Magneto-hydrodynamical simulations of sub-parsec circumbinary discs

1 Initial conditions

In this section we describe the initial conditions.

We model our system using a modified version of the smoothed particle hydrodynamics (SPH) code gadget-3, which is an improved version of the public code gadget-2 (Springel 2005). We are simulating the same system described in Cuadra et al. (2009), with the binary with initially mass ratio of $q = 1/3$ and with circular orbit. The initial mass of the disc is $M_{\rm d} = 0.2 M_{\rm bin}$. The initial conditions are set such as the gas is located from $r_{\rm in} = 0.2a$ to $r_{\rm out} = 0.5a$, where a is the binary semi-major axis (Fig. 1). However, we want to avoid spurious growth of the magnetic field due to steep gradients and the violent initial evolution of the disc, therefore we use as initial condition a system that is already in a quasi-steady equilibrium. We start with a system that is already evolves for 500 dynamical times ($250/\pi$ orbits), as the one shown in Fig. 2.

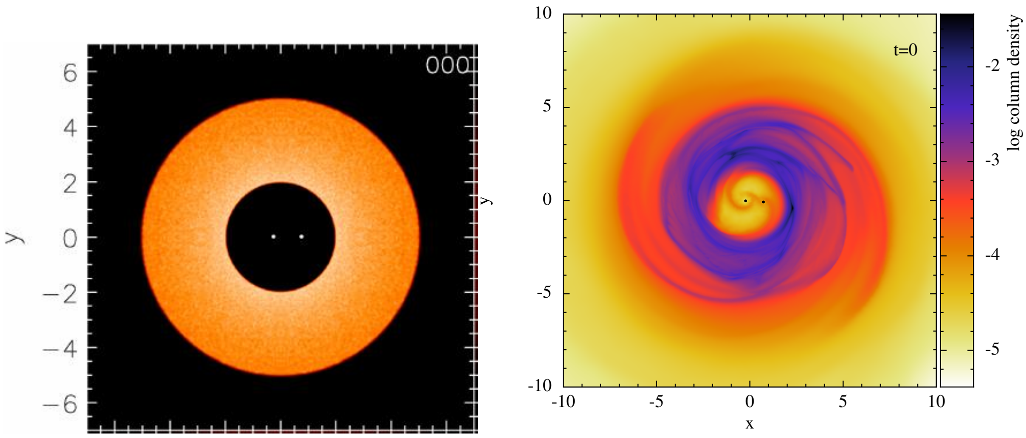

Figure 1: Left: Face-on view of the disc at $t = 0$. Right: Face-on view of the disc we use to seed the magnetic fields, shown as a column density map. The black dots show the position of the two SMBHs.

We study three distinct domains: the cavity ($r < 2$), the disk ($2 < r < 7, |z| < 1$) and the outside ($r > 2, |z| > 1$) (Fig. 3).

We performed a control hydrodynamical run (CON) and a run with magnetic field (MHD) until $t = 350$. We evolved hydrodynamic (CON) and magnetohydrodynamic (MHD) adimensional equations with Gadget. The dimensionalization is given by $l_0 = 1.2\ 10^{17}\,\text{cm} = 3.9\,\text{pc}$, $m_0 = 6.97\ 10^{39}\,\text{g} = 3.5\ 10^6\,\text{M}_\odot$, $v_0 = 6.23\ 10^7\,\text{cm/s} = 623\,\text{km/s}$, $t_0 = 61\,\text{yr}$, $\rho_0 = m_0/l_0^3 = 4.03\ 10^{-12}\,\text{g/cm}^3$.

2 Dynamics

In Figures 3 and 4, we compared the temporal evolution of the temperature (T), kinetic energy ($E_{\rm kin}$), internal energy ($E_{\rm int}$) and total energy ($E_{\rm tot} = E_{\rm kin} + E_{\rm int} + E_{\rm mag}$) densities for both runs, inside and outside of the disk.

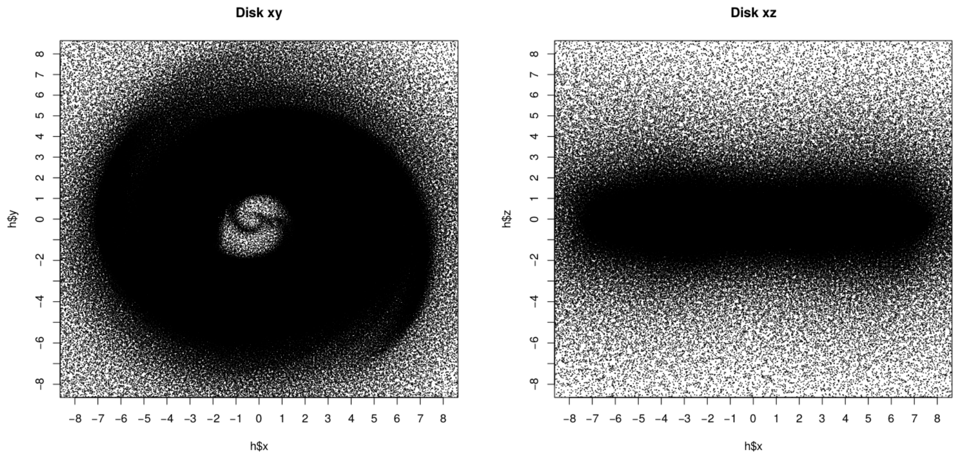

Figure 2: Face-on and Edge-on views at $t = 0$.

We plot the magnetic energy in figure 5 and all energy densities in figure 7, inside and outside of the disk for MHD run.

In Figure XX we plot the particle number in each zone.

In Figure YY we plot the evolution of the radial (B_r), toroidal (B_ϕ) and longitudinal (B_z) components of the magnetic energies in cavity, inside disk and outside disk regions.

3 Clumps

In this section we analyzed the behaviour of the clumps.

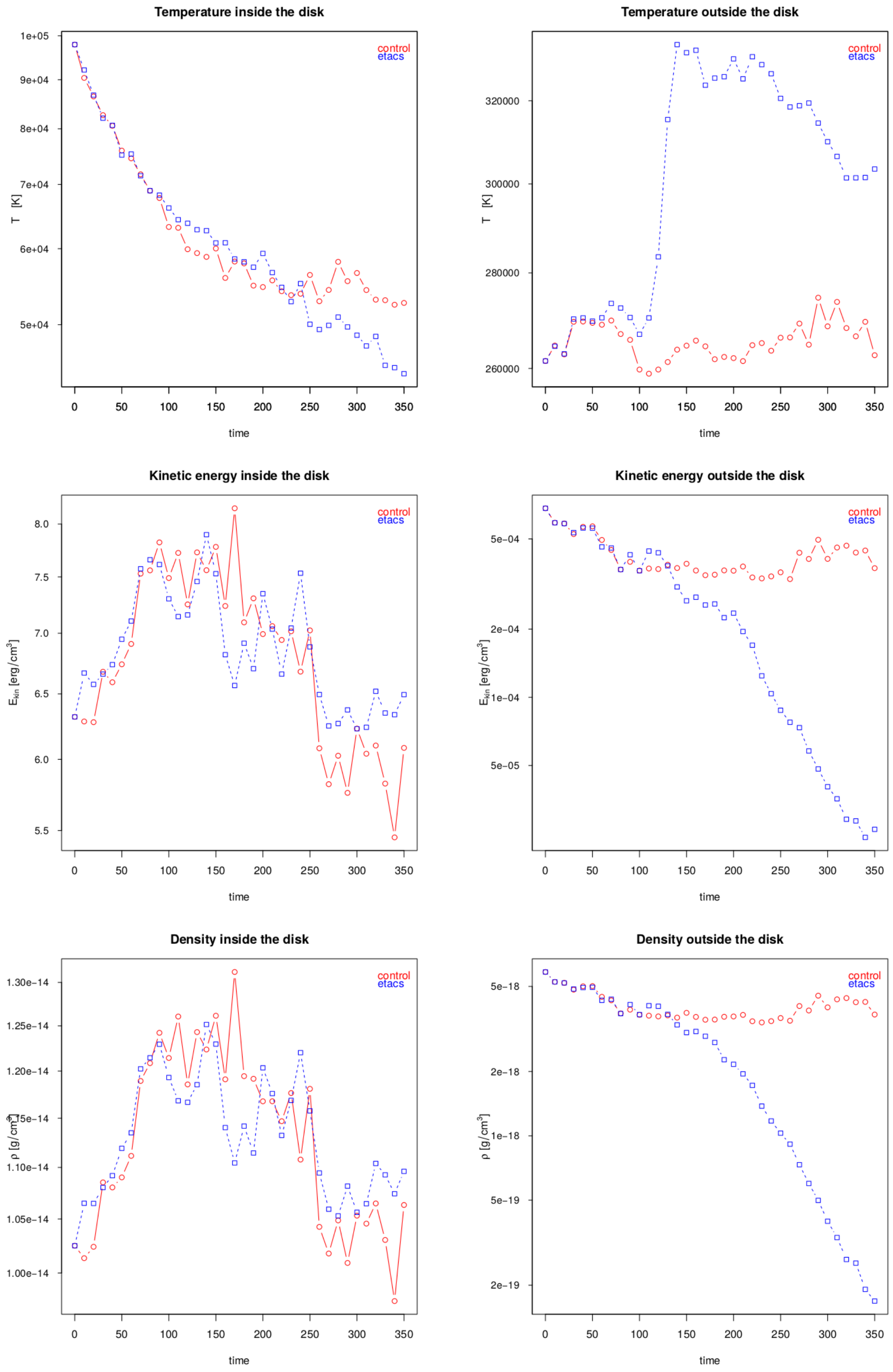

Figure 3: Temperature, kinetic energy density and number density inside and outside of the disk.

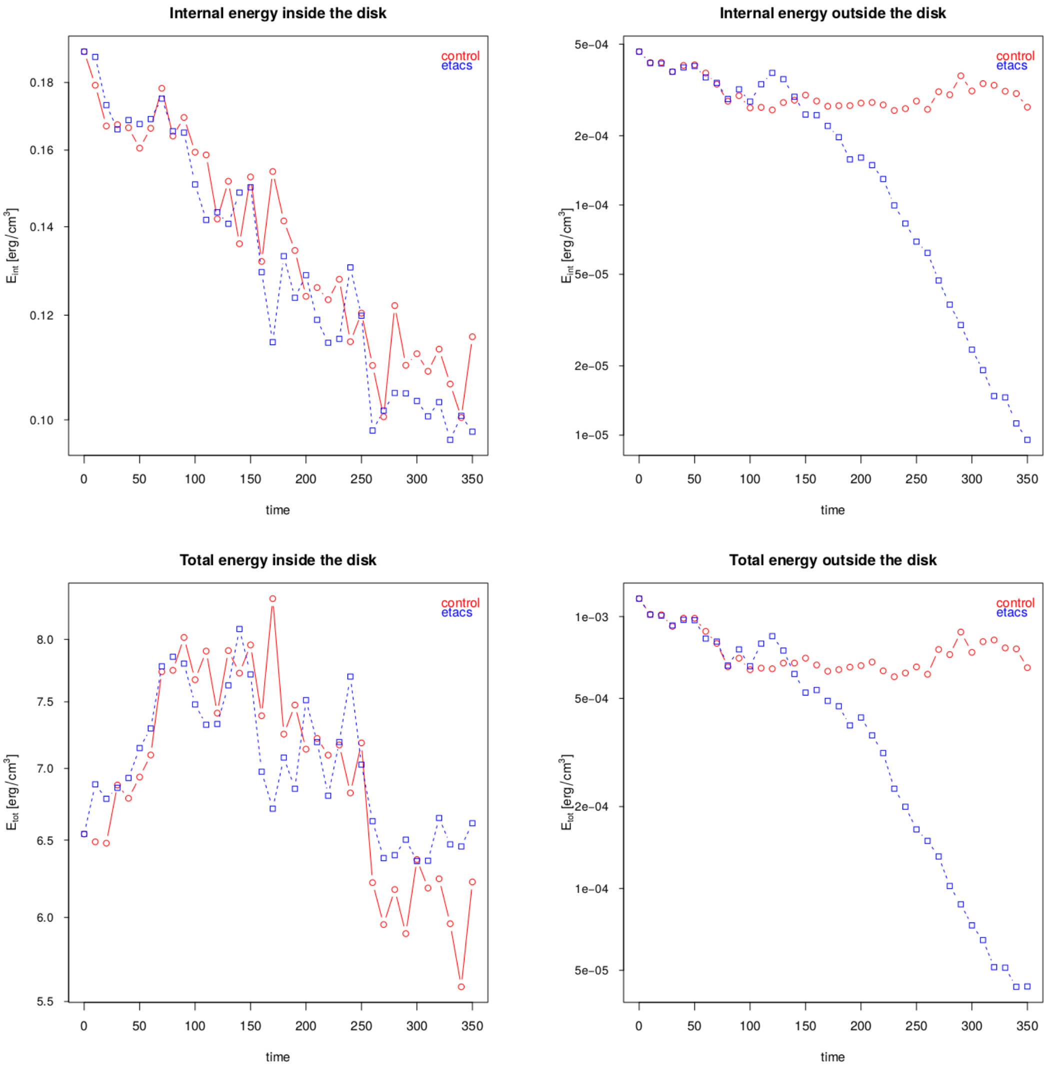

Figure 4: Internal energy and total energy density inside and outside of the disk.

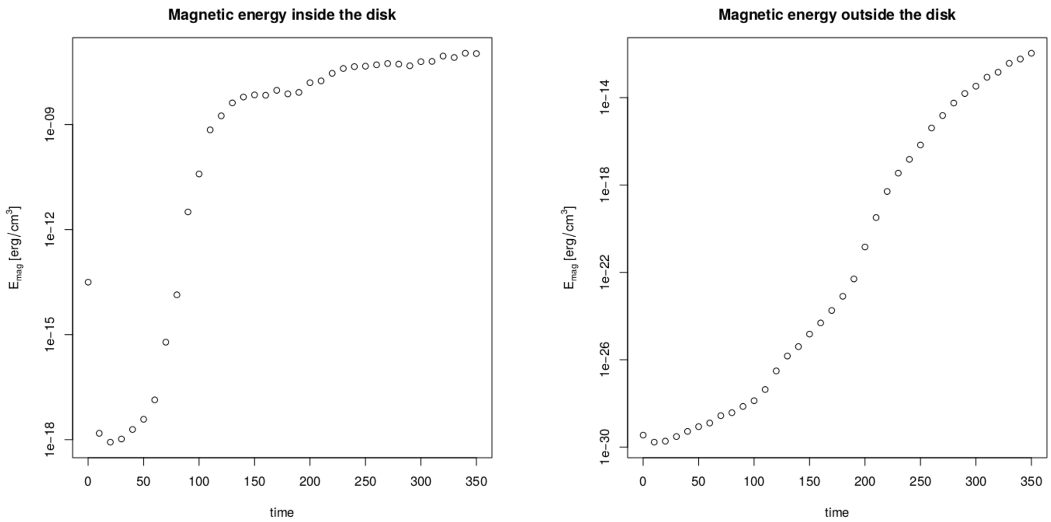

Figure 5: Magnetic energy density inside and outside of the disk.

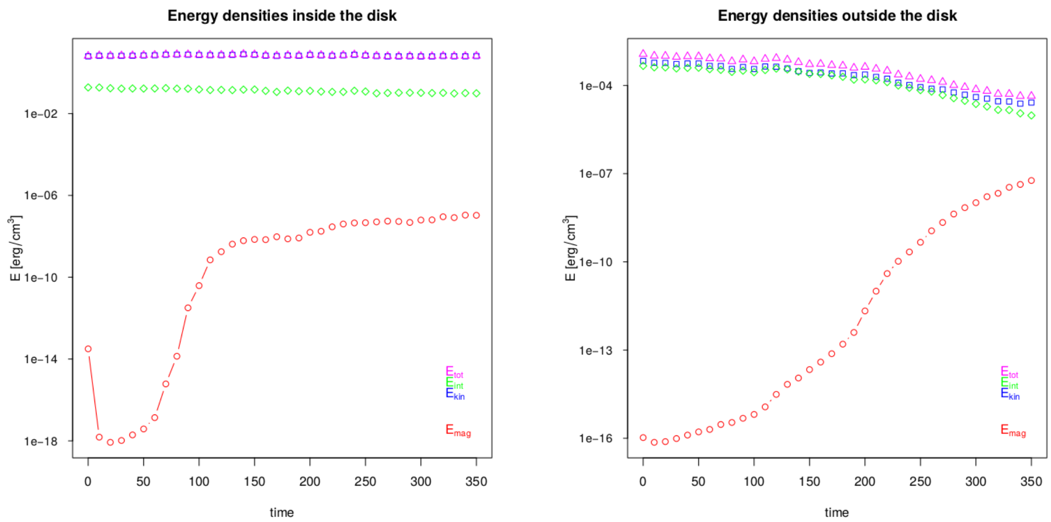

Figure 6: Energy densities inside and outside of the disk.

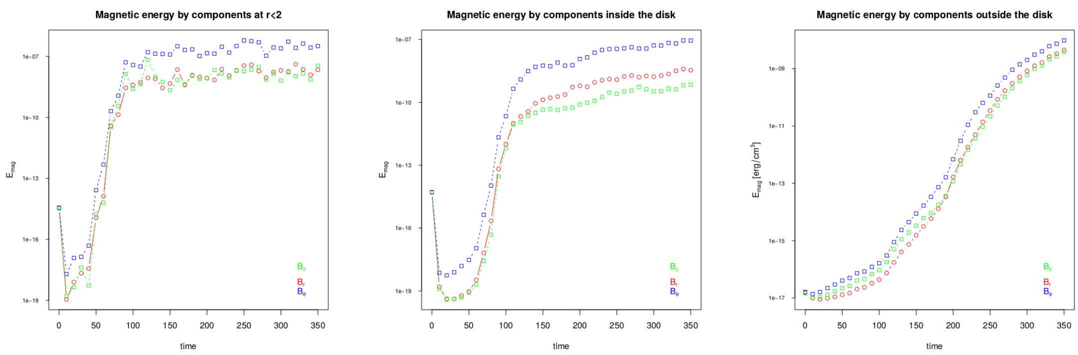

Figure 7: Magnetic energy by components in the cavity (left panel), inside disk (middle panel) and outside disk (right panel) regions.