TWO-DIMENSIONAL STOCHASTIC MOTIONS AND THE PROBLEM OF DIFFERENTIAL ROTATION FOR UNRESTRICTED ROTATIONAL RATES

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Abstract. For dealing analytically with the problem of differential rotation we investigate the spatial dependence of the angular velocity in a rotating turbulent fluid. The original turbulence unaffected by the rotation is assumed to be two-dimensional, where the stochastic motions completely lie in the horizontal planes. From the expression describing the relation between the correlations of rotating and nonrotating turbulent fields the meridional flux of momentum is derived. The resulting rotational law is determined by using Bochner's theorem for homogeneous turbulence as well as the characteristic scales of the turbulence field considered. The conclusions are:

(a) The angular velocity Ω is increasing toward the outer layers.

(b) For $2\,\Omega \ll \omega_c$ (ω_c frequency of turbulent mode) the Biermann-Kippenhahn-theory of anisotropic viscosity is deduced. An equatorial acceleration is only caused by a meridional circulation.

(c) For $2\,\Omega \lesssim \omega_c$ a latitudinal dependence of Ω is possible without any meridional circulation. If the two-dimensional eddy viscosity is negative the equatorial regions are accelerated. The expression for the two-dimensional eddy viscosity which has been derived earlier allows negativity in contrast to that for three-dimensional eddy viscosity. The scale length and the scale time of supergranulation as well as of giant cells lead to negative two-dimensional eddy viscosity.

Ward's observations including a negative sign of the two-dimensional eddy viscosity might represent an independent argument supporting the theory.

Our results agree with Gilman's (1972) numerical approach.

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DISCUSSION

Stix: The anisotropic turbulent viscosity used by Biermann and Kippenhahn was based on *gravity*, whereas here *rotation* introduces the preferred direction. I wonder whether both effects have similar consequences.

Krause: There is a misunderstanding: Here as with Biermann (1951) the anisotropic behaviour is caused by *both* the gravity *and* the angular velocity.

Durney: You seem to favour Biermann-Kippenhahn's theory of differential rotation based on an anisotropic viscosity. This theory predicts an angular velocity decreasing inward. How do you conciliate this with your dynamo theory?

Krause: This question tends in the direction of one of the dilemmas noted by Dr Parker, which have given rise to many discussions during this meeting. The theories of differential rotation only take into account the convective shell. It may be possible that the core under the convection zone may rotate a bit faster, since the surface of the Sun is (and has been all the time) decelerated by the solar wind.

Bumba and Kleczek (eds.), Basic Mechanisms of Solar Activity, 301–302.

Durney: If I remember correctly Iroshnikov has considered a similar problem. Biermann's and Kippenhahn's anisotropy is between the turbulent viscosity parallel and perpendicular to gravity. It appears to me the inclusion of vertical motions is very important.

Krause: This is true. But the discussion of pure two-dimensional motions provides for very clear statements. The situation is not completely changed, if to a certain degree vertical motions are taken into account.

Vandakurov: I should like to add that the averaged force produced by the convective motions I have spoken about is the result of the correlation between the radial and azimuthal velocities. It is therefore important to consider radial fluctuations.