two periods. One of 2·5 years applies as far as the emission of Hα is concerned, the other involving profile variations of the Hα line is a little more than a day.

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## 29*a*. SOUS-COMMISSION POUR LA THEORIE DES ATMOSPHERES STELLAIRES

### Report of Meetings

PRESIDENT: C. de Jager.
SECRETARY: Anne B. Underhill.

### Business meeting, 18 August 1961

The President, C. de Jager, announced that the Secretary would be A. B. Underhill. Names of the Vice-President and members of the organizing Committee for Commission 36 (which is the new form of the Sub-Commission) have been submitted to the Executive Committee for confirmation. The following were later appointed:

Vice-President: K. H. Böhm

Organizing Committee: E. R. Mustel, R. N. Thomas, A. B. Underhill, H. van Regemorter, M. H. Wrubel

After the *Draft Report* had been adopted with minor corrections, the President reviewed the colloquia which were organized in 1959 and in 1960 under the auspices of Sub-Commission 29*a*.

A. B. Underhill reported on the Progress of the Working Group on Nomenclature which is under the chairmanship of M. Rudkjøbing. Attention was directed towards the need for a single, clear system of notation for the mass absorption and scattering coefficients and for related quantities such as the optical depth. It was decided that the work of this Group should continue and that attempts be made to clarify further the notation used in transfer theory. It was recommended that roman or italic letters be used so far as is possible rather than greek letters.

M. H. Wrubel, chairman of the Working Group on Co-operation in the Exchange of Computer Information relating to Stellar Atmospheres, gave a brief report. The problem

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of exchange is made difficult by the rapid change in computing facilities at many institutions, by the rather short life-time of most programs, and by the unfortunate fact that programs are usually created by one person who frequently does not describe the program adequately in a report. The result is that if the key person is not available, the program cannot be used. Nevertheless, it was decided that it would be profitable to compile and distribute a list of persons working on the problems of stellar atmospheres with electronic computers, and to give in this list information about the type of equipment available at each institution and the chief areas of interest. Wrubel will prepare this list.

Seaton remarked that much basic data on absorption coefficients have been computed, but that such information is not generally available. He suggested that the problem of making such fundamental data available be explored. Ueno reported work being done by himself and others at the Rand Corporation, Santa Monica, on obtaining numerical solutions of the time-dependent, integro-differential equations for diffuse reflection. Some of this material will appear in a book on radiative transfer that is being prepared by this group.

## Scientific meetings

Two scientific sessions were held: one on solar problems and one on stellar problems. Abstracts of the invited introductory talks follow together with a summary of the discussion.

### THE RELATIVE VALUE OF THE VARIOUS PHOTOSPHERIC MODELS

*A. K. Pierce*

Homogeneous models of the solar atmosphere represent the observed limb-darkening and energy distribution within the errors of observation, that is within about one per cent for limb darkening and within about five per cent for the energy distribution, for all wave-lengths between 3200 Å and 26000 Å. Conversely, the observations determine the mean temperature distribution to limits of $\pm 50^\circ$ between optical depths 0·1 to 2·0. The uncertainties rise to $\pm 500^\circ$ at the boundary and at optical depths greater than $\tau = 3{\cdot}0$.

Several non-homogeneous models have been set forth. These represent solar granulation and limb darkening satisfactorily, but are subject to further refinement in the light of our present knowledge of granulation.

Solar models can only be improved by further observations of energy distribution, of limb darkening at the extreme limb, and of granulation. Theoretical studies of convection processes are needed.

The high photosphere can only be determined from the analysis of eclipse observations or from balloon work. Pagel's work indicates a temperature minimum at $\tau = 0{\cdot}01$ with a value of 4300 °K. $\pm$ 100°.

*Unsöld* gave a schematic diagram to show that a model based on the solar continuum is not sufficiently well-defined to be of use for interpreting medium and strong lines. He also remarked that the accuracy necessary in the constancy of the flux varied with depth in the model. The desirable accuracy for a spectral feature formed above the layer $\tau$ is of the order of $\tau$.

*De Jager*, *Rösch*, *Suemoto*, and *Gaustad* reported observations showing that the curve of limb darkening becomes irregular very near the limb. It is difficult to correct for scintillation, but it seems that these observations will help to define the upper part of the solar models more accurately and in particular give information on the temperature law in the outermost layers.

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### EMPIRICAL METHODS IN PHOTOSPHERIC STUDIES

*J.-C. Pecker*

Three types of data can be used: continuum (to obtain models), line total intensities (to obtain abundances), and line profiles (to obtain data on velocity fields). Line intensities and line profiles must be used in an iterative process to yield both abundances and velocities.

Several methods are available for exploring the physical properties of an atmosphere in depth. They may be summarized as follows:

(*a*) several lines of a given multiplet will give information on the depth dependence of the source function in a line,

(*b*) limb darkening will give information about the source function and on temperature inhomogeneities or optical roughness,

(*c*) profiles will give information about the source function and about velocity fields.

Recent results from the detailed analysis of solar spectra are summarized schematically in Figures 1 and 2 which show temperature $T$ plotted against log $\tau$. The line labelled $T_e$ gives

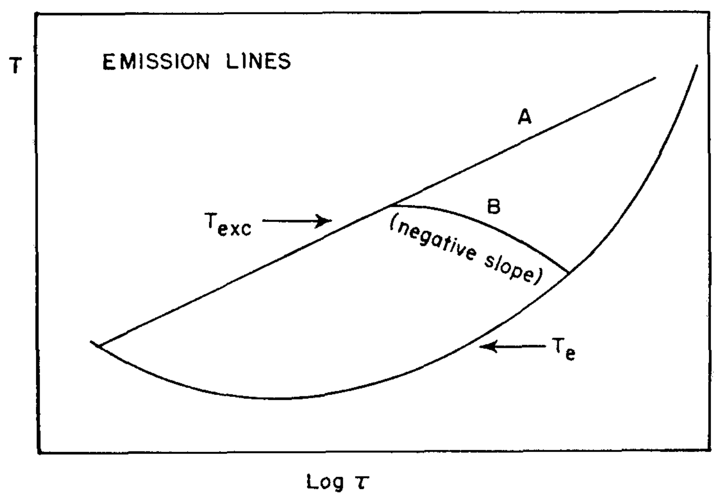


Fig. 1. A schematic diagram of temperature against log $\tau$ in the solar atmosphere. See text for description.

the variation of the electron temperature with depth. In each figure line A represents the variation of the excitation temperature with depth which is deduced from the central intensities using several lines of a multiplet; lines B represent the temperature law deduced from profile analysis at different values of $\mu$; line C represents the results from limb darkening. The cores of the lines are formed at higher levels (log $\tau$ small) than are the wings. Attention is directed to the negative slope of line B in the case of emission lines.

A lively discussion followed regarding the significance of the so-called departures from LTE. On the observational side, Waddell, Unsöld, Müller, Goldberg and Suemoto reported analyses of certain lines in the solar spectrum indicating that it is very difficult to detect possible departures from LTE. Athay reported observations of Mg I lines which suggest that large departures from LTE occur in both directions, *i.e.* $T_{exc} < T_e$ and $T_{exc} > T_e$. It

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was concluded that lines from levels of high excitation probably yield good abundances, but that the abundance estimates made from lines of low excitation may be uncertain owing to departures from LTE. The problem of estimating how valid it is to assume that LTE occurs was also discussed from the theoretical side. Seaton observed that one should consider the cross-sections for collision with atoms, ions and molecules as well as the cross-section for collision with electrons when estimating the populations of upper levels, for the first three types of collision may dominate over radiation processes and electron collisions for filling excited levels. It is certain that departures from LTE do occur at some level in an atmosphere since radiation does escape, and theories for strong lines should take account of this.

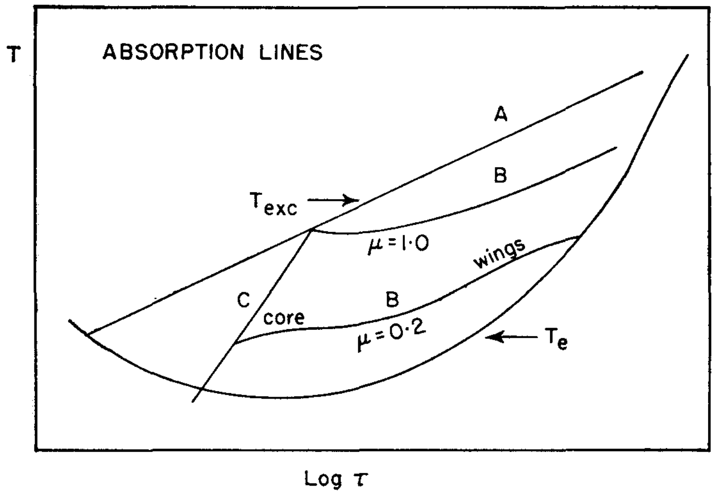


Fig. 2. A schematic diagram of temperature against log $\tau$ in the solar atmosphere. See text for description.

## COMMENTS ON THE METHODS OF ANALYSING STELLAR ATMOSPHERES

*Anne B. Underhill*

At this time with fast, large-memory computers becoming readily available, the method of model atmospheres is being developed rapidly. Swihart and Gingerich are developing methods useful for solar-type stars. Underhill is developing methods suitable for O and B type stars.

Two problems exist: (1) to construct an acceptable numerical analogue of a stellar atmosphere, and (2) to predict the theoretical spectrum of the analogue in sufficient detail that the analogue may be identified with a real star. Then abundances of the elements and other physical parameters of the star may be deduced.

The numerical procedures for forming early-type model atmospheres were summarized. Most of the work relates to solving the equation of transfer with adequate rigour yet with a method that is sufficiently flexible for the actual values of the absorption and scattering coefficients to be preserved. The physics of the interaction of radiation with matter is simplified to the case of absorption and emission under local thermodynamic equilibrium and coherent, isotropic scattering.

When a model is identified with a real star it is essential that those levels of the model are identified in which the part of the spectrum under study is formed. It is not easy to identify early-type models because of the paucity of suitable observed line intensities, etc.

### THE THEORY OF EXTENDED ATMOSPHERES

*L. H. Aller*

It is pretentious to speak of a theory of extended stellar envelopes since except in a few limiting cases all one can do is to propose hypotheses that may be helpful in assessing some special set of observations. The principle types of object are: (1) late-type giants and super-giants including objects such as Cepheids, irregular and long-period variables; (2) circum-stellar envelopes around binary stars; (3) novae; (4) combination variables; (5) Be, Of, and Wolf-Rayet stars; (6) stars with extremely tenuous outer envelopes such as planetaries; and (7) stars in the process of formation.

Theoretical analyses of extended envelopes are based on some sort of an assumed model. A preliminary geometrical picture is established from qualitative and quantitative data concerning the general level of excitation of the spectrum, line shapes and displacements. The geometrical model is linked with a physical model by adopting mechanisims of energy input and dissipation. In most models the hydrodynamical and kinematical aspects of the problem must be considered. Magnetic fields are almost surely important in orderly expanding envelopes such as planetary nebulae. So far only rather primitive models and theories have been discussed, particularly for the combination variables where departures from thermodynamic equilibrium appear to be large.

## 29*b*. SOUS-COMMISSION DES ETALONS D'INTENSITE DE RAIES

### Report of Meeting, 19 August 1961

PRESIDENT: K. O. Wright.
SECRETARY: J. Houtgast.

The President in his introductory remarks noted that, although this would be the last meeting as a Sub-Commission of Commission 29, the need for inter-observatory comparisons of line intensities seemed to be as great as ever. In the discussion of the *Draft Report*, Miss Underhill thought that some of the lower values of equivalent widths obtained by photo-electric spectral scanning might be the result of the relatively short scan in wave-length and the influence of absorption lines on the continuum.

Several short communications were presented:

1. *J. B. Oke* discussed the Photo-electric Scanning of Stellar Spectra at Mount Wilson Observatory. No results in addition to those listed in the *Draft Report* have yet been obtained, but it is possible that a dispersion of 1·1 Å/mm may be used in the future.

2. *N. J. Woolf* commented on the Fabry-Perot Monochromator that has been described by Geake, Ring and Woolf (*M.N.* **119**, 616, 1959) and that is now being tested at the Lick Observatory. Although no exact quantitative results have yet been obtained, the method appears to be very promising, especially for sharp interstellar lines.

3. *J. Houtgast* described the Photo-electric Scanning of Solar Lines at the Utrecht Observatory. The influence of spectral resolution on the equivalent widths of H$\delta$ and Ca I, $\lambda$ 4227 were investigated and appeared to be small. It was thought useful to continue this work and to include the effects that dispersion may have on equivalent widths when determined photo-electrically.

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