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ORIGINAL ARTICLE

The influence of cosmic-rays on the magnetorotational instability

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Abstract We present a linear perturbation analysis of the magnetorotational instability in the presence of the cosmic rays. Dynamical effects of the cosmic rays are considered by a fluid description and the diffusion of cosmic rays is only along the magnetic field lines. We show an enhancement in the growth rate of the unstable mode because of the existence of cosmic rays. But as the diffusion of cosmic rays increases, we see that the growth rate decreases. Thus, cosmic rays have a destabilizing role in the magnetorotational instability of the accretion discs.

Keywords Galaxies: active · Black hole: physics · Accretion discs

1 Introduction

Understanding the true nature of accretion processes in astrophysics has always been an attractive research topic over the last three decades. Accretion discs are observed in many astrophysical systems from new born stars to compact objects or even very large discs at the center of the galaxies. In spite of the diversity of the accreting systems, existence of a possible mechanism of the angular momentum transport is a common feature in all these accretion systems. Extensive efforts to understand mechanisms of the angular momentum transport in the accretion discs have lead to a better understanding of such systems, though there are many theoretical and observational uncertainties.

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It has been proposed that the magnetorotational instability (MRI) is the main driving mechanism of turbulence in the accretion discs (Balbus and Hawley 1991). Extensive subsequent works have clarified and extended our understanding of the role of MRI in various astrophysical systems from protoplanetary discs (e.g., Sano and Miyama 1999) to the protostellar discs or even quasar discs. Over recent years a multi layer model for the protoplanetary discs is proposed in which the surface layers are magnetically active due to the ionization of the CRs, while the central layers are magnetically inactive because of inability of CRs to penetrate down to the central parts (e.g., Gammie 2001). Thus, MRI can act as a driving mechanism of the turbulence and the accretion at the surface layer in a protoplanetary disc. However, possible *dynamical* effects of CRs on MRI have not been studied to our knowledge.

Cosmic Rays are very energetic particles but their energy density is in equipartition with energy densities of thermal gas and turbulence (e.g., Ferriere 2001). CRs can act as a source of heating and increase the level of the ionization in the interstellar medium (Field et al. 1969). An enhanced flux of CRs has important consequences for star formation near to the Galactic center (Yusef-Zadeh et al. 2007).

However, interaction of CRs with a plasma is not restricted just to a possible enhancement of the level of ionization as has been studied extensively over recent decades. For example, dynamical effect of CRs has a vital role in analysis of Parker instability for the structure formation in the Galaxy at large scale (e.g., Parker 1966; Mouschovias 1974; Hanasz and Lesch 2000; Kuwabara et al. 2004; Kuwabara and Ko 2006). It is also found that CRs have a stabilizing effect on the thermal instability (Kuznetsov and Ptuskin 1983; Wagner et al. 2005; Shadmehri 2009).

The problem of the diffusion of CRs and its role in MRI has not been studied in detail. Considering CRs as a sepa-