Astrophsical Jets; energy structures and quasi-periodic

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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), active galactic nuclei (AGNs), and some X-ray binaries (XRBs). 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°. Their self-similar solutions of the steady and axisymmetric magnetohydrodynamic (MHD) equations demonstrated the possibility of such acceleration and collimation of the flow from a cold Keplerian disk.

2. Resultes and Concolustion

In the early stage of evolution Fig.(1), a torsional Alfven wave is generated at the disk surface and propagates up into the corona ($t = 3.14$). Since this wave extracts angular momentum, the rotating disk begins to fall into the central region. Because the magnetic field in the disk is weak, the surface layer of the disk falls faster than the equatorial part. This is the avalanche-like accretion that was studied by Matsumoto et al. (1996). Subsequently, the cold material on the disk surface is ejected as a jet.

The ejection of the jet in all models is intermetant but it is not easy to describe the periodicity of mass ejection because it is very nonsteady . By blotting the peak times of mass ejection with the magnetic field strength Fig. (2). The resulting figure can be fitted with the theoretical approximately relation $t \sim {E_{mag}}^{-0.5}$, t is the peak time of mass ejection for different initial magnetic energy strength. Therefore the periodicity of the jet can be related to the time needed for the initial magnetic field to be twisted to generate toroidal filed.

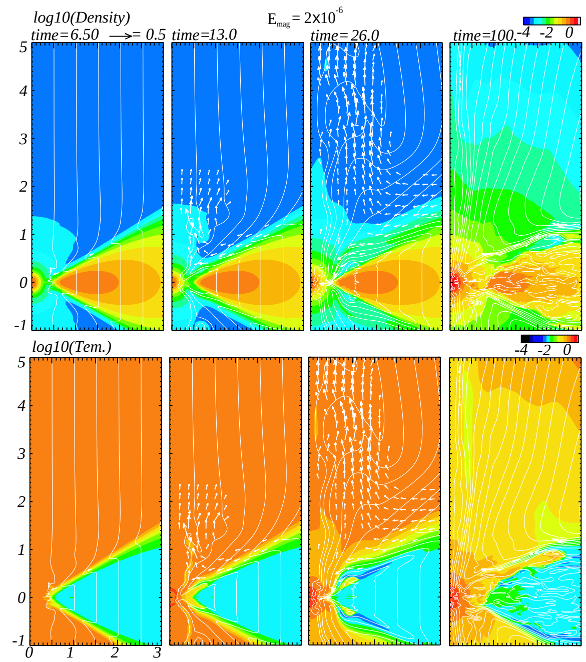

Fig. 1. Time evolution of the density upper, and temperture lower. Time $t \sim 2\pi \sim 6.28$ corresponds to one Keplerian orbit at $(r, z) = (1, 0)$). White vertical lines are magnetic field lines. arrows show the poloidal velocity vectors

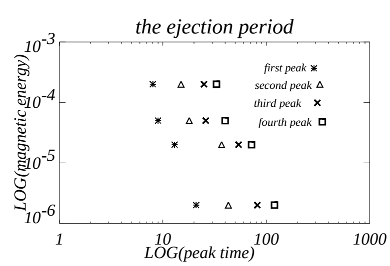

Fig. 2. The relation between the peak time of mass ejection and the magnetic energy strength