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How local thermodynamics, viscosity and stellar-mass-ratio influence the whole structure of accretion disc in close binaries: 3D SPH simulations

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Abstract. Physical turbulent viscosity in an accretion disc involves an enhanced radial mass and angular momentum transport in high compressibility conditions. However, a sticking effect throughout the disc, affects the low compressibility disc's dynamics. Pairs of compressibility-viscosity values, together with initial kinematic conditions at the inner Lagrangian point, can define a well-bound accretion disc, whilst other pairs cannot produce such well-bound structures. In this work, the role of the stellar mass ratio M_1/M_2 (SMR) between the compact primary and the companion in a close binary system (CB) is also taken into account. Results show that such role is essential in modifying domains where parameters compressibility-viscosity-injection velocity at L1 allow a well defined disc consistency. The higher the SMR M_1/M_2, the wider the domain where the accretion disc shows a well-bound consistent structure.

Key words. Accretion: Accretion Discs – Methods: Numerical – Stars: Close Binaries – Stars: Dwarf Novae

1. Introduction

The combination of gas compressibility, physical turbulent viscosity, injection velocity at L1 and SMR plays a role in accretion disc structure as far as its binding and consistency within the primary's potential well is concerned, and influences the quiescent to active and vice-versa phases as for the outburst duration of SU Uma, OY Car, Z Cha and SS Cyg-like objects. In this work, a grid of SPH disc models is produced, with the aim of detecting, in the compressibility-viscosity space, boundaries separating domains, where the disc development is supported, from domains where it is not, for assigned values of the SMR. Therefore, in order to stress this idea, according to fixed kinematic injection conditions at the L1 point as an initial boundary condition, several polytropic indexes γ have been adopted, identifying, for each of them, the boundary lower limit

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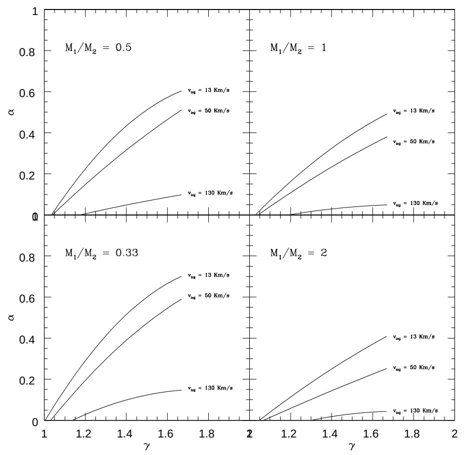

Fig. 1. Plots showing boundaries of stability in the (γ, α) diagram. Values of the SMR and the injection velocity v_{inj} at L1 are also reported.

of the Shakura-Sunyaev parameter α (Shakura 1972; Shakura & Sunyaev 1973), able to provide a sufficient particle concentration to define a well-bound accretion disc within the primary's gravitational potential well. This procedure is made by fixing, for each grid of models, assigned values for the stellar masses M_1, $M_2 \sim 1 \div 3 M_{\odot}$, while their separation is $d_{12} \sim 10^6 \div 2 \cdot 10^6$ km. All simulations are carried out ensuring a stationary final configuration where the rate of injected particles is balanced by the rates of accreted and ejected particles and the number of disc particles is statistically conserved. This work shows that the physical turbulent viscosity contributes to the gas binding in the gravitational potential well, starting from a lower threshold to be defined as a function of gas compressibility (γ), kinematic conditions at L1 and the SMR.

The SPH formulation of viscous contributions in Navier-Stokes and energy equations has been developed by Flebbe et al. (1992, 1994).

2. Results and discussion

We carried out our simulations achieving full stationary configurations within the primary's potential well. The investigation is carried out in order to pursue α for each adopted γ value, fixing the injection velocity v_{inj} at L1, for a given adopted SMR value. Physical turbulent viscosity hampers particle outflow from the disc outer edge, playing a role in both disc radial extension and thickness (Lanzafame 2003; Lanzafame et al. 2006). For each value of the SMR, each boundary, determined by v_{inj}, determines a lower threshold ($\gamma_{thr}, 0$) delimiting the γ value separating well-bound disc models from physically viscous models in which the viscosity plays a fundamental role in the disc binding. Such a threshold value (γ_{thr}, 0), is a function of both v_{inj} and SMR values, as shown in Fig. 1, showing compressibility versus physical turbulent viscosity (γ, α) diagrams, with boundaries delimiting domains supporting the disc development (above each boundary) from domains where this does not occur (below each boundary). Disc models with $\gamma < \gamma_{thr}$ develop a well-bound disc, whatever the turbulent viscosity is. Disc models for which viscosity is lower than the boundary limit: $\alpha < \alpha_b$, do not allow the disc structure in order to get a well-bound structure. For disc's models with $\alpha > \alpha_b$, the physical, turbulent viscosity is able to develop a well-bound accretion disc in the primary's gravitational potential well. These results show that all parameters: the pair of (γ, α) values, the injection velocity at the L1 point, and the adopted SMR value M_1/M_2 play a relevant role in the development of a well-bound accretion disc modelling in the primary star gravitational potential well.

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