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MAGNETISED WINDS IN TRANSITION DISCS

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Abstract. Protoplanetary discs (PPDs) have been widely observed around young stars and are supposed to be the birth cradle of planets. These objects are cold, dense and magnetised. Among them stand the so-called transition discs (TDs) characterised by a dust cavity in their inner regions, whose diameter varies from a few AU to a few hundreds AU. The formation of such cavities remains unexplained. Moreover, such cavities are not only detected in the dust radial density profiles, but they are also observed in the gas radial density profiles.

A striking observation, challenging the intuition, states that in spite of their diminished surface density profile, TDs accrete merely as much as full PPDs. Their accretion rates are similar to one measured in standard PPDs ($\dot{M}_{\mathrm{PPD}} \sim 10^{-7}\, M_{\odot}\,\mathrm{yr}^{-1}$). Such an observation suggests a fast inward motion of matter inside the cavity.

A possible explanation for these high accretion rates is the presence of magnetised winds that would allow matter to fall onto the star at high radial velocity.

The aim of my work is to address this observational discrepancy using magnetohydrodynamic (MHD) winds to account for the accretion in TDs. With my contribution, I showed with global numerical simulations how wind-emitting cavity-hosting discs could support a fast inner accretion.

I present the results of 2.5 D and 3 D simulations modelling TDs with non-ideal magnetic winds. I focus on mass accretion through the cavity and on the 3 D stability of this cavity against hydro and magnetohydrodynamic instabilities.

Keywords: accretion, accretion discs - protoplanetary discs - non-ideal magnetohydrodynamics (MHD) - numerical simulations

1 Introduction

Transition discs are the subjects of many surveys (see for example van der Marel et al. 2018) that investigate in particular the gas repartition in their cavities. Interestingly, many TDs exhibit high accretion rates, that are comparable to the one of full PPDs. These strongly-accreting TDs have cavities of various widths, some of which having very large ones, up to 100 AU such as in González-Ruilova et al. (2020).

The work I present aims at describing global numerical models of TDs whose cavities are sustained by magnetic winds, which enable a strong accretion.

The link between TDs and magnetic winds was first proposed by Combet & Ferreira (2008), while Wang & Goodman (2017) studied the magnetic diffusion properties of TDs cavities in the non-ideal MHD framework. I report the results of the first global numerical simulations (2.5 D and 3 D) of TDs sustained by magnetic winds. The MHD winds are launched with the Blandford & Payne process (Blandford & Payne 1982). The cavity is added by hand in the initial state. My model does not enforce any effective viscosity and focuses exclusively on the gas. The work presented here is based on Martel & Lesur (2022), and is a short insight on my thesis work (Martel 2022).

2 2.5 D simulations: secular evolution

I used a set of 2.5 D axisymmetric simulations to check the stability of a TD with magnetic winds on long period of time. I show the corresponding spatio-temporal profile of the surface density in the left panel of fig. 1.

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The cavity remains through time and the disc reaches a quasi-stationary state. The corresponding order of magnitude for the accretion rate is $\dot{M}_{\rm TD} \sim 10^{-7}\ M_\odot\,{\rm yr}^{-1}$. Such a strong accretion rate in the depleted cavity implies that the accretion is transsonic in this region.

The accretion rate of the cavity connects to the one of the external part of the disc. The transport of angular momentum outwards occurs throughout the whole disc in an homogeneous fashion.

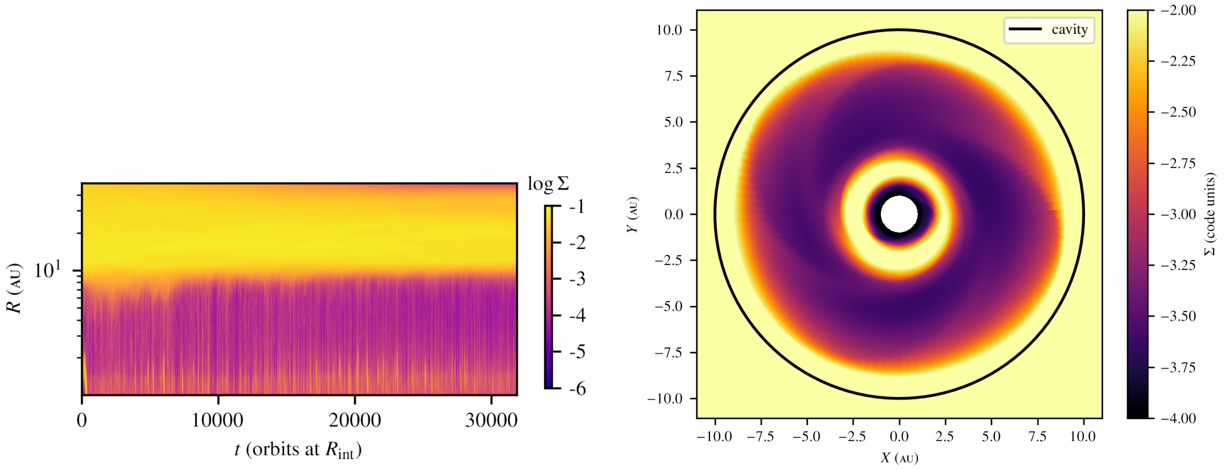

Fig. 1. Left: Spatio-temporal diagram of the surface density for the fiducial 2.5 D simulation. **Right:** Surface density in the midplane and at a given time for the fiducial 3 D simulation. The black circle indicates the location of the outer edge of the cavity.

3 3 D simulations: stability of the cavity

I ran another set of 3 D simulations to investigate the stability of the cavity under hydro- and magnetohydrodynamic instabilities. These 3 D simulations are restarted from the corresponding 2.5 D ones. After a fast transitory state, the disc remains in a similar dynamical state as it was in 2.5 D.

Nevertheless, an inner ring forms close to the inner boundary and a set of 4 spirals develops inside the cavity. These spirals can be seen in the right panel of fig. 1. I checked various stability criteria (Magnetic Rayleigh-Taylor instability, Rossby wave instability, rotational instability), but could not identify the occurring instability with certainty.

4 Conclusions

All these numerical simulations proove that magnetic winds are efficient to sustain stable inner cavities of TDs. They enable a strong accretion in the cavity as well as the radial transport of angular momentum. In essence, the simulated cavities recalls the physics of Magnetically Arrested Discs (MADs, see Narayan et al. 2003) that are studied in the context of black-holes physics.

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