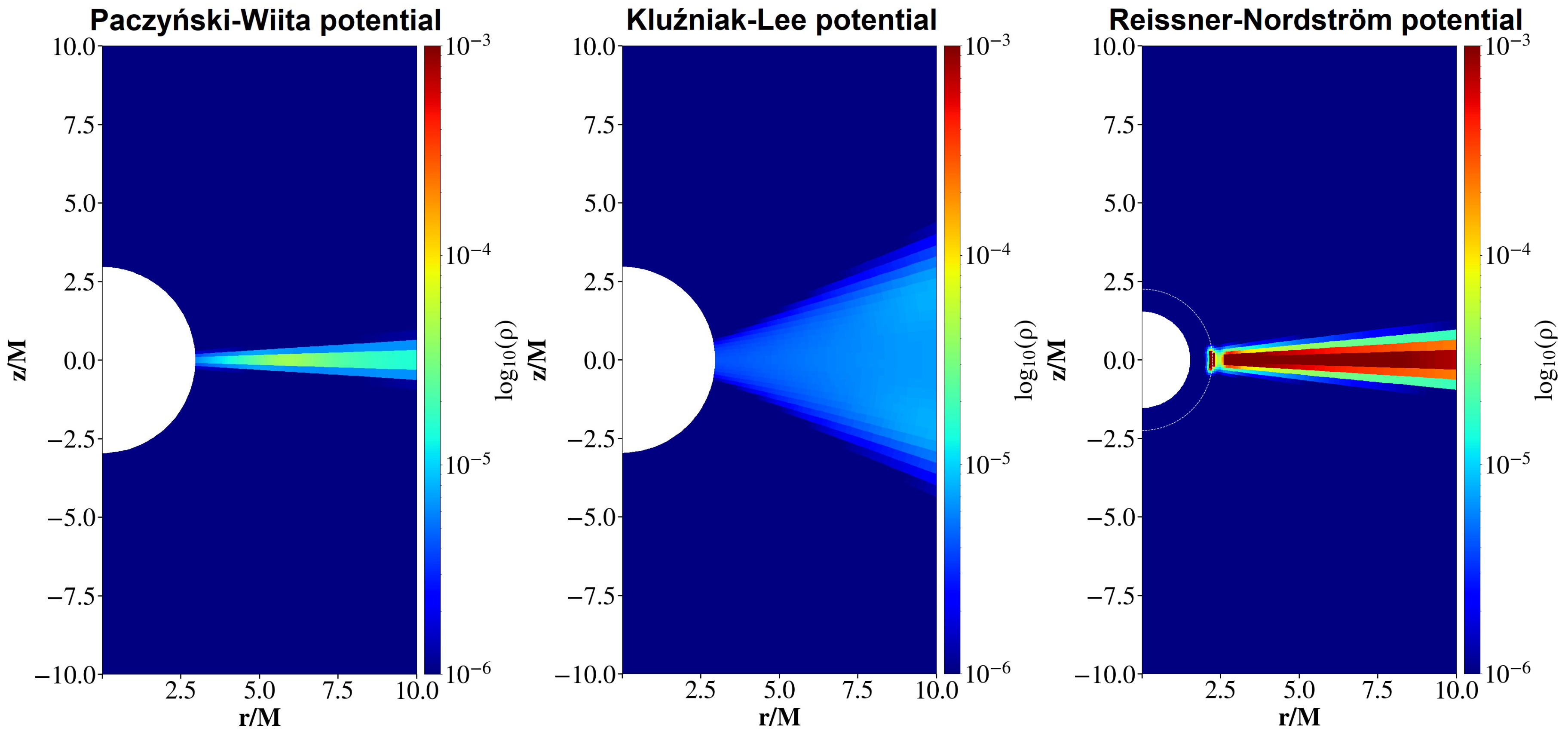
$$\Omega_{\mathrm{RN}}(r) = \sqrt{\frac{GM}{r^3}\left(1 - \frac{r_0}{r}\right)}$$

- The radius of the zero-gravity sphere $r_0 = Q^2/M$
- The radius at which the orbital frequency reaches its maximum $r_{max} = 4r_0/3$

Motivation:

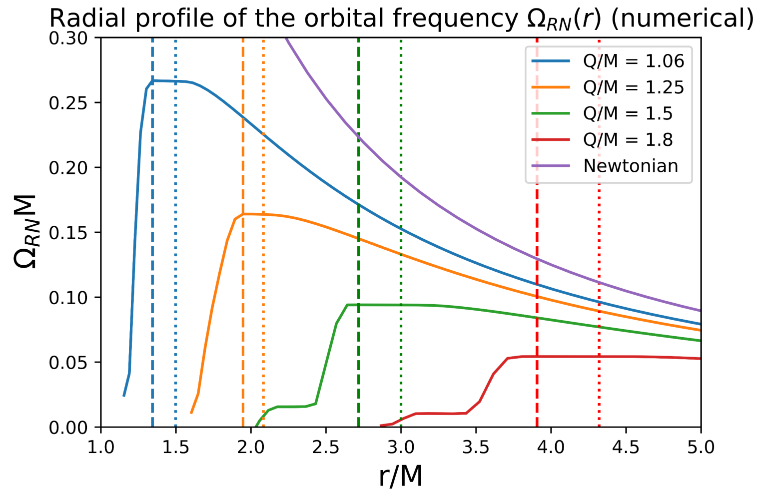
- To compare the structure of accretion disks around black holes and naked singularities to identify possibly observable differences
- To investigate the accuracy of pseudo-Newtonian potentials in reproducing key physical quantities

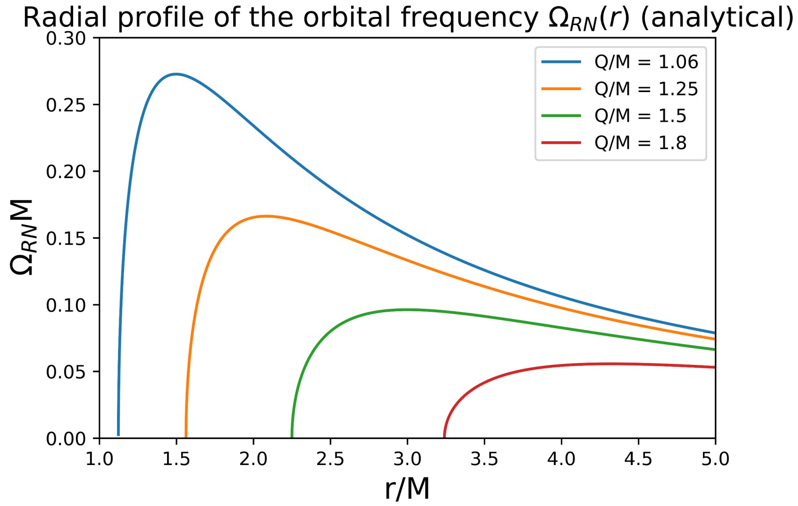
- The accretion flow exhibits different properties depending on the compact object.
- As expected, the accretion around the naked singularity halts near the zero-gravity sphere, whereas matter approaching a black hole continues to fall inward.



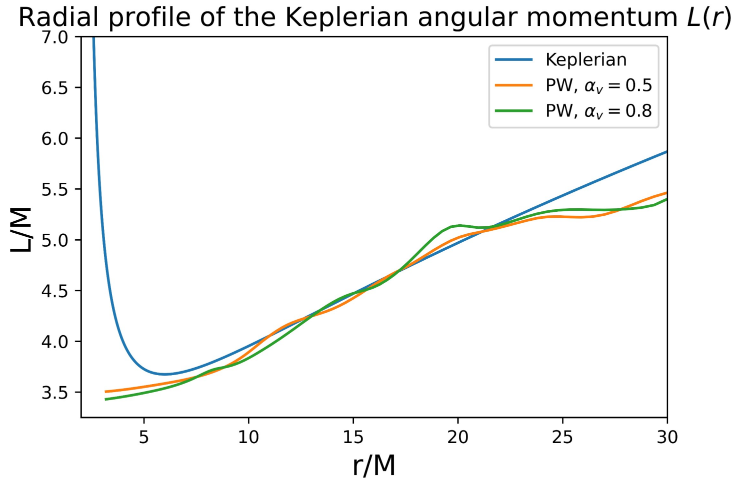
Comparison of simulation results for selected quantities with analytical solutions

The Reissner–Nordström naked singularity

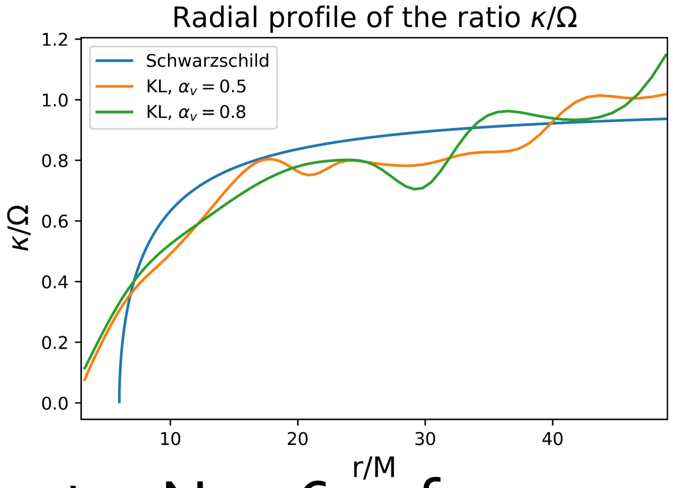




The Schwarzschild black hole modeled by the Paczyński–Wiita potential



The Schwarzschild black hole modeled by the Kluźniak–Lee potential



See the poster No.1642 for more details!