DYNAMO ACTION IN ACCRETION DISKS

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Abstract. Employing the standard theory for thin accretion disks I estimate the relevant parameters for a dynamo in an accretion disk. These estimates could then be compared to the results of numerical simulations. Some preliminary results of such simulations (Torkelsson & Brandenburg 1992) are presented too.

Key words: accretion, accretion disks – dynamo – (MHD) – cataclysmic variables – active galactic nuclei

1. Introduction

Using the theory for thin accretion disks (Shakura & Sunyaev 1973) it is possible to estimate several of the relevant parameters for a dynamo. These estimates are primarily based on the α-description of viscous friction. I assume that $\alpha = 0.1$ and the magnetic Prandtl number is of order unity. In Tab. 1 M is the mass of the compact object, R_{disk} the radial coordinate for a point in the disk, and $\dot{M}$ the accretion rate. The dynamo numbers are calculated according to $C_\alpha = \frac{\alpha_0 R_{\text{disk}}}{\eta_{\text{disk}}}$ and $C_\Omega = \frac{\Omega_0 R_{\text{disk}}^2}{\eta_{\text{disk}}}$, where α_0 is a typical velocity for the turbulent α-effect, Ω_0 the angular velocity, and η_{disk} the turbulent magnetic diffusivity in the disk. The given time scales are the Keplerian time scale, t_{Kepl}, and the magnetic diffusivity time scale, t_{diff}. Note that in the numerical calculations I use the diffusivity of the corona instead, which is assumed to be 20 times larger. The magnetic field, B_{press} is estimated by equilibrating the gas and magnetic pressure. Finally I give the temperature T of the disk. The low dynamo numbers for the AGN is due to the choice of a high accretion rate and low mass for the black hole.

2. Numerical simulations

We have undertaken numerical simulations of a disk dynamo by solving the dynamo equation

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{V} \times \mathbf{B} + \alpha \mathbf{B}) - \nabla \times (\eta_t \nabla \times \mathbf{B}), \qquad (1)$$

(Torkelsson & Brandenburg 1992). It is solved with a time-stepping method on a 2-dimensional grid in the $r\theta$-plane, where r and θ are spherical coordinates ranging from 0 to 1, and 0 to $\frac{\pi}{2}$ or π, respectively (Brandenburg et al. 1989). We assume Keplerian rotation in the disk except in the innermost 25 % where it turns over into rigid rotation. The magnetic diffusivity is small, 0.05, and constant inside the disk, and 1 outside the disk, to simulate a surrounding vacuum. Finally the α-effect is proportional to the angular velocity Ω and the vertical coordinate z.

An example of a simulation is presented in Fig. 1. If one decreases the thickness of this disk, it will be easier to excite a steady S0 mode than the oscillating A0 mode, which is in agreement with Stepinski & Levy (1990).

F. Krause et al. (eds.), The Cosmic Dynamo, 209–210.

TABLE I
Magnetic fields and time scales in accretion disks

Object	White dwarf	Neutron star	Stellar black hole	Black hole in AGN
$M(M_\odot)$	1	1	10	10^7
R_{disk} (m)	10^7	$3\,10^6$	10^6	10^{12}
$\dot{M}$ ($M_\odot$ yr^{-1})	$8\,10^{-9}$	10^{-9}	$2\,10^{-9}$	1
C_α	70	100	500	2
C_Ω	5 000	20 000	200 000	3
t_{Kepl} (s)	20	0.02	0.006	6 000
t_{diff} (s)	10 000	60	200	3 000
B_{press} (T)	80	10 000	20 000	0.03
T (eV)	70	2 000	3 000	60

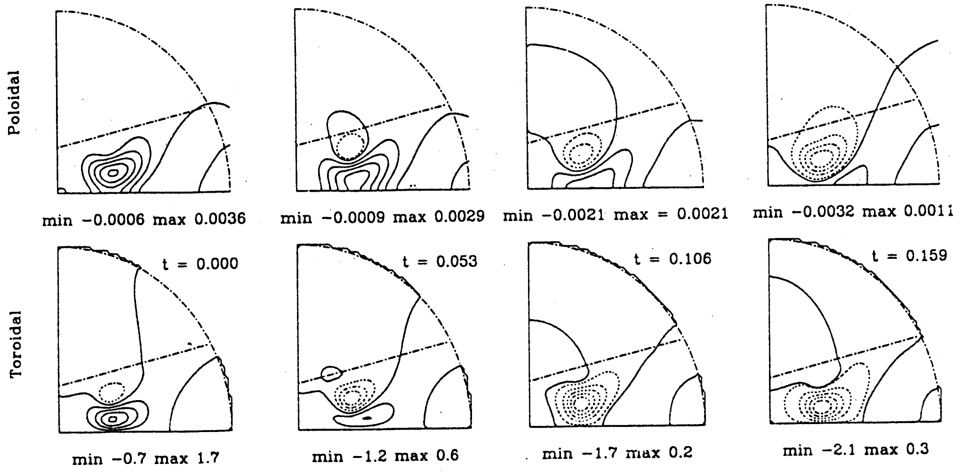

Fig. 1. For a disk with thickness 0.25 at the rotational axis and thickening outwards with a slope of 0.25, the most easily excited mode is an oscillating A0 mode with $C_\alpha C_\Omega = 43.2$ and angular frequency of 14.7 in units of the inverse of the magnetic diffusivity time outside the disk. This is in agreement with Stepinski & Levy (1988). The upper row of the figure shows the poloidal field and the lower one the toroidal field, solid lines are for positive values and broken lines for negative. $t = 0$ is chosen arbitrarily.

Acknowledgements

The numerical calculations are being carried out on the Cray X-MP/416 at the National Supercomputer Center, Linköping, Sweden.

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