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ORIGINAL ARTICLE

The role of Hall diffusion in the magnetically threaded thin accretion discs

Mohsen Shadmehri

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Abstract We study role of the Hall diffusion in the magnetic star-disc interaction. In a simplified steady state configuration, the total torque is calculated in terms of the fastness parameter and a new term because of the Hall diffusion. We show the total torque reduces as the Hall term becomes more significant. Also, the critical fastness parameter (at which the total torque is zero) reduces because of the Hall diffusion.

Keywords Accretion · Accretion discs · Stars: magnetic field · X-ray: stars

1 Introduction

Accretion discs are observed in many astronomical systems from the new born stars to the compact objects (e.g., neutron stars) or even at the center of the galaxies (e.g., Frank et al. 2002). In spite of considerable achievements in our understanding of the accretion processes, there are many uncertainties regarding to the driving mechanisms of the turbulence in the disc or possible roles of the magnetic field. Although the standard theory of the accretion discs neglects such complexities (e.g., Shakura and Sunyaev 1973), it is a successful theory to explain parts of the observational features of some of the accreting systems.

An instability related to the magnetic field and the rotation of the disc is known to be responsible in generating turbulence in such systems (Balbus and Hawley 1991). This mechanism known as magnetorotational instability (MRI) has been analyzed over recent years in detail. In addition to this role of the magnetic field, the structure of the accretion discs is significantly modified because of the magnetic effects even in the simplified models (e.g., Lovelace et al. 1994; Shalybkov and Rudiger 2000; Shadmehri 2004; Shu et al. 2007). Most of the theoretical models for the magnetized accretion discs are within the framework of the ideal MHD, in which the *diversity* of different charged particles is neglected. If ions, neutrals and electrons are considered as separate fluids, non-ideal MHD effects mainly due to the drift velocities between the charged particles will emerge (e.g., Wardle 1999; Balbus and Trequem 2001). Over recent years many authors have tried to present models in order to capture the basic physics of non-ideal MHD effects in accretion discs, in particular Hall diffusion (Wardle 1999; Balbus and Trequem 2001; Rudiger and Kitchatinov 2005; Liverts et al. 2007; Shtemler et al. 2009). Although all these studies are showing significant effects of the Hall diffusion on the magnetized accretion discs, the models are restricted to the discs around non-magnetized central object. But we know that for a disc around a magnetized object like a neutron star, the poloidal component of the central magnetic field can interact with the disc and generate a toroidal field inside disc because of different rotational velocities of the central field and the disc itself (e.g., Ghosh and Lamb 1978). Thus, a magnetically threaded thin accretion disc will experience an extra torque due to the combined effect of the poloidal component and the induced toroidal component of the magnetic field. However, the true nature of the interaction of the stellar magnetic field with the disc is still under debate (Wang 1987; Romanova et al. 2003) and the Hall diffusion is neglected for simplicity.

Following early works of magnetic star-disc interactions (e.g., Ghosh and Lamb 1978), the authors have been study-

M. Shadmehri (✉)
Department of Physics, Faculty of Sciences, Golestan University, Basij Square, Gorgan, Iran
e-mail: m.shadmehri@gu.ac.ir