Differential rotation and stellar convection

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G. Rüdiger. *Differential Rotation and Stellar Convection of Sun and Solar-type Stars.* Akademie-Verlag, Berlin, 1989, pp. 328.

The author of the book G. Rüdiger is a well-known physicist from the GDR working in the field of solar physics. The book is devoted to an investigation of the nature of differential rotation which exists in the sun and, possibly, also in other stars.

The differential nature of the rotation of the sun was discovered in the last century from the motion of sun spots. This phenomenon consists of the fact that the equatorial regions of the sun rotate faster than those at higher latitudes. Without some kind of a mechanism or mechanisms maintaining the nonuniformity of rotation the angular velocity must be the same at all latitudes (rigid-body rotation). The idea of writing the book was born in the course of conversations of the author with the well-known American scientist Professor P. H. Roberts who in 1982 suggested writing a book on the nature of differential rotation. At first G. Rüdiger rejected this idea, since at the time (and even now) there was no clear idea as to what mechanism might effectively transport angular momentum into the equatorial regions and thereby maintain the nonuniformity of rotation. However, later a compromise solution was adopted to give in the book a review of all the existing models of this phenomenon.

Part I of the book begins with a brief review associated with the history of the discovery of differential rotation of the sun. It also presents the main ideas proposed to explain this phenomenon. The first models of generation of differential rotation refer to the decade of the fifties of our century. The idea is that the source of the nonuniformity of rotation is the anisotropy of the viscosity stress tensor associated with the subphotospheric turbulence excited by the flux of heat coming from the deep regions of the sun. But in fact the subphotospheric small-scale motion is due to the convective motions of different scales. The problem consisted in determining under what conditions is it possible to pump energy from the small-scale convective motions into the energy of the large-scale differential rotation. It turned out that such a process is possible under the conditions of the rotating convective shell when under the action of the Coriolis force a transport of angular momentum in the direction of the equator takes place.

Part II is the main part of the book. In it on the basis of the theory of hydrodynamic turbulence a detailed discussion is given of the different sources of differential rotation. With this aim in mind a system of differential equations of hydrodynamics for a rotating spherical shell is investigated. An estimate is made of the efficiency of the transport of angular momentum in the case of different dimensionless parameters characterizing rotation, the thickness of the convective zone, the viscosity, the density, etc. It turned out that in the shell in addition to the differential rotation there is also a possibility of generating nonuniform distributions of temperature and density of the gas, and also of the meridional circulation. The appearance of these nonuniformities in the equations is due to the action of nonlinear terms which describe the redistribution of the quantities indicated above in the convective shell. Here also a discussion is given as to what must be the generated structure of the differential rotation so that the region of generation of magnetic fields in the shell would be displaced with time in the direction of the equator which corresponds to the direction of the drift of the zone of sun spot formation in the course of a solar cycle. With this aim in mind the book presents the appropriate analysis of equations of magnetic hydrodynamics describing the generation of magnetic fields ($\alpha\Omega$-dynamo model).

Part III presents the theory of transport of angular momentum by turbulence which is illustrated by simple models. To a considerable extent this part is devoted to the technique of calculating the stress tensor in a turbulent medium with which the appearance of the differential rotation is then associated.

On the whole the book gives quite a complete idea about the theories and modern models describing the differential nature of rotation of stars. It can be of interest for a wide circle of physicists and astrophysicists.