35. COMMISSION DE LA CONSTITUTION DES ETOILES

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INTRODUCTION

The following bibliographical review indicates the wide extent of research on the interior of the stars that has been carried out during the past three years. At the same time, this review makes apparent some striking deficiencies. Progress has been distressingly slow in efforts to follow systematically the evolution of stars after the onset of helium burning; the main difficulties appear to be of an applied mathematical nature, in spite of the availability of large computers. The theoretical curves for the HR-diagrams of clusters are still often not in full quantitative agreement with the observed ones, so that the consequent age determinations contain a little more insecurity than one might wish. The construction of stellar models in fast rotation—aiming towards the understanding of rotational instability such as that suggested by the T Tauri stars—does not seem to have been attempted as yet. Similarly, only very few investigators have attacked the problem of the internal structure of close binaries during their evolution. Last, but not least, the mechanism of mass ejection from red giants still does not seem to be understood. Nevertheless, much positive is to be reported, as follows.

BIBLIOGRAPHICAL REVIEW

General

General review articles have been written by M. H. Wrubel ('Stellar Interiors', *Handbuch der Physik*, **51**, 1, 1958) and E. M. Burbidge and G. Burbidge ('Stellar Evolution', *Handbuch der Physik*, **51**, 134, 1958).

Nuclear Energy Generation and Opacity

W. A. Fowler (*Mém. Soc. Sci. Liège*, 5th Series, III, 207, 1959) has reviewed the latest nuclear data for the proton-proton reaction as well as for the C-N cycle. He (*Ap. J.* **127**, 551, 1958) has also indicated the possibility of strong neutrino emission from reactions following the proton-proton reaction under special conditions.

B. Strömgren, A. Arking and J. Herring (in preparation) are re-determining the opacity for temperatures and densities occurring in the interior of early-type stars, including the effects of absorption lines. Similarly, a detailed evaluation of the effects of line absorption is being carried out by A. N. Cox (in preparation) for most of the temperature and density ranges of interest.

Convective Envelopes

St. Temesvary (*Mém. Soc. Sci. Liège*, 5th Series, III, 403, 1959) has discussed an upper limit for the turbulent velocities in stellar convection zones.

R. Kippenhahn, St. Temesvary and L. Kippenhahn (*Z. Ap.* **46**, 257, 1958) have recalculated convective envelopes for population II giants and have found the resulting radii highly sensitive to the assumed mixing length. E. Böhm-Vitense (*Z. Ap.* **46**, 108, 1958) has derived a number

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of convective envelopes, including some for red giants having zones in which the density increases outwards.

M. S. Vardya and R. Wildt (*Ap. J.* in press) have constructed models for M dwarfs on the basis of adiabatic envelopes previously produced by M. S. Vardya (*Ap. J. Suppl.* **4**, 281, 1960). These adiabates include the hydrogen molecule and improve the agreement with observations.

Pre-main-sequence Contraction

E. V. Kotok (*A. J. Moscow* **37**, 492, 1960) has pointed out that gravitationally contracting models fit well the observed faint stars in the Pleiades.

A. N. Cox *et al* (*A.J.* **65**, 486, 1960) have followed the pre-main-sequence contraction of a star of solar mass, including the deuterium burning. A. Boury (in press) has studied the contraction phases of very massive, pure hydrogen stars, with special attention to the early formation of carbon.

V. V. Sobolev (*A. J. Moscow* **37**, 387, 1960) emphasises the importance of non-stationary transfer of radiation in fast evolution phases such as the initial gravitational contraction.

P. Ledoux (*Bull. Acad. Belg.*, 5th series **46**, 429, 1960) has formulated the problem of secular stability of a star in exact equations.

Initial Main-Sequence

C. B. Haselgrove and F. Hoyle (*M.N.* **119**, 112, 1959) have compared in detail initial main-sequence models for populations I and II. A similar investigation was carried through by P. Demarque (*Ap. J.* **132**, 366, 1960) for a variety of compositions. M. Simoda (*Publ. Astr. Soc. Japan* **12**, 124, 1960) has criticised the opacity formulae used in some of these investigations.

D. N. Limber (*Ap. J.* **127**, 363 and 387, 1958) and K. Kaminisi (*Kumamoto J. Sci.*, A, **4**, 11 and 229, 1960; *Publ. Astr. Soc. Japan*, in press) have investigated the structure of faint red dwarfs.

D. Ezer (*Ap. J.* **133**, 159, 1961) has constructed models for massive stars of pure hydrogen which might represent the first stars formed in a galaxy.

Early Evolution Phases

R. L. Sears (*Ap. J.* **129**, 489, 1959; *Mém. Soc. Sci. Liège*, 5th Series, III, 479, 1959) has derived a detailed evolutionary model sequence for the Sun. A. G. Massevitch and T. A. Volkonskaja (*A.J. Moscow* **37**, 42, 1960) have constructed a detailed model of the Sun.

S. Sakashita and C. Hayashi (*Prog. Theor. Phys.* **22**, 830, 1959) have derived a model sequence for the main-sequence phases of a star of 47 solar masses. The same has been done by S. Sakashita, Y. Ono and C. Hayashi (*Prog. Theor. Phys.* **21**, 315, 1959) for a star of 16 solar masses, and by M. P. Savedoff and S. R. v. Dyck (*Mém. Soc. Sci. Liège*, 5th series, III, 523, 1959) as well as J. Uchida (*Sci. Rep. Tohoku Univ.*, Ser. I, **43**, 171, 1959) and Y. Iinuma (*Sci. Rep. Tohoku Univ.*, Ser. I, **43**, 232, 1959) for a star of 10 solar masses.

L. G. Henyey *et al* (*Ap. J.* **129**, 2, 1959) have derived model sequences for the main-sequence phases of stars from 1·5 to 30 solar masses, by a method developed by L. G. Henyey *et al* (*Ap. J.* **129**, 628, 1959). The results are used to derive new ages for a number of galactic clusters. Similarly, F. Hoyle (*M.N.* **120**, 22, 1960) has derived evolution sequences for stars from 1·5 to 30 solar masses and has obtained with their help the age of the Scorpio-Centaurus group.

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F. Hoyle (*M.N.* **119,** 124, 1959) has recomputed evolutionary model sequences for population I and II stars of appropriate masses and thus provided a much improved basis for the age determination of old galactic clusters and of globular clusters. A. Reiz and I. Torgård (in preparation) have derived a detailed evolutionary model sequence for stars containing no heavy elements.

Advanced Evolution Phases

C. B. Haselgrove and F. Hoyle (*M.N.* **118,** 519, 1958) have followed the evolution of a population II red giant, with increased accuracy.

R. Harm and M. Schwarzschild (*A.J.* in press) have followed through in detail the helium flash in population II red giants. In contrast H. Yamazaki *et al* (*Prog. Theor. Phys.* **21,** 354, 1959) have come to the conclusion that the temperature in the brightest red giants of population II is too low for helium burning.

C. Hayashi, J. Jugaku and M. Nishida (*Prog. Theor. Phys.* **22,** 531, 1959), M. Nishida (*Prog. Theor. Phys.* **23,** 896, 1960) and C. Hayashi and R. C. Cameron (in preparation) have found the advanced models with hydrogen and helium burning in different zones highly sensitive to the assumed conditions.

Z. Hitotuyanagi and K. Suda (*Publ. Astr. Soc. Japan* **10,** 8, 1958 and **12,** 21, 1960), and M. Simoda and S. Obi (*Publ. Astr. Soc. Japan* **10,** 26, 1958) have investigated inhomogeneous models with isothermal cores.

Final Stellar State

E. Schatzman (*Handbuch der Physik* **51,** 723, 1958) has reviewed the theory of white dwarfs.

A. G. Massevitch (*A.J. Moscow* **36,** 794, 1959) has discussed stellar models with partially degenerate cores as representing white dwarfs.

T. A. Emin-Zade (*C. R. Azerbaidzhan Ac. Sc.* **15,** no. 11, 1005, 1959) has derived the total energy of a white dwarf in the limiting case of relativistic degeneracy.

J. P. Cox and E. Salpeter (*Ap. J.* in press) have shown that models of helium stars with modest hydrogen envelopes can represent the observed pre-white-dwarf stars.

E. Schatzman (*Mém. Soc. Sci. Liège*, 5th series, III, 320, 1960) has pointed out the possible instability of a white dwarf caused by hydrogen accretion.

Rotation and Binaries

V. V. Porfinyev (*A.J. Moscow* **36,** 546, 1959; *Bull. Lwow Obs.* no. 35-36, 1959) has investigated the rotation of polytropes.

R. Kippenhahn (*Z. Ap.* **46,** 26, 1958) has emphasized the strong dependence of the meridional circulation in rotating stars on the deviations from solid-body rotation.

N. Baker and R. Kippenhahn (*Z. Ap.* **48,** 140, 1959) and R. Kippenhahn (*Z. Ap.* **48,** 203, 1959) have shown that the meridional circulation in the layers near the stellar surface is much faster than earlier assumed. L. Biermann (*Symp. IAU* **6,** 248, 1958) and R. Kippenhahn (*Mém. Soc. Sci. Liège*, 5th Series, III, 403, 1959) have estimated the time scale of the meridional circulation in the convective envelope of the Sun to be some ten years.

J. Crampin and F. Hoyle (*M.N.* **120,** 33, 1960) have determined the phases of maximum rotational instability during the evolution of a star.

D. C. Morton (*Ap. J.* **132,** 146, 1960) has found that the evolutionary mass exchange in close binaries generally will occur at a rate governed by the Kelvin time scale. M. Kitamura

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(*Publ. Astr. Soc. Japan*, **12,** 1, 1960) has investigated the effects on the structure of the secondary component in a binary by the mass gained from the primary.

V. A. Krat (*Pulkovo Bull.* **21,** no. 163, 106, 1960) has analyzed the effect of mass ejection on the evolution of close binaries.

Pulsations and Shock Waves

Review articles have been written by P. Ledoux (*Handbuch der Physik* **51,** 605, 1958) on 'Stellar Stability' and by P. Ledoux and Th. Walraven (*Handbuch der Physik* 51, 353, 1958) on 'Variable Stars'.

S. A. Zhevakin (*A.J. Moscow* **36,** 269, 1959; *ibid* **36,** 394, 1959; *ibid* **36,** 996, 1959; *ibid* **37,** 443, 1960) has continued his investigation (started in 1953) of the energising of stellar pulsations by the second ionization zone of helium, with highly encouraging results. J. P. Cox and C. A. Whitney (*Ap. J.* **127,** 561, 1958) and J. P. Cox (*Ap. J.* **130,** 296, 1959; *Ap. J.* **132,** 594, 1960) have carried out a detailed study paralleling that of Zhevakin, again with positive results.

P. Ledoux and A. Boury (in preparation) have determined the vibrational instability of pure hydrogen stars.

P. Ledoux (*Ap. J.* **128,** 392, 1958) returned to the problem of the double periodicity of Beta Chephei stars. I. Ottelet (*Ann. Astrophys.* **23,** 218, 1960) has studied the non-radial oscillations of the Roche model, including slow rotation.

S. A. Kaplan and I. A. Klimishin (*A.J. Moscow* **36,** no. 3, 1959; *ibid* **37,** no. 2, 1960; *Mém. Soc. Sci. Liège*, 5th series, III, 296, 1960) have studied shock waves in stars, with special attention to the effects on the radiation field. Y. Ono *et al* (*Prog. Theor. Phys.* **23,** 294, 1959 and **24,** 155, 1960) have investigated shock waves in inhomogeneous layers.

Mass Ejection

T. J. Cowling and F. T. Rubbra (*Mém. Soc. Sci. Liège*, 5th Series, III, 274, 1959) have critically reviewed various suggested processes for mass ejection.

V. G. Fesenkov and G. M. Idlis (*Ann. Astrophys.* Suppl. no. 8, 113, 1959) have assembled arguments in favor of corpuscular radiation as an important phenomenon during the early evolution phases of massive stars. A. G. Massevitch (*Ann. Astrophys.* Suppl. no. 8, 109, 1959) has compared evolution with and without mass ejection for massive main-sequence stars.

I. S. Shklovsky (*A.J. Moscow* **36,** 579, 1959) has discussed the recent rocket observations of ultra-violet nebulous emission under the hypothesis of strong corpuscular emission from hot stars.

E. N. Parker (*Ap. J.* **132,** 821, 1960) has developed a detailed model for the solar wind arising from the solar corona.

S. V. Rublev (*A.J. Moscow* **36,** 73, 1959) has considered the possible outflow of matter from late super-giants. R. Weymann (*Ap. J.* **132,** 380, 1960) has investigated mass loss from red giants by coronal evaporation, with negative results.

Origin of Stars

The theories of the origin of stars have been reviewed and re-analysed in detail in three essays, the first by R. Ebert, S.v. Hoerner and St. Temesvary, the second by F. Kahn, and the third by G. and E. M. Burbidge (*Die Entstehung von Sternen durch Kondensation diffuser Materie.* Springer Verlag, Berlin, 1960).

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I. M. Kopylov (*A.J. Moscow* **35,** 390, 1958) has pointed out in detail the similarity of groups of young stars with the system of diffuse interstellar matter. E. A. Dibai (*A.J. Moscow* **35,** 469, 1958) has shown that the contraction of a globule may be promoted by shock waves caused by nearby hot stars.

L. Biermann and L. Davis (*Z. Naturf.* **13a,** 909, 1958) as well as St. Temesvary and S. v. Hoerner (*Z. Ap.* **49,** 30, 1960) have investigated the relations between the frequency of white dwarfs, the amount of interstellar matter and its helium content and the rate of star formation.

V. A. Ambartsumian and G. S. Saakyan (*A.J. Moscow* **37,** 193, 1960) have investigated the possible origin of stars from matter in a super-dense state.

L. Mestel (*M.N.* **119,** 223, 1959; *M.N.* **119,** 249, 1959) has investigated the effect of stellar magnetic fields on the accretion rate and on the loss of angular momentum. E. Schatzman (*Technical Report* no. 3, Mt. Wilson and Palomar Obs., 1960) has discussed the loss of angular momentum by magnetic activity during the pre-main-sequence phases.

L. Mestel (in preparation) has studied the gravitational instability of a rotating disk, with a view towards the formation of binaries.

Origin of Elements

H. Reeves and E. E. Salpeter (*Phys. Rev.* **116,** 1505, 1959), C. Hayashi *et al* (*Prog. Theor. Phys.* **20,** 110, 1958 and **22,** 101, 1959) and A. G. W. Cameron (*Ap. J.* **130,** 429, 1959; *Ap. J.* **130,** 895, 1959) have continued the analysis of the beginning of the build-up of heavy elements based on carbon, as well as on neon and oxygen.

A. G. W. Cameron (*Ap. J.* **130,** 452, 1959) R. A. Becker and W. A. Fowler (*Phys. Rev.* **115,** 1410, 1959), M. Nishida *et al* (*Prog. Theor. Phys.* **24,** no. 3, 1960) and F. Hoyle and W. A. Fowler (*Ap. J.* **132,** 565, 1960) have studied further the nucleo-synthesis of the heavy elements.

E. Anders (*Ap. J.* **129,** 327, 1959) has critically reviewed the explanation of supernovae light-curves by nuclear decays.

W. A. Fowler and F. Hoyle (*Ann. Phys.* **10,** 280, 1960) have deduced from present isotope ratios the age of the heavy elements in the solar system.

B. Pontecorvo (*J. Exp. Theor. Phys.* **36,** 1148, 1959) has pointed out new reactions which may lead to violent neutrino emission in advanced evolution phases.

A. G. W. Cameron (*Ap. J.* **130,** 884, 1959; *Ap. J.* **130,** 916, 1959) and E. E. Salpeter (*Ann. Phys.* **11,** 393, 1960) have studied nuclear reactions and stellar models at very high density.

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