COMPLETE ALPHA-TENSOR FOR SOLAR DYNAMO

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Abstract. We applied the results of recent derivations of the α-effect to the solar convection zone model by Stix (1989) to find the depth and latitude dependences of the α-tensor. Pronounced inhomogeneity and anisotropy are revealed: the α-coefficients for different directions are quite different and strongly latitude-dependent.

Knowledge of the complete tensoral representation of the α-effect is important to develope stellar dynamos. The expressions for the coefficients α_n of the α-tensor,

$$\alpha_{ij} = \alpha_1(\mathbf{g}\cdot\mathbf{\Omega})\Omega^{-1}\delta_{ij} + \alpha_2(g_i\Omega_j + g_j\Omega_i)/\Omega + \alpha_4(\mathbf{g}\cdot\mathbf{\Omega})\Omega_i\Omega_j/\Omega^3 \ , \qquad (1)$$

have recently become available as fully-nonlinear functions of the angular velocity (Rüdiger and Kichatinov, 1993). In the Eq. (1), $\mathbf{g}$ is the radial unit vector and $\mathbf{\Omega}$ is the angular velocity. The tensor (1) has five non-zero components in the spherical coordinates system, r, θ, ϕ:

$$\alpha_{\phi\phi} = \alpha_1 \cos\theta, \ \alpha_{rr} = (\alpha_1 + 2\alpha_2)\cos\theta + \alpha_4\cos^3\theta,$$

$$\alpha_{\theta\theta} = \alpha_1\cos\theta + \alpha_4\sin^2\theta\cos\theta, \ \alpha_{r\theta} = \alpha_{\theta r} = -\alpha_2\sin\theta - \alpha_4\cos^2\theta\sin\theta \ .$$

All the coefficients α_n are superpositions of the contributions made by the two basic inhomogeneities of density and the turbulence intensity: $\alpha_n = \alpha^{dens} + \alpha^{int}$. We used the solar convection zone model by Stix (1989) to evaluate the α-tensor components. The results are shown in the figures 1 to 3.

Only $\alpha_{\phi\phi}$-component is important for the $\alpha\Omega$-dynamos. Fig.1 shows that the inhomogeneities of density and the turbulence intensity contribute this component with opposite signs. The $\alpha_{\phi\phi}$ varies rather slowly with depth except for the near-bottom layer where strong intensity gradient makes the $\alpha_{\phi\phi}$ to change its sign.

The often used isotropic representation, $\alpha_{ij} = \alpha_0\cos\theta\delta_{ij}$, implies the same depth-dependences for all components of the α-tensor and the independence of $\alpha/\cos\theta$ of latitude. Our findings are in drastic contrast to the isotropic picture. The depth-dependences shown in the Figures 1 and 2 are quite different one from another and display pronounced variations from pole to equator. Next, Fig.3 shows that the α-tensor possesses the off-diagonal component which is also a manifestation of anisotropy.

It is very tempting to look at the consequences of the strongly anysotropic α-effect for solar dynamo. Some preliminary results are presented by Elstner and Rüdiger (1993).

F. Krause et al. (eds.), The Cosmic Dynamo, 25–26.

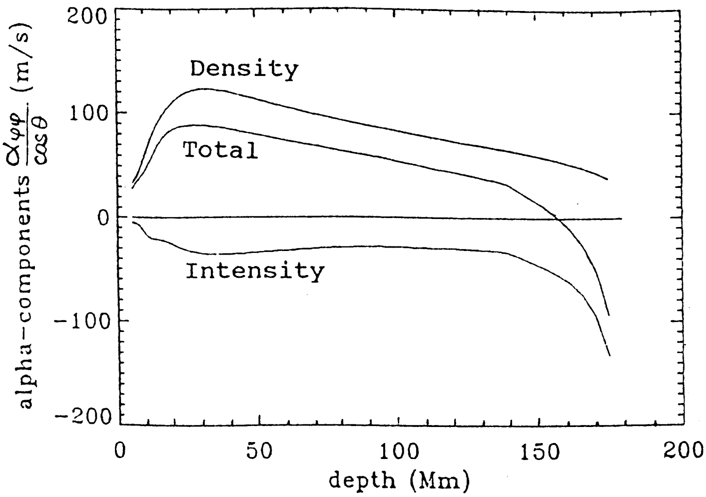

Fig. 1. The total value of $\alpha_{\phi\phi}/\cos\theta$ and its constituents due to inhomogeneities of density and the turbulence intensity as functions of depth in the SCZ

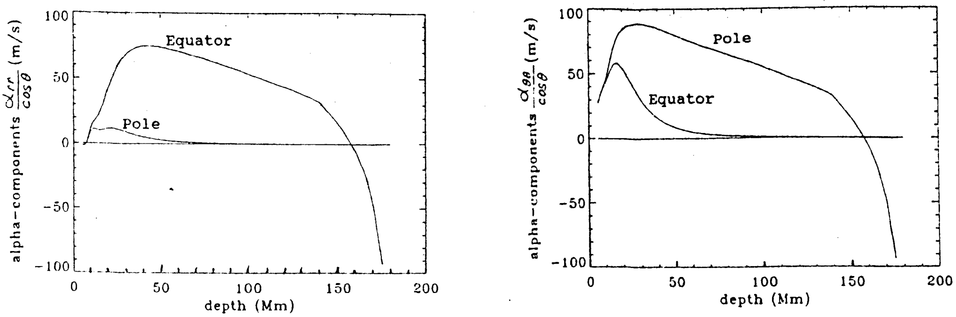

Fig. 2. The total values of $\alpha_{rr}/\cos\theta$ (left) and $\alpha_{\theta\theta}/\cos\theta$ (right) as functions of depth in the SCZ at the pole and the equator

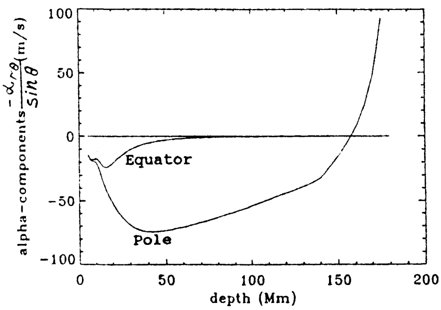

Fig. 3. The same as in Fig.2 but for the off-diagonal component, $-\alpha_{r\theta}/\sin\theta$

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