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Comparison of solutions with different pseudo-Newtonian potentials in numerical simulations of accretion disk around compact objects

I present hydrodynamic simulations of a thin accretion disk around compact objects using three different pseudo-Newtonian potentials: the Paczyński–Wiita and Kluźniak–Lee for a Schwarzschild black hole, and the newly devised potential for a Reissner–Nordström (RN) naked singularity. I study the differences between the properties of disks surrounding Schwarzschild black holes in two related pseudo-Newtonian potentials and compare the results with those for the RN naked singularity. The Paczyński–Wiita solution accurately reproduces the location of stable and bound orbits, as well as the form of the Keplerian angular momentum, while the Kluźniak–Lee potential reproduces the ratio of the orbital and epicyclic frequencies. I analyze the radial dependence of angular momentum, angular velocity, and epicyclic frequency, comparing these properties with those predicted by each pseudo-Newtonian potential. For the RN naked singularity, I consider different values of the charge-to-mass ratio, which affects the localization of orbits for test particles. Accretion around the naked singularity stops at the zero-gravity sphere, where angular velocity vanishes. Due to the effective potential, gravity inside this sphere is repulsive, causing the disk to assume a toroidal structure that encompasses the singularity, which is consistent with the analytic solution in general relativity. In the case of black holes, matter approaching the event horizon undergoes narrowing, with the disk either remaining thin for the rest of its length or thickening, depending on the chosen pseudo-potential. Unlike black holes, naked singularities in the simulations are found to be sources of outflows which, combined with the distinct geometry of the sources, may provide a valuable tool for distinguishing these compact objects in observations with facilities such as the Event Horizon Telescope.

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