3D MHD Numerical Simulation of Astrophysical jet; energy structures

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Abstract

We have performed self-consistent 2.5-dimensional nonsteady MHD numerical simulations of jet formation as long as possible at the National Astronomical Observatory(NAO), including the dynamics of accretion disks. Thus we have investigated long term evolutions of mass outflow rate, poynting flux, kinetic energy flux, enthalpy flux and the energy of the toroidal magnetic field. We found that average poynting flux is dominant over both kinetic energy flux and enthalpy flux especially when initial magnetic field is strong. The radial dependences of different energies reveal that the main source of collimation comes from the pinching by toroidal field. Also the ejection of jet is quasi-periodic and the periodicity of the jet can be related to the time needed for the initial magnetic field to be twisted to generate toroidal filed.

1. Introduction

Astrophysical jets have been observed in young stellar objects (YSOs) (e.g., Fukui 1993 et al.; Ogura 1995; Burrows et al. 1996; Bachiller 1996), active galactic nuclei (AGNs) (e.g., Bridle & Perley 1984; Biretta, Zhou, & Owen 1995), and some X-ray binaries (XRBs) (e.g., Margon 1984; Mirabel & Rodriguez 1994; Tingay et al. 1995; Kotani et al. 1996). Although the acceleration and collimation mechanisms of these jets are still not well understood, these objects are believed to have accretion disks in their central regions. One of the most promising models for jet formation is magnetic acceleration from accretion disks (Blandford 1993). Blandford & Payne (1982) pointed out that a magneto-centrifugally driven outflow from a Keplerian disk is possible if the angle between the disk surface and the poloidal component of the magnetic field makes an angle of less than 60°.

2. Resultes and Concolustion

As a result of the differential rotation of the accretion disk, the toroidal magnetic field is generated and propagated upward as a torsional Alfven wave. This action takes out the angular momentum of the disk surface. Kato et al (2002) show that, in case of thin accretion disk, the jet is accelerated mainly by magnetic pressure, while, in case of thick disk (this simulation) the gas pressure affects the ejection of the jets initially because the pressure in a thick disk is larger than that in a thin disk. Pressure-driven outflows were studied by Bell (1994) and Bell & Lucek (1995). Fig (1) shows the driving forces of jet i.e. poynting, kinetic and enthalpy force for different initial magnetic field strength. Both the poynting energy and thermal energy play the dominant effect in driving the jet while the effect of kinetic energy is very limited. In case of strong magnetic field, initially the poynting force is more dominant but after about 7.5 rotations the thermal and poynting force become equivalence. On the other hand, in the case of weak initial magnetic field, the thermal energy become dominant at beginning of the simulation and continue dominant during the first 10 rotations. At the last stage of our simulations the poynting force becomes more effective.

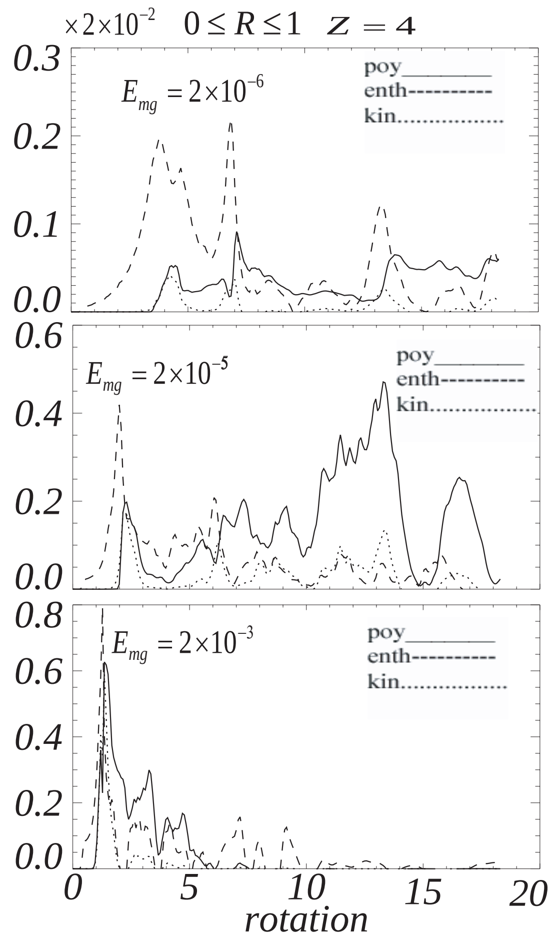

Fig. 1. Time evolution of the poynting, thermal, and kinetic forces for different initial magnetic field