Magnetic islands & flux ropes

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Outline of 2020

- Chinese 8 months: General Relativity MHD Athena++ simulations in 3D; lectures “Introduction to PLUTO code”
- Two long-term projects finished (with simulations using the PLUTO code)
- Students’ year

Athena++ code, GRMHD simulations, initial conditions

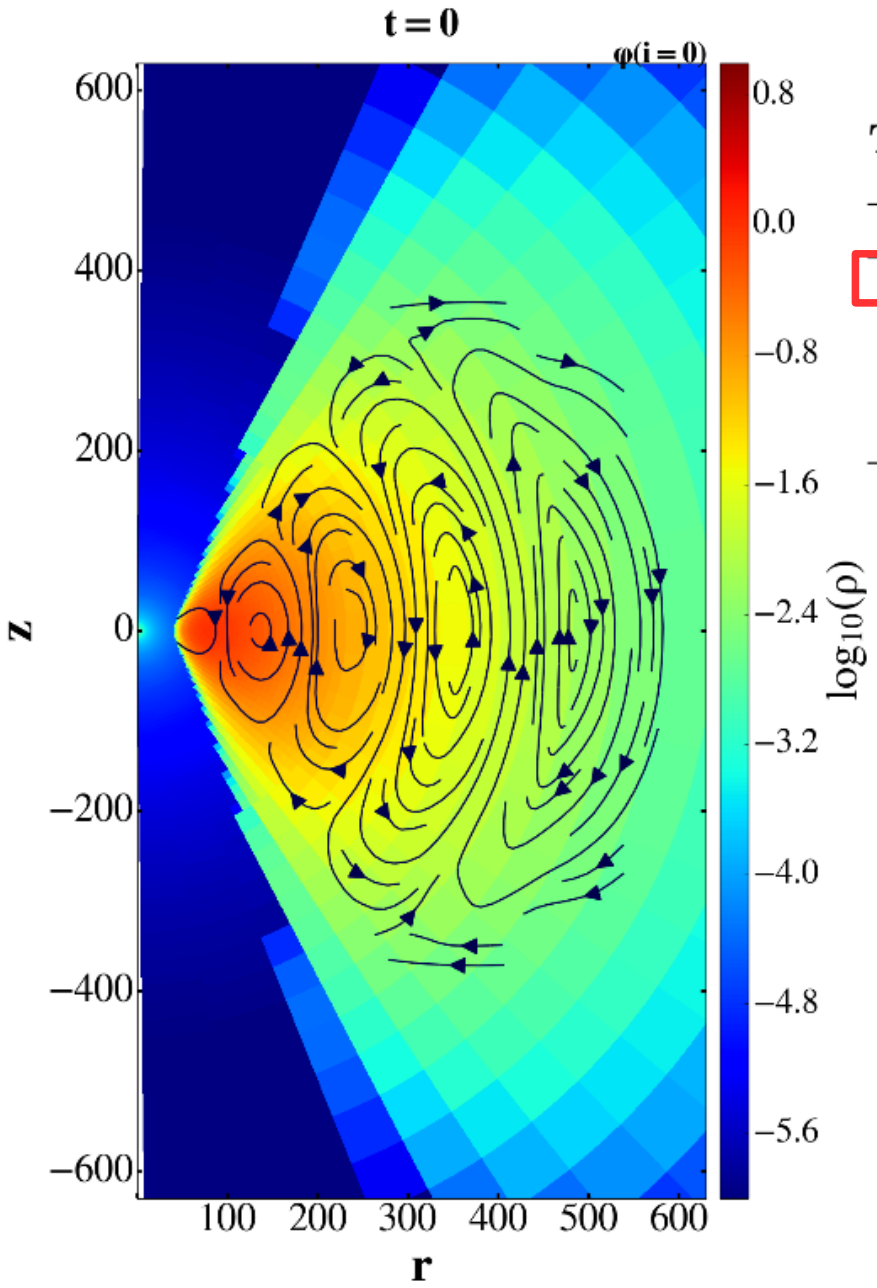
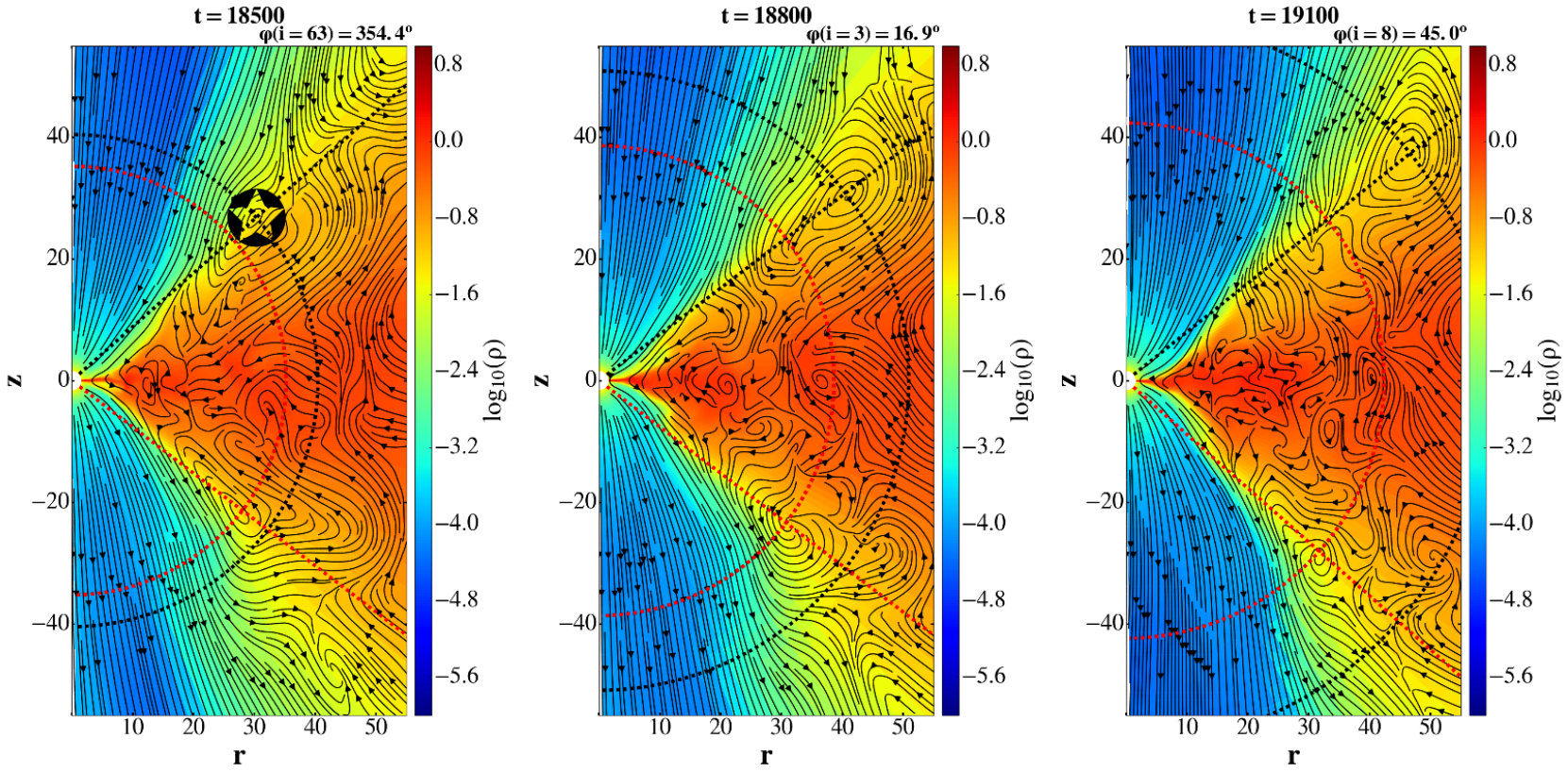


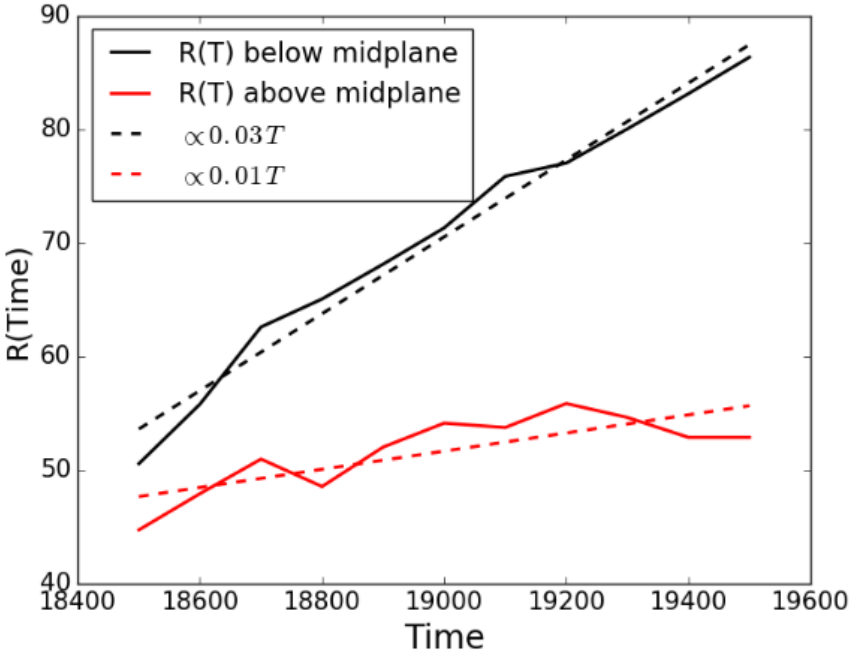
Fig. 1. Density in a logarithmic colour grading and a poloidal magnetic field contained inside the torus around a black hole in our SANE setup. Loops of poloidal magnetic field are shown with solid lines, with arrows showing the clockwise and counter-clockwise direction of the initial loops of magnetic field.

Table 1. Parameters used in different cases in our simulations.

Model	a	β_{min}	N_r	N_θ	N_ϕ	*Duration*
SANE00	0	0.05833	288	128	64	40000
MAD00	0	0.1	288	128	64	40000
SANE98	0.98	0.03	352	128	64	40000
MAD98	0.98	0.1	352	128	64	40000

Motion of magnetic islands in SANE00 case

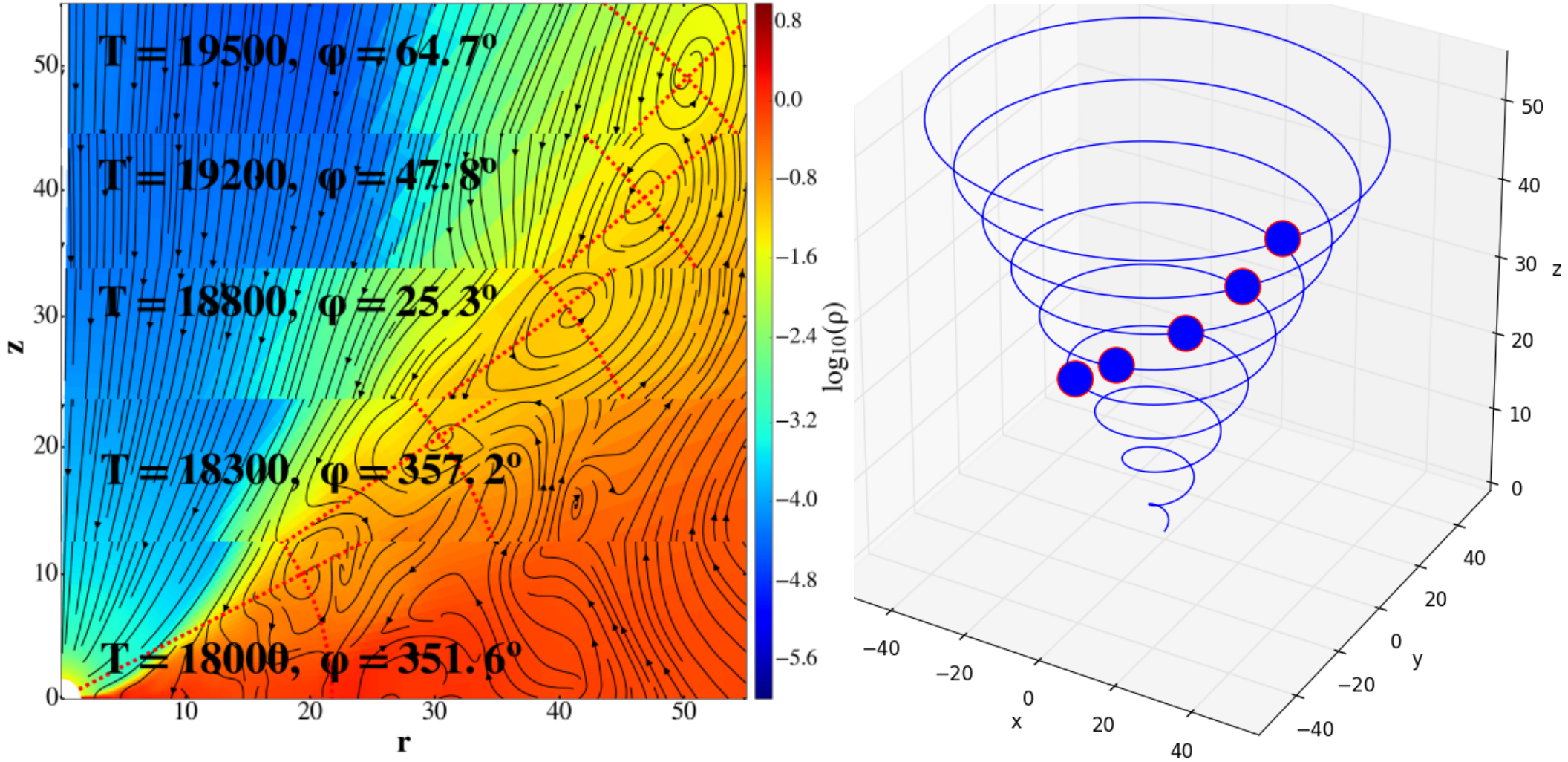




-Snapshots at three different times in our simulation, showing density in logarithmic colour grading, overplot with poloidal magnetic field lines, with arrows showing the direction of the poloidal magnetic field. The dotted black and red lines are r = const lines passing through the centers of two magnetic islands. We describe the magnetic islands motion by tracing the positions of their centres. A star mark in the left panel denotes a magnetic island above the equatorial plane.

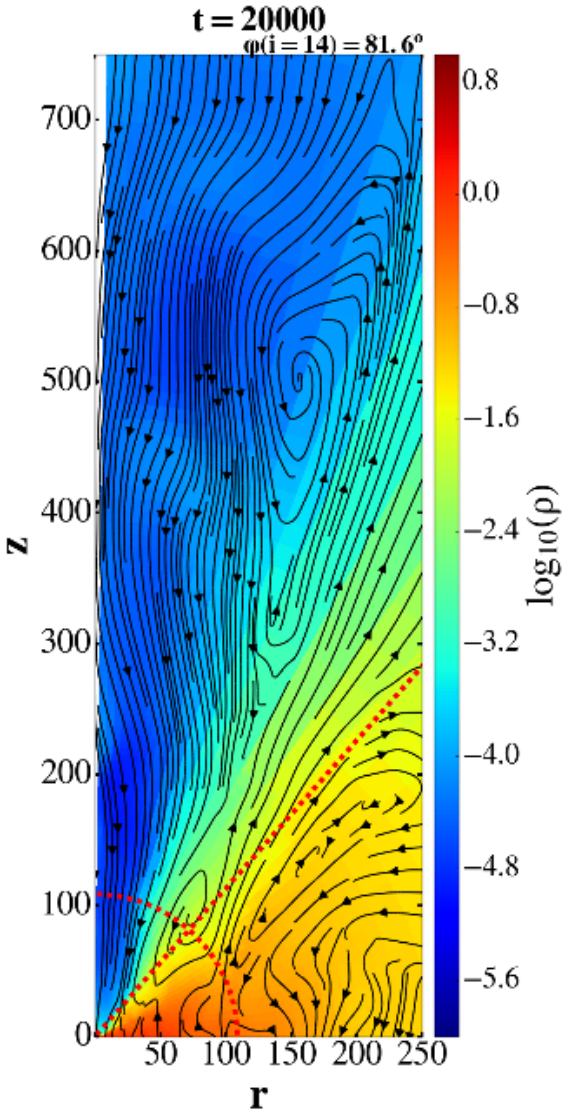
-Time dependence of the positions of the magnetic islands above (red) and below (black) the equatorial plane of the accretion flow shown in Fig. 3. The dashed lines are least square fits, slopes of which are about 0.01 and 0.03 for the red and blue lines, respectively.

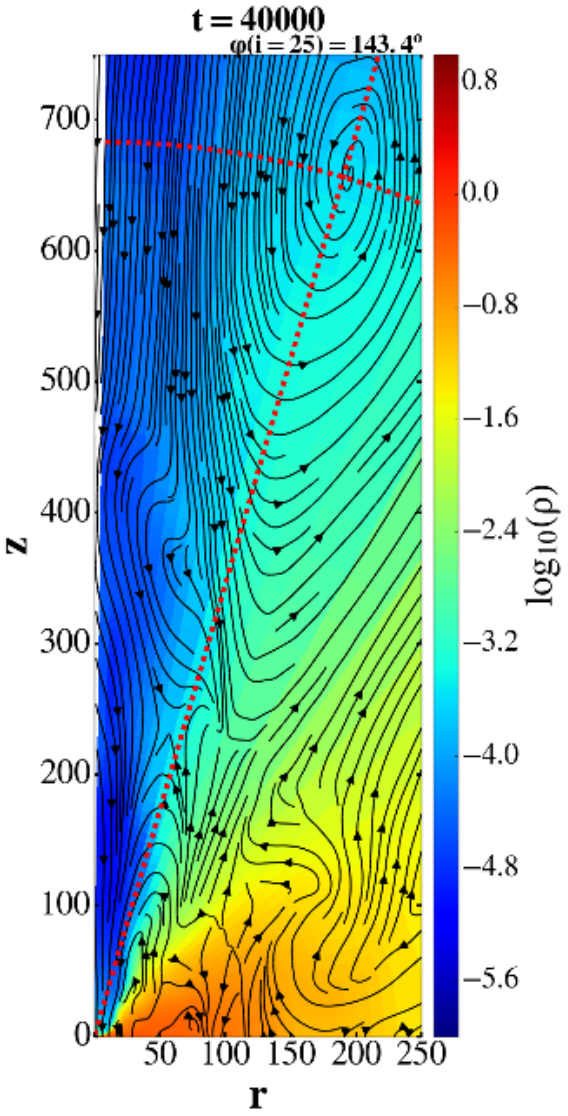
Spiraling-out of the flux ropes

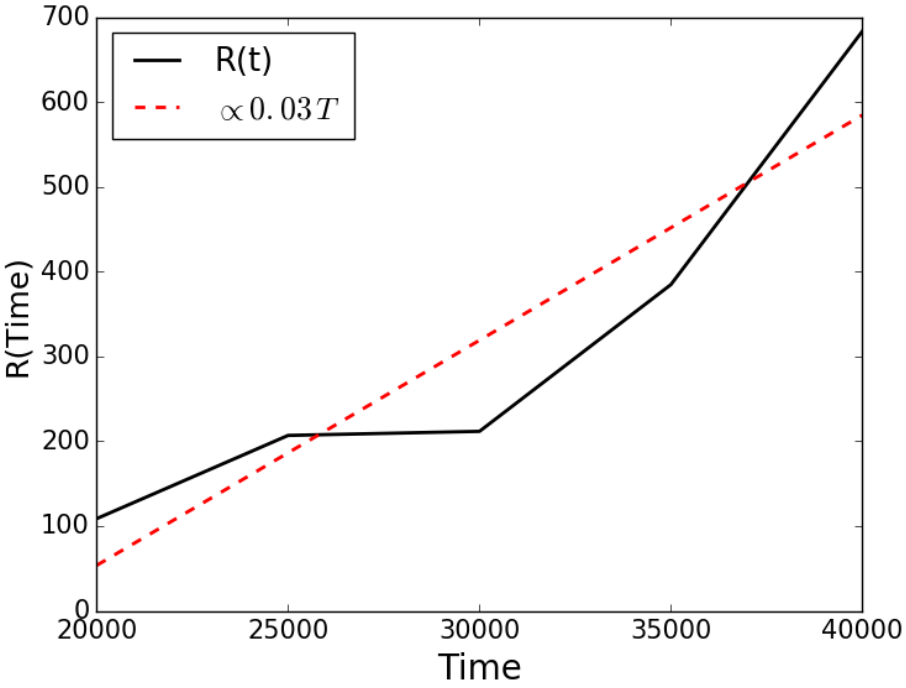


•Magnetic islands are slices at different times crossing the middle of the flux rope in our simulation (left panel). The distance from the origin is increasing in time. The angle φ of the colatitudinal plane in which the middle of the flux rope is positioned, is also increasing with time and given in the figure. The flux rope is spiraling away from the black hole, as shown in the 3D schematic plot (right panel) depicting the trajectory of its center.

Ejection of the flux ropes

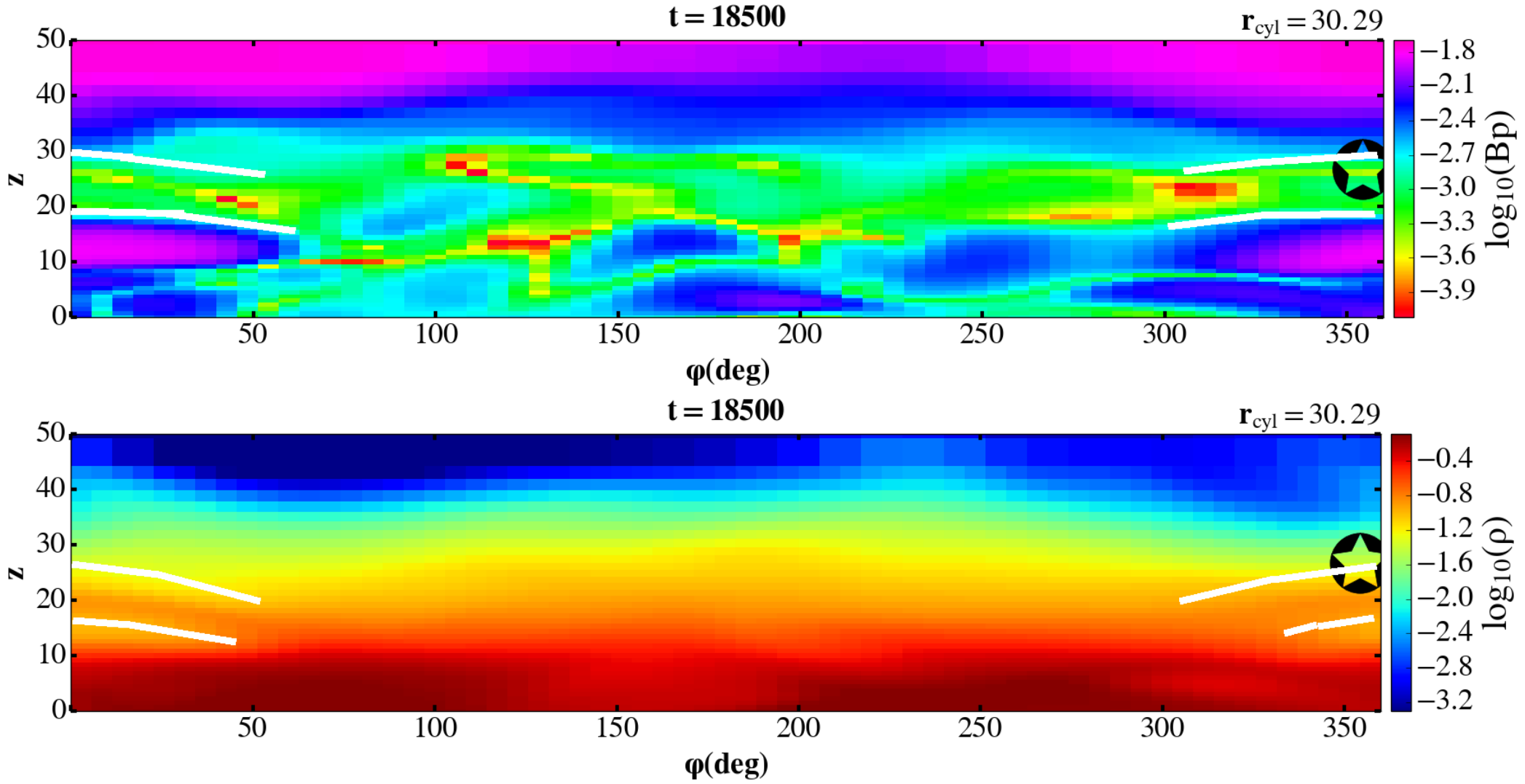






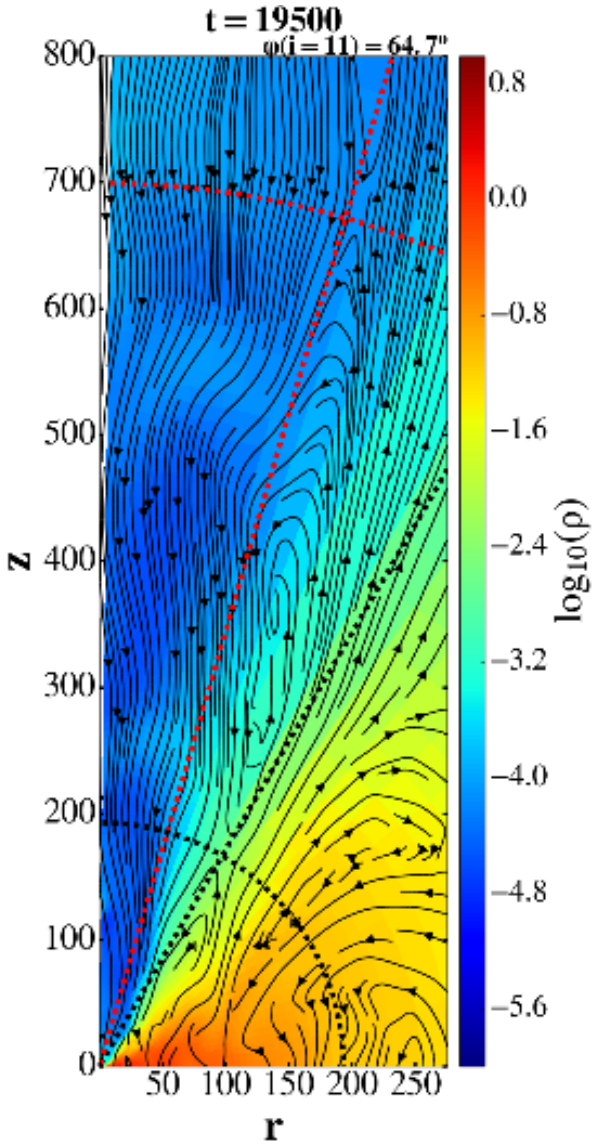
•Slices at different azimuthal planes at times T=20000 and T=40000, during the ejection of the flux rope in the corona. We describe the motion of the flux ropes by following the positions of their centers in such slices.

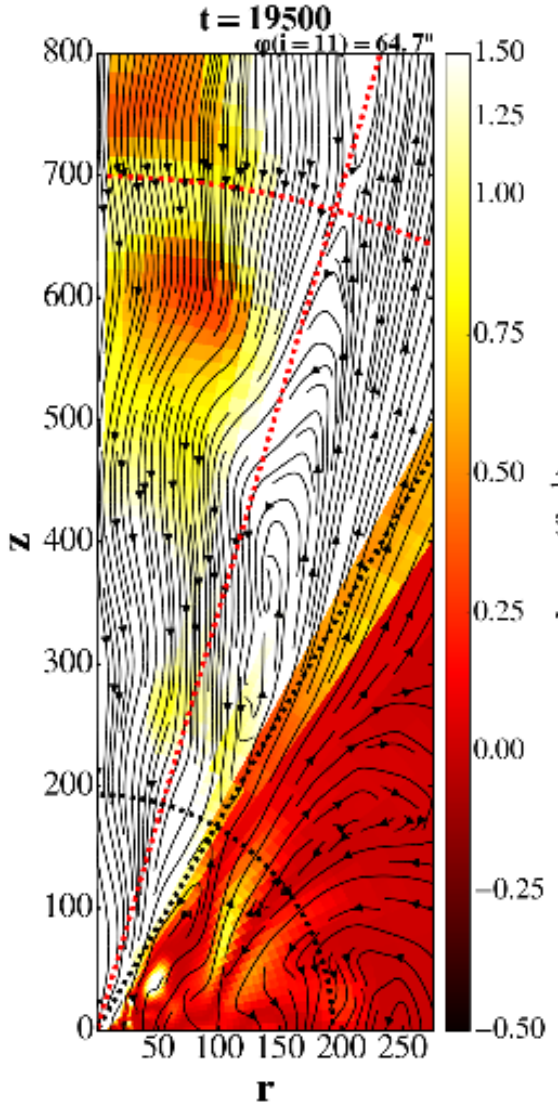
Ejection of the flux ropes



•*Top panel*: The distribution of the poloidal magnetic field strength in the φ − z plane with a constant cylindrical radius r cyl above the equatorial plane at T = 18500 r_g /c. A star mark corresponds to the position of the magnetic island from Fig. 3 at the same time. We trace the minima of the poloidal magnetic field, showing a slice through the azimuthal extensions of the magnetic islands–which would be seen as flux ropes. Parts of the arcs of the flux ropes lie in this plane. *Bottom panel*: Distribution of density in the same φ − z plane. A local increase of density, by an order of magnitude, along the flux rope profile corresponds to the positions of minimum Bp in the azimuthal direction. Flux ropes are visible in both panels.

Motion of the reconnection layers





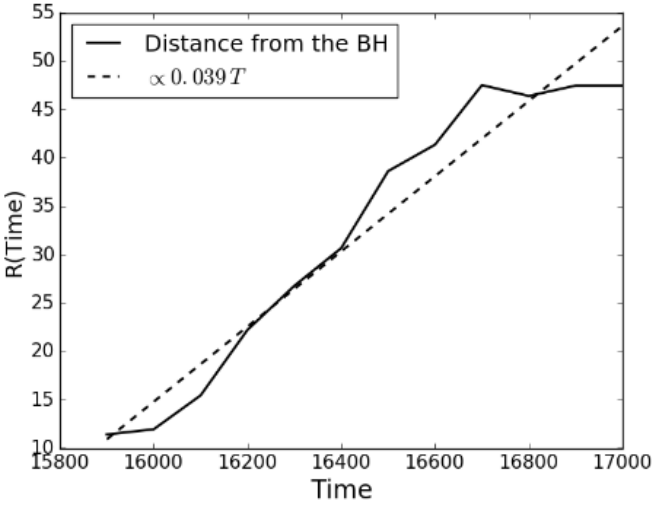


Fig. 15. Radial distance of a reconnection layer, followed along its trajectory from the vicinity of the central body is shown with the solid line. Slope of the least squares fit, depicted with a dashed line, gives the average velocity of 0.039 c. It is of the same order as the velocity of the magnetic islands.

•Reconnection layers are clearly visible in the snapshot at T=19500 in our simulation along the disk boundary, where the flux rope emerges. In the left panel are shown the poloidal magnetic field lines with density in logarithmic colour grading as a background, and in the right panel the background is plasma β. With red and black dotted lines are shown the coordinate lines, along which we compute the physical quantities.

Completing long time projects

1 2021MNRAS.500..506V 2021/01

Inner dusty regions of protoplanetary discs - II. Dust dynamics driven by radiation pressure and disc winds

Vinković, Dejan; Čemeljić, Miljenko

2 2020arXiv201213194M 2020/12

Backflow in simulated MHD accretion disks

Mishra, Ruchi; Čemeljić, Miljenko; Kluźniak, Wlodek

3 2020arXiv201200916C 2020/12

Flux ropes in SANE disks

Čemeljić, Miljenko; Yuan, Feng; Yang, Hai

4 2020past.conf..275K 2020/10

Asymmetric Jet launching

Kotek, Aleksandra; Čemeljić, Miljenko; Kluźniak, Włodek *and 1 more*

5 2020past.conf..204J 2020/10

Towards pseudo-Newtonian black hole jets: comparison of forces

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Transport of dust grain particles in the accretion disk

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The tool DUSTER for computation of dust trajectories in a protoplanetary disk

Turski, Cezary; Jaros, Robert; Čemeljić, Miljenko *and 3 more*

9 2020MNRAS.491.1057C 2020/01

Light-curve variation caused by accretion column switching stellar hemispheres

Čemeljić, Miljenko; Siwak, Michał

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Thank you!