Astronomy in Focus, XXIXB, Focus Meeting 18
XXIXth IAU General Assembly, August 2015
Piero Benvenuti, ed.

doi:10.1017/S1743921316006670

Magneto-rotational instability with the effect of cosmic rays

Takuhito Kuwabara[1] **and Chung-Ming Ko**[2]

[1]Computational Science and Engineering Division I, AdvanceSoft Corporation, 4-3, Kanda Surugadai, Chiyoda-ku, Tokyo 101-0062, Japan
email: kuwabrtk@nifty.com

[2]Institute of Astronomy, Department of Physics and Center of Complex Systems, National Central University, Jhongli District, Taoyuan City, Taiwan (R.O.C.)
email: cmko@astro.ncu.edu.tw

Abstract. Cosmic ray (CR) is an important component of the interstellar medium. It interacts with plasma via embedded magnetic irregularities. We study the magneto-rotational instability (MRI) in the presence of CRs. We analyse the effect of CRs including their diffusion using both linear stability analysis and MHD simulations. Two models are studied. (1) In the shearing box model, uniform initial state is adopted. Linear analysis shows that the growth rate of MRI is not sensitive to the value of CR diffusion coefficient. (2) In the differentially rotating cylinder model, the initial state is taken as a constant angular momentum polytropic disk threaded by weak uniform vertical magnetic field. Linear analysis shows that the growth rate of MRI becomes larger if the CR diffusion coefficient is larger. Both linear results are confirmed by MHD simulations.

Keywords. accretion disks, instabilities, magnetic fields, cosmic rays, diffusion

---

The dynamical effect of CRs on magnetized plasma can be efficiently studied by considering the plasma and CR as a two-fluid system in which plasma and CR are considered as different fluids. An interesting property of this multi-fluid system is the diffusion of CRs. In this contribution we consider CR diffusion along magnetic fields only and neglect cross-field line diffusion. The tendency of reducing gradient in CR energy density (or pressure) by diffusion adds a new factor to the dynamics.

We apply the two-fluid system to study MRI (Kuwabara & Ko 2015). We consider two models: (1) shearing box and (2) differentially rotating cylinder. As described in the abstract, the two models have somewhat different unperturbed background states, in which the most significant difference is the CR pressure is uniform in the former model and nonuniform in the latter one. We did both linear stability analysis and MHD simulations (including CR with diffusion). In the shearing box model, the growth rate barely depends on the diffusion coefficient of CR as the unperturbed background is uniform in CR pressure. In contrast, in the differentially rotating cylinder model, the growth rate increases with the diffusion coefficient and saturates at large diffusion coefficient.

Physically, as MRI develops, it drives the system to develop gradients including CR pressure gradient. When the diffusion coefficient is large, the CR pressure tends to approach uniform distribution rapidly. The CR pressure gradient along a magnetic field line remains small and cannot help to curb the outward movement of plasma by the centrifugal force.

Reference

Kuwabara, T. & Ko, C. M. 2015, *ApJ*, 798, 79