36. COMMISSION DE LA THEORIE DES ATMOSPHERES STELLAIRES

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I. INTRODUCTION

Commission activity between the assemblies. The third informal colloquium of the Commission (previously: Sub-Commission 29*a*) was held at Herstmonceux Castle on 15 and 16 August, 1962, on the theme: Transfer of Radiation in Stellar Atmospheres (**1**). There were 37 participants, and 22 communications. About half of the time was used for discussions following the presentations. Two afternoons were completely given to guided discussions. After three colloquia of this kind we are more and more convinced of the advantages of such small working meetings on restricted topics, over the modern giant meetings where everything is discussed by everybody.

Symposium no. 26 of the IAU, on 'The Determination of Spectral Abundances', will be held in Utrecht under the auspices of Commissions 29 and 26, from 10–14 August, 1964.

Other colloquia, partly or wholly dealing with the theory of stellar atmospheres were:

The symposium on the Solar Spectrum held from 24–31 August 1963 in Utrecht, on the occasion of the retirement from active duties of Prof. Minnaert, the first President of the Sub-Commission.

The working colloquium on stellar atmospheres, held 20–22 January 1964 at the Smithsonian Astrophysical Observatory, Cambridge, Mass.

For books and reviews published during the report period, see section I of the bibliography. In this list an attempt has been made to cover material published between 1 January 1961 and 31 December 1963.

II. THE THEORY OF STELLAR ATMOSPHERES

(*a*) *Theory of radiative equilibrium.*

Investigations of the mathematical problem of the transfer of radiation in semi-infinite plane-parallel layers of gas have been continued by several groups, in particular by Ueno *et al*, and by Sobolev *et al.* A certain part of these investigations refers to atmospheres with a reflective bottom, and belongs to the field of planetary astrophysics; these investigations are not mentioned in the list of references. The severe, and—for the greater part—intolerable, approximations that have to be introduced to make the problem analytically treatable make one doubtful of the

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value of the above-mentioned investigations for the problem of radiative transfer in real *stellar atmospheres*; naturally this statement does not imply a judgement on the *mathematical* and the heuristic value of these investigations.

For increasing our insight into the real structure of stellar photospheres much more is to be expected from the large computational programs existing nowadays in several institutes, where the detailed values of the functions $\kappa(\nu)$, $\sigma(\nu)$, $P_e(P_g, T)$ and $\mu(P_g, T)$ are taken into account, where the source function is computed exactly, and where an attempt is made to have the radiation flux constant to $\pm$ 1% or less (Swihart; Underhill (**42–45**)). Hollweger and Unsöld (**18**) showed that in radiative models the constancy of the radiation flux required for 1% accuracy in the temperature distribution is:

for:	$\bar{\tau}$ = 0·01	0·1	1·0
of the order of:	0·03%	0·3%	2·5%

(*b*) *Theory of the mechanical energy flux; convection and turbulence; pressure and shock waves; hydromagnetism.*

While on the one hand the theory of radiative equilibrium of stellar atmospheres is reaching a high degree of perfection, there is increasing evidence that in quite a number of cases parts of the stellar atmospheres, and even parts of the photospheres, are not in radiative equilibrium but that a flow of mechanical energy plays a certain part in the energy balance of the atmosphere. For the Sun this flux and its variation with height is approximately known; we also have some rough ideas about the mechanisms of its origin in the solar convection zone of its subsequent decrease in intensity due to absorption and reflection. But these ideas have hardly been applied to stars; moreover the source of the observed turbulent motions in early-type main-sequence stars (see **36**), where no convection is to be expected, is unknown and has not been examined during the report period.

The theoretical investigations made during the report period have given more insight into the regions in the Hertzsprung-Russell diagram where convection occurs (**25**). Böhm (**6, 7**) found that solar convective motions with a horizontal scale larger than 6000 km 'overshoot' up to the middle chromosphere; he thus paved the way to the solution of the very old problem of the occurrence of the chromospheric coarse mottling. The generation of pressure waves has been re-examined, but now for an atmosphere in a gravity field (**38, 15, 16**). A number of investigations deal with the heating of outer stellar envelopes by shock waves (**30**); many of them refer to variable stars (**1–3**) and to unstable stars (**8, 40**); see further Schatzman's review (**27**). A few investigations refer to the heating by gravitational waves and to magneto-hydrodynamic waves in the solar atmosphere (**9**); see further J. W. Evans: *The Solar Corona*, and the Report of the President of Commission 12.

(*c*) *Stellar chromospheres and coronas; extended atmospheres; mass loss.*

We have omitted from this review all that is concerned with the spectrum of the solar chromosphere and corona; this is dealt with completely in the report of the President of Commission 12. Also the solar wind, though belonging to the field of this report, is only mentioned; a full coverage is neither attempted nor desirable.

Some work has been done on extended atmospheres (**1, 6, 7, 10**) and on nova-envelopes. Mustel (**11**) attempted to explain the observed acceleration of nova envelopes by the hypothesis that an intense cosmic ray flux is generated in the nova's envelope before the light maximum. Gorbatsky (**4**) assumed the pressure of the gaseous streams ejected by the star to be the main factor acting on the envelope. The luminescence behind the shock wave front has been studied.

The general problem of solar and stellar winds was treated by Parker (**12**), following his earlier work on the solar wind. The velocities are supersonic up to 10–10^3 A.U. from the star;

there a shock front is found. The motion is subsonic in the outer regions. Similar problems were discussed by Minin (**10**) and Klimishin (**8**). The great acceleration of particles often observed in solar phenomena is thought to orginate in shock fronts; Schatzman gave a theoretical discussion (**13**).

III. SPECTRAL LINES

(*a*) *Astrophysical effects producing broadening of spectral lines*

We do not intend to summarize work on the pure physical parameters defining the width of a spectral line: the important work done on damping constants should rather belong to the field of a Commission like Commission 14. The few investigations dealing with the astrophysical broadening are referred to in section III(*a*) of the bibliography.

(*b*) *The source function in a spectral line.*

The Meudon group found more evidence for the occurrence of deviations from local thermodynamic equilibrium in the solar and stellar *photospheres*; see in particular (**2, 5, 10, 13**), and also the remarks by Unsöld (**21**). It is the present reviewer's opinion that this problem has not yet been solved completely and is waiting for a rigorous treatment on the basis of the best available observational material. One has not always taken into account the influence of photospheric *motions* well enough in deriving the so-called deviations from LTE (in this concept, deviations from LTE are defined as cases for which $S \neq B$).

The influence of noncoherent scattering on the source function was treated by Uesugi in a series of papers (**18, 19, 20**). Thomas and Zirker (**15, 16, 17**) and Ch. Pecker-Wimel and Thomas (**12**) continued their investigations on the source function in chromospheric or extended atmospheric conditions. See on this subject also (**7, 11, 14**).

(*c*) *The computation of spectral line intensities in stellar spectra.*

Electronic programs for the computation of line profiles in stellar spectra have been described by Baschek and Traving (**1**) and by Underhill (**28, 29**). The method of weighting functions has been revised and extended by Gussmann (**8**) and Elste (**4**). The influence of re-distribution on line profiles was investigated by Ivanov (**12–14**) and Giovanelli (**5**).

The extreme ultra-violet spectrum of the Sun was discussed by Koyama (**17**) and Ch. Pecker-Wimel and Rohrlich (**20**). For the extreme UV of the stars, see J.-C. Pecker (**21**), Pottasch (**22, 23**) and Underhill (**27, 28**).

Studies referring to spectral lines in a magnetic field include those of Boyarchuk (**3, 13**), Račkovskij (**24, 25**) and Michard (**19**).

IV. THE STRUCTURE AND COMPOSITION OF STELLAR ATMOSPHERES

(*a*) *The computation of model photospheres; special series of models.*

Theoretical model atmospheres have how been calculated at various institutes. In all cases the models were computed according to the criterion of constant flux; for more sophisticated models the theory has not yet far enough advanced.

A short summary of available recent models is as follows:

Temperature or spectral type	Other characteristics	Number of models	References
3500° — 7000°	metals/H: 0·01 to 1·0; log g = 4·5	40	(**2**)
4200 — 8400°	log g = 4·1 and 4·44		(**8**)
B9 — O9	log g = 4; 3·7 and 4	14	(**10**)
40 000 — 200 000°	log g = 4·2; 4·8 and 6·0	3	(**3**)

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(*b*) *The empirical determination of stellar atmospheric structure.*

We give a list of stars for which photospheric parameters have been determined:

Star	*Ref.*
γ Ori	(1)
α Cyg	(7)
κ Cas	(8)
B and Be stars (only *g*-values)	(9)
γ Ser	(12)
HD 30353	(16)
τ Ceti	(17)
HD 122563	(17)
β Peg	(27)
Extreme population II *stars:*	
HD 140283 (sub-dwarf)	(2)
RR Lyrae stars	(10)
Some other types of stars	
white dwarfs	(25)
S type stars	(21)
31 Cyg	(4)
ζ Aur stars	(11)

(*c*) *Abundances*

We summarize some results about which reports were obtained:

Star	Element(s)	Results	References
Sun and stars	FeII		(1)
ϵ Vir (G9 III)		Abundances as in the Sun; Na over-abundant	(2)
99 Her	metals	under-abundant	(5)
7 stars	metals/H		(6)
metallic line stars			(7)

C. DE JAGER

President of the Commission

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