Simulated outflows from accreting magnetized white dwarfs

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We perform self-consistent numerical simulations of star-disk magnetospheric interaction assuming beta-viscosity accretion disks, as well as alpha-disks. For a range of parameters we obtain steady accretion and characteristic outflows at mid-latitudes. We compare these outflows launched from the innermost white dwarf magnetosphere for the two viscosity prescriptions. The results may be relevant to symbiotic stars in which white dwarfs are capturing material from a red giant star, for which occasional outflows are usually transient and coincide with optical outbursts.

Introduction:

Outflows are observed in a small fraction of the symbiotic stars (SSs), close binaries containing white dwarf orbiting a red giant star. Magnetospher interaction of the stellar and disk magnetic field in the closest vicinity of the white dwarf results in the launching of outflows. In the SSs outflows are usually transient and coincide with optical outbursts. Solutions of the 3D hydrodynamical model of thin accretion disc were derived analytically in Kluźniak & Kita (2000, hereafter KK), and a magnetic extension of this solution is given in Čemeljić et al. (2023). An extensive parameter study was performed in Čemeljić (2019) and Čemeljić & Brun (2023) for slowly rotating stars (up to 20% of the stellar breakup rotation rate) with different magnetic field strengths and disk resistivities, assumin the α-ansatz for anomalous viscosity and resistivity, which scales with the disk height and sound velocity. The results match with solutions from Romanova et al (2009) and Zanni & Ferreira (2009, 2013). In some of the cases, launched outflows are axial outflows and in other they are conical outflows, away from the axis. Here we compare those α-ansatz results with our new obtained β-ansatz solutions (Duschl et al, 2000), wher the dissipations depend on the radial position and the azimuthal velocity. While α-prescription is usually working well in the models of dwarf novae and symbiotic stars, it is less then satisfying in many other cases. Here we verify if the β-prescription offers some advantages in the results of simulations.

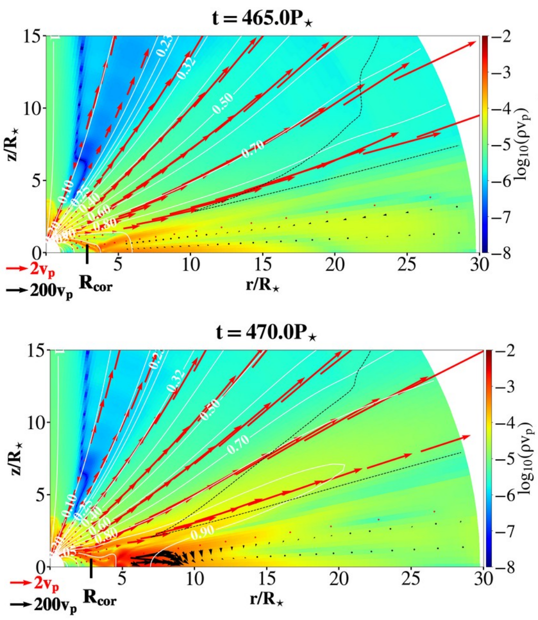

Figure 1: *A zoom in the solutions in our simulations with the β-prescription at two time instances in the simulation with the smaller (top panel) and larger (bottom panel) mass inflow onto the star and in the disk, at the low and and at the peak of the oscillations, respectively. Shown is the momentum in code units in the logarithmic color grading, and vectors show the poloidal velocity, with different scaling in the disk and its corona. The velocities near the star are omitted to show the flow and the corotation radius, where the material is corotating with the stellar surface at the equator, is marked with the black vertical line.*

Simulations setup:

The setup is the same as presented in Čemeljić (2019). We use the PLUTO code (Mignone et al., 2007). As the initial condition we used the KK disk solution, with the viscosity and resistivity proportional to the radial distance from the star and azimuthal velocity (Duschl et al, 2000), with the proportionality constant β of the order between 0.001 and 0.01. The computational domain is R×Θ = [(1,30)R$_*$x(0,π/2)] in [217x100] grid cells, which are radially increasing logarithmically and uniform in the poloidal direction. The time t is measured in stellar rotation periods at the equator. We set β=0.005 for both viscous and resistive dissipation, with magnetic Prandtl number $2\beta_v/(3\beta_m)$=0.67.

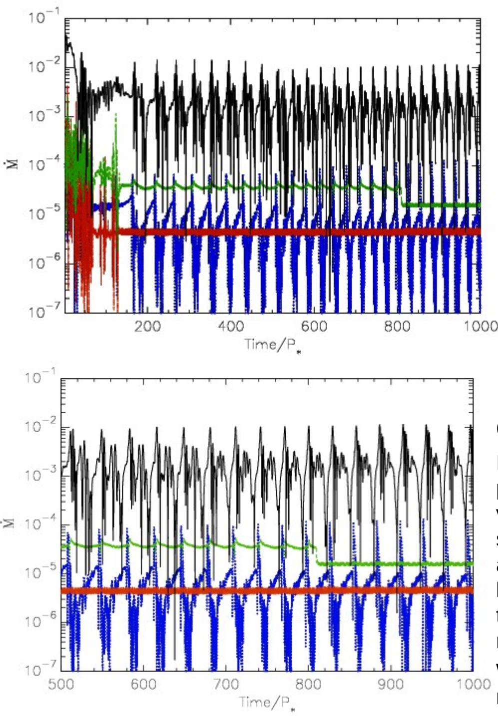

Figure 2: *Periodic oscillations in the disk accretion rate (black line) at R=15 and mass flux onto the star (blue line) at R=1. In the bottom panel is shown only the second part of the time interval from the top panel, to enable the better visibility of the pattern details. The red and green lines show the mass fluxes in the axial outflow and the magnetosphere above the disk, respectively. The results are shown in the code units.*

Results:

Qualitatively the results with β-ansatz, shown in Fig.1 appear similar to the ones wih α-ansatz fro our previous works, but with one interesting additional feature: extremely regular periodic oscillations of the disk over hundreds of stellar rotations, leading to regular episodic dumping of the material onto the star through the accretion column, as shown in Fig.2. Initial study indicates that the period of such oscillations depends on th characteristic length scale of the disk radial density distribution.

We will further investigate the dependence on the other parameters in the simulation.

The intermittent backflow near the disk midplane is also retained, confirming the results from Mishra et al. (2023), obtained with α-ansatz. There also the periodicity was present, but not with such extreme regularity. Such oscillations could help to explain the mechanism behind the periodic oscillations in some systems with symbiotic stars.

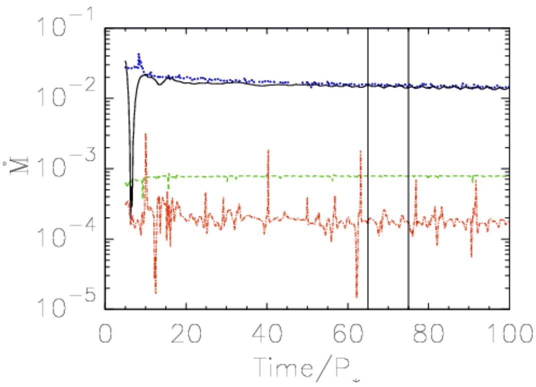

Figure 3: In our simulations with α-ansatz, of which a typical example is shown here. there is no regular oscillations. Extension of the simulation in time does not show difference to the first 100 stellar rotations shown here. The meaning of the lines is the same as in Fig.2.

Conclusions:

In our numerical simulations with PLUTO code, performed with both the α- and β-prescriptions for viscous and resistive dissipations, we find similar quasi-stationary solutions, but in the simulations with β-ansatz we find extremely regular disk oscillations at the long timescale, feeding the periodic matter dumps onto the star. Oscillations were not present with such regularity in the simulations with the α-ansatz.

We also confirm that in both prescriptions the meridional backflow occurs, adding to the argumentation for the physicality of such backflows in the thin accretion disk.

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