GALACTIC DYNAMOS WITHOUT SHARP BOUNDARIES: NON-AXISYMMETRIC FIELDS IN AXISYMMETRIC DISKS?

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Radio polarization observations of spiral galaxies suggest the existence of large-scale galactic magnetic fields which are of either axisymmetric-spiral (ASS) or bisymmetric-spiral (BSS), i.e. non-axisymmetric, structure (cf. Beck, 1989). Clear evidence for a BSS field was indicated for M81 by M. Krause et al. (1989).

Mean-field galactic dynamo models presented so far were not able to explain the preferred excitation of non-axisymmetric fields in axisymmetric disks (cf. Ruzmaikin et al., 1988). As long as dynamo theory is restricted to the so-called kinematic level a serious explanation of BSS fields would require a model for which the smallest critical (marginal) dynamo number corresponds to a BSS field configuration (cf. Krause and Meinel, 1988).

In order to investigate this question further Elstner et al. (1989) developed a numerical concept for studying galactic dynamo models which avoids the typical restrictions of other approaches described by Krause (1989). Within this new concept we are able to determine the critical dynamo numbers (excitation conditions) for axisymmetric and non-axisymmetric magnetic field modes generated by an axisymmetric galactic dynamo model characterized by given profiles of the (turbulent) conductivity, $\sigma(r,z)$, the angular velocity, $\Omega(r,z)$ and the so-called α-parameter, $\alpha(r,z)$. (r,Φ and z are the usual cylindrical coordinates.) In order to investigate the influence of a possible anisotropy of the α-effect (cf. Rüdiger, this volume) we allow different values of α parallel and perpendicular to the rotational axis (z-axis) denoted by $\alpha_{\parallel}(r,z)$ and $\alpha_{\perp}(r,z)$. The velocity field with its small-scale as well as its large-scale part, i.e. "α" and "Ω", is assumed to be much more localized than the electrically conducting region ("σ"). This assumption which seems to be rather well justified for realistic galaxy models allows the treatment of the dynamo equation without any sharp boundary of the conducting region (Meinel, 1989). Possible vacuum regions, however, may also be considered within this frame simulating them by a sufficiently low conductivity.

We investigated first the following disk model:

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 115–116.

$$\Omega = \begin{cases} \Omega_o, & \text{for } r \leq R/3 \\ \Omega_o R/3r, & \text{for } r > R/3 \end{cases} \quad \text{and} \quad \alpha_\perp(r,z) = \begin{cases} \alpha_o, & \text{for } 0<z\leq H,\ r\leq R \\ -\alpha_o, & \text{for } -H\leq z<0,\ r\leq R \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

with α_o, Ω_o being positive constants and R=10 H. We considered the following cases:

$$\text{(a)} \qquad \alpha_\parallel(r,z) = \alpha_\perp(r,z) \tag{2a}$$

$$\text{(b)} \qquad \alpha_\parallel(r,z) = 10\alpha_\perp(r,z) \tag{2b}$$

$$\text{(c)} \qquad \alpha_\parallel(r,z) = 0.1\alpha_\perp(r,z) \tag{2c}$$

For the conductivity we assumed either

$$\text{(i)} \qquad \sigma = \sigma_o = \text{const, everywhere, or} \tag{3}$$

$$\text{(ii)} \qquad \sigma = \begin{cases} \sigma_o, & \text{for } |z|\leq H,\ r\leq R \\ 0.01\sigma_o, & \text{otherwise.} \end{cases} \tag{4}$$

The following dimensionless numbers are defined:

$$C_\Omega = \mu\sigma_o\Omega_o H^2, \qquad C_\alpha = \mu\sigma_o\alpha_o H. \tag{5}$$

Our results (for details see Krause et al., this volume) show that a preference of non-axisymmetric magnetic field configurations in axisymmetric disks can only be expected if the α-effect is highly anisotropic and differential rotation is not too strong. Otherwise we always find an axisymmetric mode having the smallest marginal dynamo number.

Of course, a natural explanation of BSS fields may possibly be found for galaxies which show strong deviations from an axisymmetric structure (non-axisymmetric velocity field, non-axisymmetric σ). For M81 this is obviously the case.

References

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