TORUS–DYNAMO

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Accretion disks around compact objects as well as the gaseous components in galaxies often have the form of a torus. To study the structure and behaviour of magnetic fields generated in such rings, a dynamo is investigated, which is working inside a torus embedded into vacuum. The equations for the kinematic $\alpha\omega$–dynamo are written down in toroidal coordinates (see Figure 1). Besides loss of magnetic flux by Ohmic diffusion (characterized by the magnetic diffusivity D) they describe its production by the inductive effects of differential rotation and of turbulent matter, which we have chosen as $\omega(r) = \omega_0' r$ and $\alpha = \alpha_0 \sin\theta$, respectively. These equations are solved by series expansion into the exponential decay modes of slender tori, which are available in analytical form. A linear homogeneous system of equations follows for the expansion coefficients; its eigenvalues determine the time–dependence of the solutions, the dynamo modes.

Modes symmetric and antisymmetric with respect to the equatorial plane are obtained separately. In Table 1 the results are presented for different torus sizes, η_0, and for different excitation conditions, i.e. dynamo numbers

$$P = \frac{\alpha_0 a}{D} \frac{\omega_0' a^3}{D};$$

here a is related to the equatorial radius of the torus, cf. Figure 1. At critical dynamo numbers P_c the dynamo evolves from a damped to an excited solution. By far the most easily excited dynamo mode is stationary and of quadrupolar symmetry. The field configuration is shown in Figure 2. This basic mode appears for negative dynamo numbers. Quadrupolar modes for positive dynamo numbers as well as all excited dipolar modes are of oscillatory nature. For fixed η_0 they need considerably higher excitation than the stationary solution and hence they are not expected under galactic conditions. The strong increase of critical dynamo numbers with η_0 goes approximately as ρ^{-3}, where $\rho = a/\sinh\eta_0$ is the radius of the meridional torus cross section. This means that the excitation conditions are much more sensitive to the thickness of the torus than to its equatorial radius. The fields of oscillating dynamos evolve in vertical direction along the surfaces of constant rotation, which are cylinders in this investigation. The spatial distribution of α does not seem to be of much importance for the results.

This project only deals with axisymmetric $\alpha\omega$–dynamos. The observation of bisymmetric fields in some spiral galaxies calls for non–axisymmetric dynamos, seated (as above) in the

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HI–rings found far away from the center. Strong poloidal fields observed in the central parts of our Galaxy and of mildly active edge–on galaxies might be generated by α^2–dynamos in partially ionized gaseous rings found in these regions. Research on both lines is under way.

Table 1: Critical dynamo numbers P_c of fundamental dynamo modes; *: stationary modes, all others: oscillatory modes

	Dipole		Quadrupole	
η_0	$P > 0$	$P < 0$	$P > 0$	$P < 0$
1.0	1558	−1287	854	−106*, −1886
1.5	8713	−7423	4572	−527*, −10919
3.0	866050	−766450	444850	−47750*, −1134600

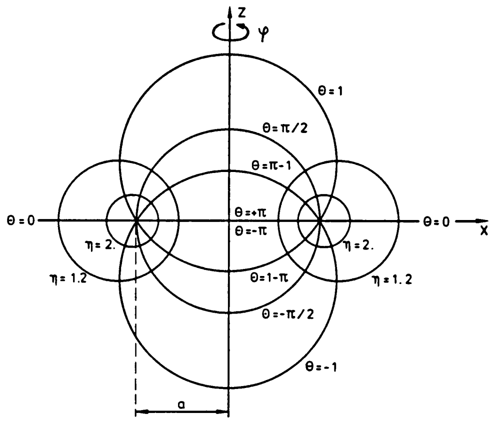

Figure 1. Toroidal coordinates (η, φ, θ):
$x = a \sinh\eta \cos\varphi/c, y = a \sinh\eta \sin\varphi/c, z = a \sin\theta/c, c = \cosh\eta - \cos\theta, r = (x^2 + y^2)^{1/2}$.

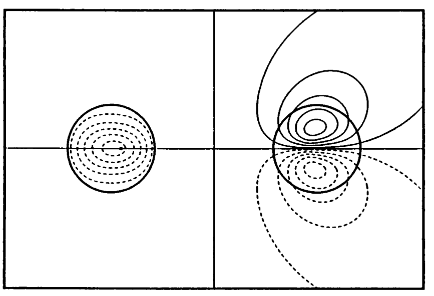

Figure 2. Field configuration of the first excited mode, a stationary quadrupole at $P = -527$. Shown are meridional cross sections of the torus for $\eta_0 = 1.5$, lines of constant toroidal field strength to the left, and poloidal field lines to the right. Solid and dashed lines indicate opposite directions.

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