THE ALPHA-EFFECT IN GALAXIES IS HIGHLY ANISOTROPIC

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The alpha-tensor

Besides the mean flow the alpha is the other input quantity for any mean-field dynamo model. It describes the generation of turbulent electromotive force <u′x B′> from a large-scale field <B> for a given turbulence. The necessary helicity of the turbulence results from the joint action of Coriolis force and density stratification. The standard estimate of 1 km/s for alpha in galaxies is a surely well-established approximation. One of the essentials, however, remains open. Due to the extremely anisotropic structure of disks the tensorial character of alpha can no longer be ignored. In stellar applications anisotropy in the α-tensor leads to a preferred excitation of non-axisymmetric magnetic fields. That is true for α^2-dynamos if the alpha parallel to the rotation axis, $\alpha_{\parallel}$, is much smaller than that in the equatorial plane, $\alpha_{\perp}$. The idea is that also for disk-like configurations a similar behaviour makes the existence of the observed large-scale non-axisymmetric magnetic BSS modes understandable within the frame of the mean-field dynamo theory.

For galaxies the following concept is employed. Explosions (stellar winds, supernovae) form a homogeneous and isotropic field of fluctuating *forces* maintaining the turbulence. For frequency spectra of turbulence-type the vertical turbulent intensity $\langle u_{\parallel}^{\prime 2}\rangle$ dominates then the horizontal one just as a pure consequence of the steep vertical slope of the density profile. Both the density gradient as well as the slow basic rotation (rotation period ≫ correlation time) impose helicity to the turbulence so that an α-effect,

$$\langle u' \times B' \rangle_i = \alpha_{ip} \langle B_p \rangle ,$$

appears with the general structure

$$\alpha_{ip} = \alpha_{\perp}(\mathbf{g}\Omega)\ \delta_{ip} + \tfrac{1}{2}\ (\alpha_{\parallel} - \alpha_{\perp})(g_i \Omega_p + g_p \Omega_i).$$

Our calculations yield the vertical alpha, $\alpha_{\parallel}$, always exceeding the horizontal alpha. In the high-conductivity limit ($\sigma \to \infty$) values such

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 113–114.

https://doi.org/10.1017/S0074180900189685 Published online by Cambridge University Press

as

$$\alpha_{\parallel} / \alpha_{\perp} \approx 5$$

are quite characteristic for the strength of the anisotropy. This finding basically contrasts to that for fast rotating stars where the $\alpha_{\parallel}$ vanishes for $\Omega \to \infty$.

Both the computed alpha-values are positive in the northern and negative in the southern "hemisphere" of the disk.

"Negative buoyancy"

There is a thermodynamic effect influencing the overall-structure of the originated flow pattern and also thus the resulting α-effect. Due to its uniform mean temperature the vertical galactic stratification is *not* convectively unstable. Consequently, a rising eddy does *not* remain warmer than the ambient gas hence it is *not* accelerated by buoyancy. On the contrary: due to the adiabatic cooling during its expansion its upward motion is actually braked. The inclusion of this effect into the computations does indeed reduce the vertical turbulence intensity and also the α-effect in both directions. But the reduction is stronger in horizontal direction rather than in the vertical one. What we thus find is a further amplification of the anisotropy of the α-effect with all the (negative?) consequences for the excitation of magnetic BSS modes.

Applying the real galactic vertical density stratification we find $\alpha(z) \approx \sin(\pi z/2Z)$ to be a rather good approximation.

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