

MAGNETIC AVALANCHE MODEL OF MASS SUPPLY IN ACTIVE GALACTIC NUCLEI

T. KUWABARA AND R. MATSUMOTO

*Department of Physics, Faculty of Science, Chiba University,
1-33 Yayoi-Cho, Inage-ku, Chiba 263, Japan*

AND

K. SHIBATA

National Astronomical Observatory, Mitaka, Tokyo 181, Japan

We present the results of axisymmetric, two-dimensional magnetohydrodynamic (MHD) simulations of weakly ionized gas torus threaded by large scale vertical magnetic fields. The gas torus corresponds to the 100pc scale circumnuclear torus observed by HST in nearby AGNs (e.g. NGC4261) or $10^{10} M_{\odot}$ circumnuclear gas found by CO observations in luminous IR galaxies and quasars (e.g. Scoville et al. 1991). The initial state of simulation is a constant angular momentum polytropic torus threaded by uniform vertical magnetic fields. The torus is assumed to be rotating in a static, spherical hot halo. The model parameters are $E_{th} = v_{s0}^2 / (\gamma v_{k0}^2) = 5 \times 10^{-3}$ and $E_{mg} = v_{A0}^2 / v_{k0}^2 = 6.6 \times 10^{-6}$ where γ is the adiabatic index and v_{s0} and v_{A0} are the sound speed and the Alfvén speed at $r = r_0$ respectively.

When the resistivity $\eta = 0$, the surface layer of the torus accretes like an avalanche because magnetic braking most efficiently extracts angular momentum from that layer (Matsumoto et al. 1996). The avalanching gas creates a Keplerian accretion disk around the equatorial region inside the innermost radius of the initial torus ($r < 10\text{pc}$). In circumnuclear torus, resistive effects may be important either by classical resistivity in low-ionized gas or by turbulent diffusivity enhanced by the magnetic turbulence driven by the magneto-rotational instability. We found that in circumnuclear torus, the classical resistivity $\eta \sim 8 \times 10^3 (T/500K) / \chi$ where χ is the ionization rate (Gammie 1996) is small enough to excite the avalanche flow and magnetic turbulence. On the other hand, 3D MHD simulations indicate that the turbulent diffusivity is the order of $\eta \sim 10^{-2} v_A H$ where v_A

is the Alfvén speed and H is the scale height (Matsuzaki et al. 1997 in preparation).

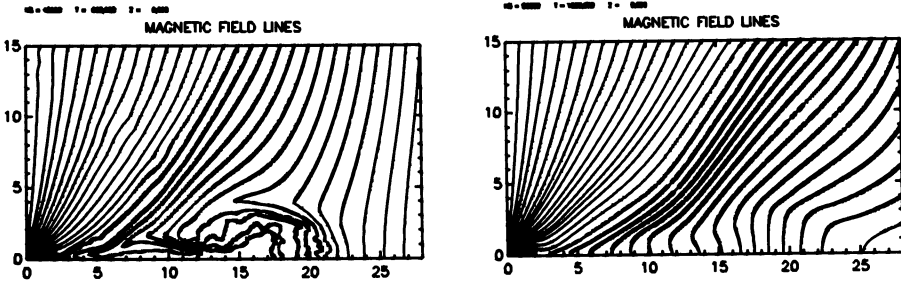


Figure 1. Magnetic field lines in the nonlinear stage for $\eta = 0$ and $\eta = 10^{-2}v_A H$.

TABLE 1. The dependence of mass supply rate on resistivity

$\eta/(v_A H)$	0.0	10^{-3}	10^{-2}
$\dot{M}_{acc}/(M_{10} M_{BH9}^{1/2})$	$720 M_\odot/\text{yr}$	$576 M_\odot/\text{yr}$	$61.6 M_\odot/\text{yr}$

Figure 1 shows magnetic field lines for models with $\eta = 0$ and $\eta = 10^{-2}v_A H$. When $\eta = 10^{-2}v_A H$, avalanche flow is not so prominent as the non-resistive $\eta = 0$ model. Table 1 shows the dependence of accretion rate \dot{M}_{acc} on η where $M_{10} = M_{gas}/(10^{10}M_\odot)$ and $M_{BH9} = M_{BH}/(10^9M_\odot)$. We found that although the mass accretion rate decreases an order of magnitude when $\eta = 10^{-2}v_A H$, magnetic braking still can supply $60M_\odot/\text{yr}$ when the mass of the central black hole is 10^9M_\odot and the mass of the gas torus is $10^{10}M_\odot$.

We conclude that even if we include the effects of enhanced magnetic diffusivity, magnetic braking can supply enough mass to explain the activity of AGNs.

Numerical computations have been carried out by using VPP300/16R at the National Astronomical Observatory.

References

- Gammie, C.F. (1996) *ApJ*, 457, 355-362.
 Matsumoto, R., Uchida, Y., Hirose, S., Shibata, K., Hayashi, M.R., Ferrari, A., Bodo, G., & Norman, C. (1996) *ApJ*, 461, 115-126.
 Scoville, N.Z., Sargent, A.I., Sanders, D.B., Soifer, B.T. (1991) *ApJ*, 366, L5-L9.