VI. EFFECTS OF ROTATION, MAGNETIC FIELDS AND EXTERNAL GRAVITATIONAL FIELD

The progress of our knowledge of actual stars, of their formation and of their evolution is somewhat hampered by the complexities raised by the effects of rotation, magnetic fields and external gravitational fields (binaries) at least when the intensity of the corresponding forces becomes appreciable.

These complexities are of two main types. Even if these fields of forces are reduced to their simplest models, quite serious difficulties are encountered in trying to build a hydrostatic configuration as soon as the density is allowed to vary with depth as is well illustrated by the considerable and not too successful efforts devoted to the classical problem of the heterogeneous incompressible fluids in uniform rotation. The second type of difficulties of a more physical character arises when the thermodynamical properties of an actual gaseous star are taken into account allowing the establishment of thermal baroclinic fields generating secondary circulations.

A renewal of interest in the first type of problems seems to have developed recently. Chandrasekhar and Lebovitz (**1**) have discussed the integral relations yielded by the second-order virial equations for uniformly rotating configurations and Chandrasekhar and Roberts (**2**) have used them, in the case of a slow rotation, to set up upper and lower bounds for m/ϵ_R where m is the ratio, at the equator, of the centrifugal to the gravitational accelerations and ϵ_R the ellipticity of the external surface. Roberts (**3**) has built approximate polytropic configurations in high uniform rotation assuming equidensity surfaces to be similar oblate spheroids and determining, by variational methods, the excentricity of these spheroids and the distribution of density. A detailed discussion of the polytrope of index $n = 1$ led him to the conclusion that bifurcation to a Jacobi form will occur for a critical compressibility corresponding to a value slightly less than $n = 1$ ($\gamma = 2$) which is only slightly larger than that of Jeans ($n = 0{\cdot}83$, $\gamma = 2{\cdot}2$). This discussion is generalized in another paper (**4**) in which the excentricity of the equidensity surfaces is allowed to vary. This type of problem allowing however for non-uniform rotation has also been tackled by R. Stoeckly (**5**) in Princeton. Kalitzin (**6**) has discussed some consequences of a cylindrical law of rotation (ω, function of the distance to the axis) both for the homogeneous and Roche's models and generalized some classical propositions. On his side, V. V. Porfiriev (**7**) has continued his studies of stellar models in rotation looking for stable stationary situations and evaluating the resulting circulations for different models.

Strong anisotropic viscosity such as may arise due to turbulence in the hydrogen convection zone can also produce meridional circulation and differential rotation as it has been shown by Kippenhahn (**8**) and Roxburgh (**9**) who finds that this gives rise to large scale motion towards the equator at low latitudes and towards the poles at high latitudes. Here we touch the second aspect of the problem referred to in the introduction and which has been the object of a detailed review by Mestel (**10**) which covers not only rotation but also the other factors susceptible to create such circulations. However before coming to this point, let us note first the articles of Wentzel (**11**) and Woltjer (**12**) in which the effects of a magnetic field on the shape of stars in static equilibrium are discussed.

The combined effect of rotation and magnetic fields have been further discussed by Mestel (**13**) who finds that in a rotating star, an initially poloidal field acquires a toroidal component which will lead to a steady increase of angular velocities towards the equator. In another paper with Roxburgh (**14**), it is shown that the Biermann effect (i.e. the building up of an appreciable toroidal magnetic field due to the electron partial pressure in a rotating star devoid initially of any magnetic field) is much reduced by the presence of a primeval magnetic field with a weak poloidal component. Roxburgh (**15**) finds that in radiative zones in presence of arbitrary angular velocity and magnetic fields there are only two steady solutions: (1) uniform rotation maintained by a weak magnetic field and Sweet circulation currents, (2) dominant toroidal field and the splitting of the circulation into two zones allowing mixing between the convective

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core and the envelope. In absence of a poloidal field, one must distinguish two cases depending on whether the centrifugal force is larger or smaller than the magnetic force and the corresponding solutions are presented in different papers (**16**).

The effects of a magnetic field in a contracting star have been considered by Chvojková and Kohoutek (**17**) who find that a thick equatorial shell could be detached from the star. Schatzman (**18**) has persued his studies of the consequences of conservation of angular momentum and mass loss in presence of strong magnetic activity during star formation. In his lectures in Varenna (**19**), he has also discussed the effects of mass loss from the equator of a fast rotating star and made a first attempt to find the resulting meridan circulation.

A short review of the rotational, magnetic and tidal effects on the shape of a star and of the influence of the resulting circulations on the mixing between different parts of the star as their chemical composition varies in the course of evolution was presented by Kippenhahn (**20**) during the same course in Varenna.

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VII. GRAVITATIONAL INSTABILITY — ORIGIN OF STARS

A short but very pertinent review of the classical problem of gravitational instability as introduced by Jeans has been presented by S. Chandrasekhar (**1**) including the effects of a uniform rotation and a uniform magnetic field alone or in combination. Quite a number of papers have been devoted to generalizations of this problem to somewhat more complex situations. For

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