LARGE SCALE MAGNETOHYDRODYNAMICAL CONSIDERATIONS IN SPIRAL GALAXIES

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ABSTRACT.-A magnetohydrodynamical result is deduced, which could contribute to our understanding of spiral and ring structures in galaxies.The usual expressions for the continuity, momentum and induction equations are adopted for the gas of a galaxy, and the following simplifying hypotesis are made : a) Steady state conditions, b) Axisymmetry, c) A velocity field given by (π=0, $\theta=\theta(r)$, Z=0) for the interstellar gas (where π,θ and Z are the radial, azimuthal and vertical to the galactic plane components and r is the distance from the galactic center).Then, the direction of magnetic field must be azimuthal and the plasma distribution is compatible with ring structures.

The aim of this work is to determine the distributions of magnetic field and gas in a steady state galaxy, in which the gas corotates with the stellar field. The equations of continuity, momentum and induction must be integrated. The form adopted for these equations are standard in galactic gas dynamics. The above mentioned hypothesis are made and cilindrical coordinates are used. Then the following results are obtained, after a lengthy but easy derivation

$$B_r = 0 \tag{1}$$

$$B_z = 0 \tag{2}$$

$$\frac{\partial p}{\partial z} + \rho \frac{\partial F}{\partial z} + \frac{\partial}{\partial z}\left(\frac{B_\phi^2}{8\pi}\right) = 0 \tag{3}$$

$$\frac{\partial p}{\partial r} + \frac{\partial}{\partial r}\left(\frac{B_\phi^2}{8\pi}\right) + \frac{2}{r}\left(\frac{B_\phi^2}{8\pi}\right) = 0 \tag{4}$$

where F is the gravitational potential, and p the gas pressure due mainly to clouds turbulence. Some of the equations give trivial results, and are not included. Equation (2) has been obtained from $\nabla \cdot \vec{B}=0$, and it has been assumed that intergalactic magnetic fields are negligeable. The fo

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 157–158.

https://doi.org/10.1017/S0074180900032733 Published online by Cambridge University Press

llowing conclusions arise directly :

1) Equations (1) and (2) indicate that only the azimuthal component B_ϕ of $\vec{B}$ can be different from zero. Therefore the magnetic field lines in a steady state galaxy should be circles around the rotation axis. This is a severe restriction to the possible directions of $\vec{B}$. Measurements of $\vec{B}$ in the Galaxy, seem to agree with this restriction.

2) When B_ϕ is removed in (3), the equivalent width obtained agrees reasonably with the observations. The magnetic force is probably not so important in deciding the vertical distribution of gas.

3) Equation (4) cannot be solved to obtain both p and B_ϕ. Near the center $B_\phi^2/r >> dB_\phi^2/dr$ and p should decrease approximately exponentially. In outer regions $B_\phi^2/r << dB_\phi^2/dr$ and the sum of magnetic pressure and gas pressure should remain approximately constant. A ring structure is compatible with equation (4). Rings should be favoured to form in the outer parts of the galaxy and the magnetic field should have lower values within the rings.

Active galaxies are clearly not in a steady state, and the above conclusions should be related to normal galaxies, mainly ellipticals and spirals, which are in conditions probably not very far from steady. Some facts may indicate the identification of galaxies having an azimuthal magnetic field ; second, ellipticals have less gas content and magnetization should be less important. Speculations might also be made if current ejection theories could explain the slight deformation of ring patterns into spirals in expanding galaxies slightly separated from the steady state.

More details of the calculations can be found in Battaner and Sanchez-Saavedra (1982).

REFERENCE

Battaner, E. and Sánchez-Saavedra, M.L.: 1982, Astron. and Space Sci. 86, 55.