The Cosmic Battery and Astrophysical Magnetic Discs

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18 June 2014

International Workshop:" Extreme-Astrophysics in an Ever-Changing Universe". Ierapetra, Crete-Greece.

The Induction Equation

$$\frac{\partial A}{\partial t} = E_{\phi}\hat{\phi} + u \times B - \eta \nabla \times B \tag{1}$$

where A is the magnetic vector potential, $B = \nabla \times A$ is the magnetic field, η is the magnetic diffusivity and the flux is $y = r \sin \theta A_{\phi}$ (in spherical coordinates (r, θ, ϕ)).

The Induction Equation

The Electric field is equal to:

$$E_{\phi} = -A_{c}e^{-\frac{(r-r_{in})^{2}}{2r_{in}^{2}}}v_{\phi}(\frac{r}{r_{in}})^{2}e^{-\frac{(\theta-\frac{\pi}{3})^{2}}{2(\frac{\pi}{6})^{2}}}$$
(2)

where $A_c = 0.1$ and $r_{in} = 1$. The magnetic diffusivity is (see for example Lovelace, Rothstein and Bisnovatyi-Kogan 2009):

$$\eta = \frac{ac_s^2}{\Omega_\kappa Pr} \tag{3}$$

Pr = 0.8(Prandtl number), a=0.1 (the usual accretion constant- Shakura and Sunyaev 1973), c_s the isothermal sound speed and Ω_{κ} keplerian angular velocity.

ADAF

In the case of ADAF disks we have the following equations (Narayan & Yi 1994)

$$v_{r} = -\frac{3a}{5+2\epsilon_{1}}v_{\kappa}$$

$$\Omega = \frac{2\epsilon_{1}}{5+2\epsilon_{1}}\Omega_{\kappa}$$

$$c_{s}^{2} = \frac{2}{5+2\epsilon_{1}}v_{\kappa}^{2}$$

$$\epsilon_{1} = \frac{\epsilon}{f}$$
(4)

where Ω and v_r are the angular velocity and the circular velocity. The Ω_{κ} and v_{κ} are the Keplerian angular velocity and the Keplerian velocity. $\epsilon = (\frac{5}{3} - \gamma)(\gamma - 1)$ where γ is the ratio of specific heats $\gamma = \frac{4}{3} \Rightarrow \epsilon = 1$. The f (f = 0.2) measures the degree to which the flow is advection-dominated.

Force-free Magnetosphere

The force-free condition satisfies:

$$(\nabla \times B) \times B = 0 \tag{5}$$

Under conditions of axisymmetry, the equation can be rewritten in spherical coordinates as:

$$\frac{\partial^2 y}{\partial r^2} - \frac{1}{r^2} \frac{1}{\tan(\theta)} \frac{\partial y}{\partial \theta} + \frac{1}{r^2} \frac{\partial^2 y}{\partial \theta^2} = -I \frac{dI}{dy}$$
(6)

where I is the electric current distribution which has the simple form I = 0.75y.

Results



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Cosmic Battery

THANK YOU