Thin accretion disc in strong gravity influenced by interaction with radiation field

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ABSTRACT

Accretion structures in the vicinity of neutron stars are significantly influenced by the radiation emitted from the surface of stars and from the boundary layer. Apart from the radiation pressure, the accreted matter is also affected by the Poynting-Robertson effect, which causes angular momentum loss and therefore acts as an additional source of viscosity in the disk. Using numerical simulations, we studied the influence of the Poynting-Robertson effect on the thin accretion disks in accreting binary systems with a neutron star. In the parallelized simulation code, we implement the complete general relativistic description of the Poynting-Robertson effect. The motion of matter in the disk thus results from a complex interplay of strong gravitational field, the Poynting–Robertson effect, radiation pressure and disk viscosity. The results demonstrate that the presence of even constant star's luminosity qualitatively influences the distribution of mass density in thin disks and can create strong inhomogeneous structures of the disk.

DISK MODEL

We used a numerical model of a thin accretion disc with a constant accretion flow based on the description of collective behavior of test particles interacting with fixed strong electromagnetic radiation field emitted by a source in the close vicinity of an accreting compact object. We study a time evolution of the accretion disc on the background of the axially symmetric Kerr metric with spin *a*.

The source of radiation may be a neutron star surface, a boundary layer of a neutron star or a corona of a black hole. We assume that scattering of radiation as well as the momentum-transfer cross section σ (assumed to be a constant) of the test particle is independent of the direction and frequency of the radiation, which corresponds to the mechanism of Thomson scattering. Therefore, the key components of the model are fully relativistic equations of motion for the test particles influenced by the interaction with the radiation field (see [1] and [2]) and their numerical integration. We also include semianalytically the standard Shakura-Sunyaev model with α prescription (Shakura and Sunyaev 1973). The chosen hybrid approach allows us to model the time dependent radial optical depth as well as the penetration of the radiation field into the disc matter.

The boundary separating the inner part of the disk primarily influenced by the interaction with the radiation field and the outer part which maintains the quasi-Kepler behaviour is the Poynting-Robertson radius R_{PRE}.

Prtrajectories code integrates trajectories up to millions of test particles in modeled area of a thin disc defined by radial coordinates of inner and outer edge R_{outer} and R_{inner}. We use OpenMP library for the massive parallelization of the integration by the method of symmetric multiprocessing with shared computer memory. The code is able to process also simulations with variable relative luminosity *L(t)* which in principle does not have to reach any quasi-stationary state. The code is also able to trace trajectory of single test particle.

The model allows study a thin accretion disk whose inner edge is exposed to the flux from a central radiation source. Althought the structure of the accretion disc is significantly disordered by the radiation and the Poynting-Robertson effect, the disc can still reach a new quasi-stable state with new properties.

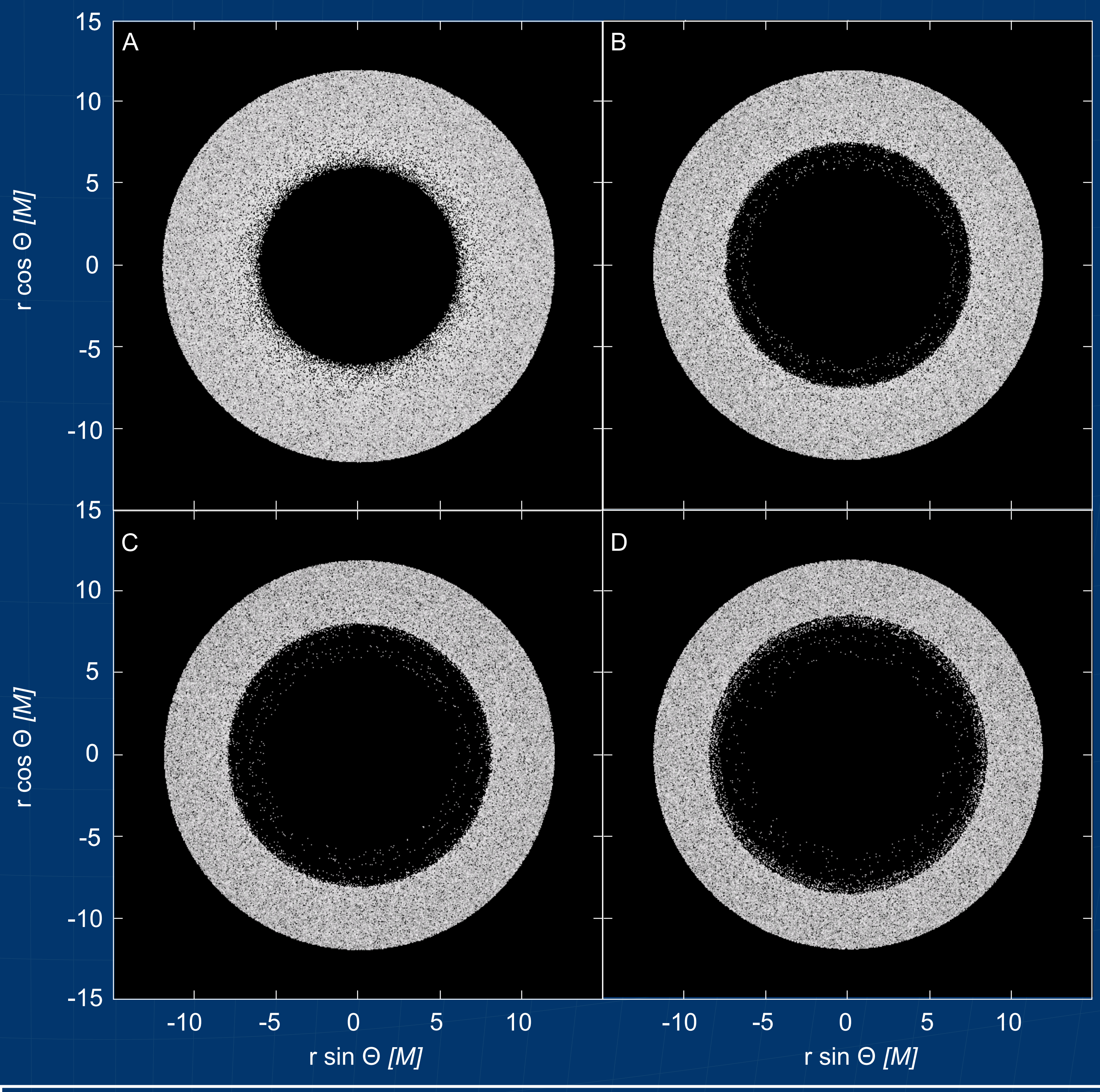

Figure 2: **Accretion disc evolution.** L = 0.01, a = 0.0, α = 0.01, M = 1.5 $M_{\odot}$
Test particle distribution at = 93.0 ms (A), 117.0 ms (B), 139.6 ms (C), 156.9 ms (D). The distribution corresponds to stable state of the disc. The outer region correspond to quasi-keplerian Shakura-Sunyaev disc while the inner parts are disturbed by the radiation pressure and the Poynting-Robertson effect. The border of these two areas is the R_{PRE}, in this case R_{PRE} = 9.85 M.

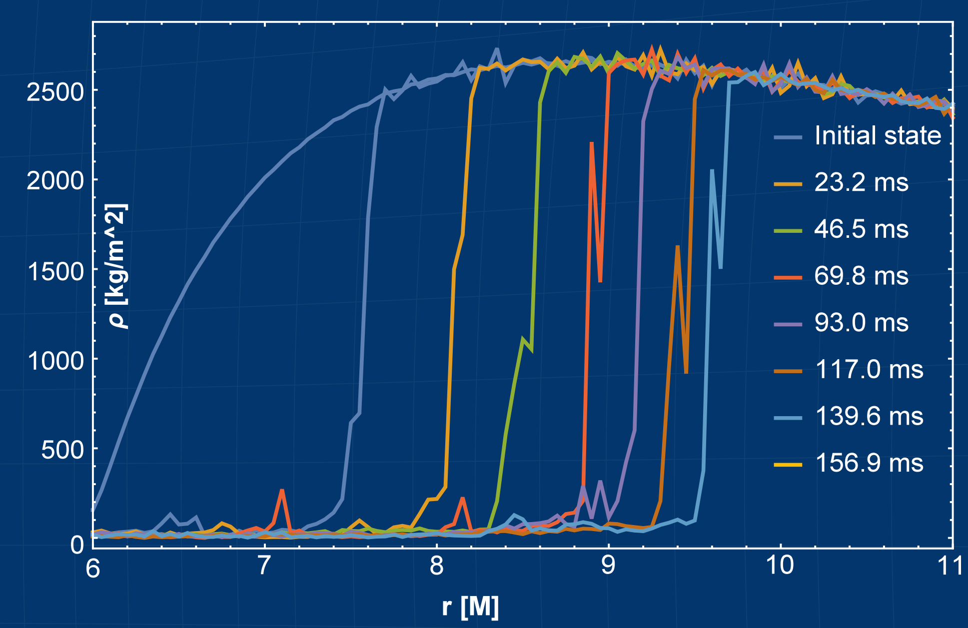

Figure 3: **The time evolution of disk density profile.** L = 0.01, a = 0.0, α = 0.01, M = 1.5 $M_{\odot}$. In the profile are visible peaks of density, which are one of the most prominent consequence of Poynting-Robertson effect. We can find a „loops" in the time evolution of radial component of 4-velocity of test particle. The particles then stay longer on some radii and this creates peaks in density profile. This effect is not clearly visible from Fig. 2 because the diference between the density of quasi-keplerian area and PRE area is very high.

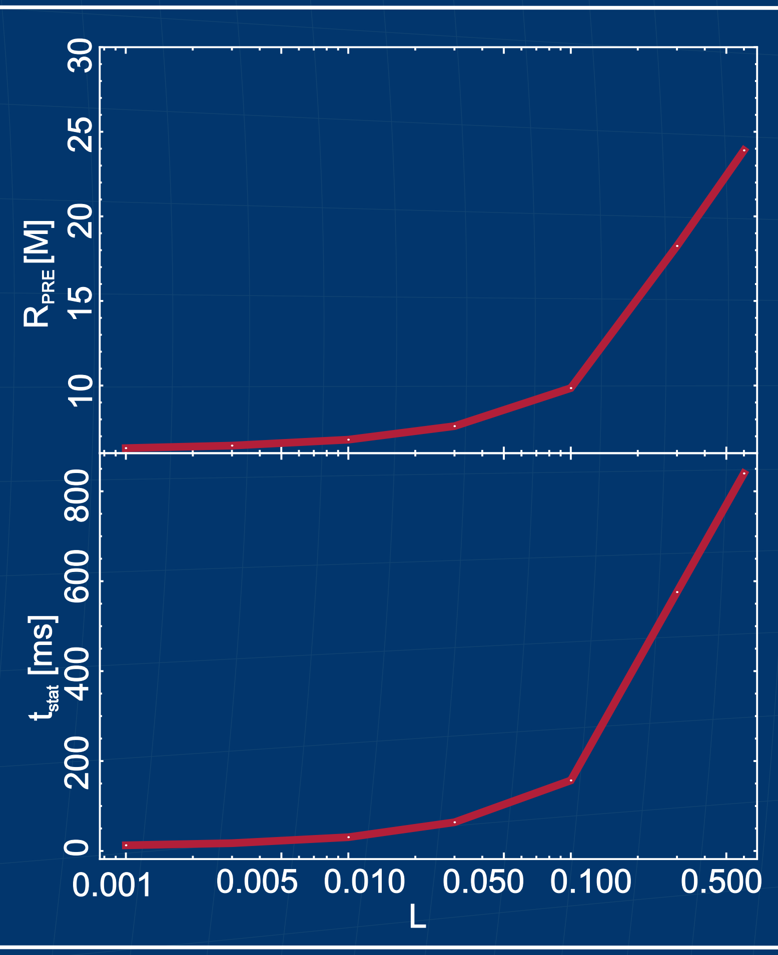

Figure 1: **Final states of Schwarzschild configurations** (a = 0.0) with α = 0.01. Top panel: PRE radius as a function of the luminosity L. Bottom panel : t_{stat} as a function of the luminosity L.

Simulation parameters							Output values	
L	a	α	M [M_{SUN}]	Δt [μs]	R_{inner}[M]	R_{outer}[M]	R_{PRE}[M]	t_{stat}[ms]
0.1	0.0	0.01	1.5	22.1	6.0	12.0	9.85	156.9
0.01	0.0	0.01	1.5	22.1	6.0	12.0	6.8	30.6
0.03	0.0	0.01	1.5	22.1	6.0	12.0	7.6	63.8
0.001	0.0	0.01	1.5	22.1	6.0	8.0	6.3	12.6
0.003	0.0	0.01	1.5	22.1	6.0	8.0	6.45	17.3
0.01	0.5	0.01	5.0	73.9	4.233	8.0	4.683	15.3
0.01	0.9	0.01	5.0	73.9	2.321	8.0	2.478	6.0
0.01	0.0	0.001	1.5	22.1	6.0	12.0	7.75	48.5
0.01	0.0	0.1	1.5	22.1	6.0	8.0	6.3	10.6

Table 1: The summary of simulations results.

REFERENCES

The poster is based on a paper of Bakala et al., to be published in 2018
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