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Damping of surface Alfvén waves in accretion disks

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The transport of angular momentum and matter is essential for the evolution of astrophysical disks, particularly protostellar disks. Recently, several works investigated the role of non-ideal MHD effects in those objects and their impact on angular momentum transport. On the other hand, the damping of Alfvén waves was already proposed as a viable mechanism for disk heating, increasing its ionization fraction and, consequently, the region of the disk subject to Magneto-Rotational Instability. In this work, we analyze the effects of the resonance of surface Alfvén waves in protostellar disks with a local approximation, in the presence of both resistivity and viscosity. In general, we find that depending on the propagation properties, the waves may be damped or amplified, and these processes are independent of the dissipation coefficients, at least for the hypotheses adopted.

The angular momentum (AM) transport is a key process to describe various astrophysical systems, including accretion disks found around young stars. The transfer of AM is necessary to promote the evolution of these protostellar disks, however, is still a matter of debate, with several mechanisms proposed to explain this transportation, including the Magneto-Rotational Instability (MRI, Balbus & Hawley 1991). In the last years, though, it was found that in the partially ionized disk, the presence of nonideal MHD effects may diminish the effectiveness of this instability, or even suppress it entirely, in the sense that extra mechanisms may be taken into account (e.g. Bai 2011).

Vasconcelos et al. (2000) proposed the damping of Alfvén waves as a source of non-thermal disk heating, which could provide the additional ionization process necessary to guarantee the AM transport. Jatenco-Pereira (2013) also considered the damping of those waves for dusty disks. In the present work, we explore this hypothesis further, by considering the resonance of surface Alfvén waves. To provide an analytical approach to our problem, we use the fact that surface waves propagate at the interface between two media and apply a local approximation. In this approximation, we may define a new cartesian system of coordinates, centered at a reference point, r_0, which allows us to write the radial shear associated with the disk differential rotation as $\mathbf{v_0} = -q\Omega_0 x\hat{\mathbf{y}}$, where q corresponds to the power-law index of the angular frequency, $\Omega \propto r^{-q}$, Ω_0 is the angular frequency at our reference point, r_0, and x corresponds to our local radial coordinate. With this simplified model, if we apply incompressible perturbations of the form $g(x, y, z, t) = g(x)\exp\left[i(-\omega t + k_y y + k_z z)\right]$, and assume that $k_y a, k_z a \ll 1$, where $2a$ is the width of the region where the local approximation is valid, with $k_y > k_z$, we find, through the perturbation method that, depending on the propagation properties, an instability may be triggered in the system or a damping regime is achieved. Indeed, for what we call the *forward* case, where $\mathrm{sign}(\omega_0/\omega_A) > 0$, where ω_0 is the real principal part of the perturbation frequency, and ω_A is the Alfvenic frequency, a shift in the regime occurs: initially, the wave is amplified, due to the development of instability and as we increase the velocity shear, a damped regime is achieved. For the backward case, on the other hand, the wave is always damped. We also quickly compared the damping rate obtained with our mechanism and the turbulent damping, already studied in the literature as a source for non-thermal disk heating (see Vasconcelos et al. 2000). We found that, under reasonable conditions, resonant damping is more effective than turbulent damping in heating the disk, indicating that the proposed mechanism can decrease the dead zone extent. We are now performing a more robust numerical analysis to fully describe the effect of the resonant damping of surface Alfvén waves over the ionization fraction and transport of angular momentum in those disks.

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