36. COMMISSION DE LA SPECTROPHOTOMETRIE

PRÉSIDENT: H. Kienle.

MEMBRES: Mlle Adam, MM. L. H. Aller, Barber, Barbier, Beals, W. Becker, Biermann, Brück, Mlle Busbridge, MM. Butler, Chalonge, Chandrasekhar, Code, de Jager, A. J. Deutsch, Mlle Divan, MM. Dufay, Gascoigne, Goldberg, Gratton, Greaves†, Greenstein, Gyldenkerne, Henyey, Hitotuyanagi, Houtgast, Hunaerts, Hunter, Mlle Iwanowska, MM. Järnefelt, R. B. King, Kourganoff, Kozyrev, Kuprevich, Labs, McCrea, Mlle J. K. MacDonald, MM. Melnikov, Menzel, Minnaert, G. Münch, Mustel, Neven, Öhman, Oke, Pannekoek, Pecker, Phillips, A. K. Pierce, Plaskett, Rahman, Righini, Rudkjøbing, Saha†, Sobolev, Spitzer, Stebbins, Strassl, Strömgren, Suemoto, ten Bruggencate, Thackeray, R. N. Thomas, Mlle Underhill, MM. Unsöld, Vandekerkhove, Wempe, Westerlund, Weston, Whitford, O. C. Wilson, R. Wilson, K. O. Wright, Wrubel.

36*a*. SOUS-COMMISSION DES ÉTALONS D'INTENSITÉ DE RAIES

PRÉSIDENT: K. O. Wright.

MEMBRES: MM. Butler, Greenstein, Hiltner, Houtgast, Melnikov, Plaskett, Righini, Wrubel.

36*b*. SOUS-COMMISSION POUR LA THÉORIE DES ATMOSPHÈRES STELLAIRES

PRÉSIDENT: A. Unsöld.

MEMBRES: MM. Barbier, Biermann, Mlle Busbridge, MM. Chandrasekhar, de Jager, Goldberg, Henyey, Kourganoff, Kozyrev, Labs, Mlle J. K. MacDonald, MM. Menzel, Minnaert, G. Münch, Neven, Pecker, Plaskett, Rudkjøbing, Saha†, Sobolev, Spitzer, Strömgren, R. N. Thomas, Mlle Underhill, M. Wrubel.

METHODS

The general trend is to replace the photographic method of photometry by direct photo-electric recording, using either monochromators (preferably with grating) or interference filters of small band-width for scanning the spectrum. Research work with such photo-electric devices has been done at Michigan Observatory, Ann Arbor (Aller and Liller), Asiago Observatory (Geake and Wilcock of the Physical Laboratory of Manchester) [1], Warner and Swasey Observatory, Cleveland (Bronsach and Stock) [2], Dunsink Observatory, Dublin (Smyth, Thomson), David Dunlap Observatory, Toronto (Oke), Observatoire de Haute-Provence (Guérin) [3], Uccle (Vandekerkhove) and at Crimea and Pulkovo Observatories (Dobronravin, Melnikov).

Six-colour photo-electric photometry has been continued by Stebbins, Kron and Whitford. Two- and three-colour photometries are not included in the report of this Commission.

ABSOLUTE SPECTROPHOTOMETRY

Chalonge has started, at Jungfraujoch, a comparison of some bright stars and the Sun with standard radiation sources (tungsten ribbon lamp, fluorescent disk), whilst Peyturaux has begun measuring the absolute energy distribution of the continuous spectrum of the Sun between λ 3190 and λ 23 130, using a black body of his own design ('corps noir dans le vide') for comparison [4].

Labs has determined the absolute energy distribution of the solar spectrum between λ 3300 and λ 6900 by comparison with the positive crater of standard carbon arc. A brightness temperature of 6470° K was found for λ 5263, corresponding to an elevation of the hitherto used standard values of solar radiation by nearly 15% [5].

Stebbins and Kron have determined the stellar magnitude and colour index of the Sun by six-colour photometry using tungsten ribbon lamps of exactly known flux for comparison [6].

Inauguration of the 'Happel-Laboratorium für Strahlungsmessung' which was announced at the Dublin meeting to be installed at Heidelberg-Königstuhl Observatory, took place at the end of February 1957. Problems of spectrophotometry were treated in a two-day symposium at this occasion. [7] Meanwhile the first calibrations of secondary radiation standards have been performed with the tungsten ribbon lamps used by Stebbins and Kron in six-colour photometry, and with lamps and diffusing screens used by Chalonge and Vigroux at Jungfraujoch.

MISCELLANEOUS RESEARCHES

Aller and Liller use the photo-electric spectrophotometer either with the Curtis Schmidt telescope of the University of Michigan or with the 100-inch reflector at Mount Wilson. Their investigations refer to four items: (1) A stars from galactic clusters and associations, and long-period variables, (2) gaseous nebulae, (3) bright comets, (4) bright aurorae. Work on A stars is confined to wave-lengths λ 3400 to λ 6000; all other work covers the whole range from λ 3200 to λ 12 000.

Chalonge and his group have continued and extended work on more dimensional classification of stars by spectrophotometric criteria. [8]

Wilson (Edinburgh) has done further work on the mean spectrum of B stars along the lines laid down by Baker (see report 36*a*).

Gratton (La Plata, Cordoba) reports that all his efforts are concentrated on η Carinae in different respects, whilst Jaschek works on peculiar A stars.

Gyldenkerne (Copenhagen-Brorfelde) is applying B. Strömgren's interference-filter method to bright G and K stars. [9]

Iwanowska (Torún, Poland) uses a 30-cm Schmidt telescope with objective prism for relative comparisons of stars of different populations. Järnefeldt (Helsinki) is working on Praesepe and on irregular variables with a Väisälä-camera.

Hitotuyanagi reports that Japanese astronomers have taken up especially variables (δ Cep, χ Cyg, μ Cep) and late-type stars (see report 36*b*). Melnikov, in an account of spectrophotometric work done in U.S.S.R. refers to researches on gaseous nebulae and O and B stars with special view to associations, variables (Algol, 59 Cyg, BD + 67° 922, Nova Her 1934, β Lyr, AG Dra, γ Cas, ζ Tau), aurorae and the night sky. He derives absolute spectrophotometric gradients from observations of cepheids in maximum and minimum light and gets therefrom a colour temperature of 15 400° K for the mean A 0 star [10].

Öhman refers to continuation of the spectrophotometric work done at Stockholm Observatory along the lines of work by Lindblad (luminosity criteria) and to experiences of his own with different kinds of iceland-spar photometers which are used at Anacapri for solar research.

Oke and his collaborators at David Dunlap Observatory, Toronto, have a photoelectric spectrophotometer in operation with the 74-inch telescope and are concerned with the relative energy distribution for selected stars of various spectral types, using a resolution of 7 Å in the range from λ 3400 to λ 5200, to be extended in future with new kinds of receivers to 10 000 Å or even 12 000 Å. The research programme contains also some variables.

Ten Bruggencate (Göttingen) has made an analysis of the properties of two large gratings to be used in spectrophotometric researches on intensities and profiles of solar lines. [11]

Miss Underhill draws attention to the difficulties, arising in the study of line intensities, in the problem of fixing the height of the reference curve of the continuum (see report 36*a*).

Vandekerkhove (Uccle) has published some remarks about emission-line stars; he has continued the measurements of gradients of some bright stars in the region of 5000 Å; for γ Cas, the mean values of this gradient have had a maximum of 1·30 in 1951, 1·15 in 1954·3 and a minimum of 0·82 in 1953, 0·80 in 1956·95 [12].

Wempe (Potsdam) has made calculations of the influence of insufficient resolution upon the continuous spectrum. It is made probable by Miss L. Oetken that the anomalies near Hβ revealed by Chalonge are due to an absorption continuum of oxygen, and it is pointed out that the law of interstellar absorption may be falsified by the Chalonge anomalies which depend on luminosity.

Wright (Dom. Astr. Obs., Victoria, Canada) reports that they are concerned with detailed studies of the variables 31 Cyg, VV Cep, ζ Aur, ε Aur, and V 448 Cyg. [13]

H. KIENLE

President of the Commission

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36*a*. SUB-COMMISSION ON LINE-INTENSITY STANDARDS

The work of this Sub-Commission has been devoted almost entirely to equivalent-width measurements at a few observatories in order that representative stellar-line intensities might be available for other workers in the field. At the Dublin meeting it was emphasized that observations of line profiles were also very desirable in connexion with stellar-atmosphere computations. A circular concerning line profiles was sent to members of the Sub-Commission and other interested astronomers and their comments are summarized.

Miczaika *et al.* [1] have published equivalent widths for lines in the spectrum of 15 Vul (A 5) in the region λλ 3700–6600, and Wellmann [2] has given data for α CMi and 110 Her in the region λλ4070–4600.

The following reports relating to line-intensity standards have been received:

Edinburgh. Butler [3] reports that results are available for 50 stars of types O 6 to B 3 in the regions λλ4125–5000 and λλ5600–6700. Comparisons with other observatories are urgently desired and the Edinburgh astronomers are prepared to make such comparisons for any star of these types observable from Edinburgh brighter than $7^{m}.5$.

Harvard. At Sacramento Peak, techniques for standardization of coronal, prominence and solar spectra are being developed and also methods for correcting observed profiles for instrumental effects using an extension of the radio-astronomy methods proposed by Bracewell [4].

Indiana. Programmes for computing line profiles on an I.B.M.-650 machine have been prepared for several model atmospheres and the results are being applied to the data available for *Procyon*.

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McDonald. Abt is working on high-dispersion spectra of the luminous stars and is prepared to make measurements for stars on which other observatories agree to make comparisons.

Michigan. Aller has studied numerous B stars using spectra obtained at the Mount Wilson and McDonald observatories in both the photographic and visual regions. Results for τ Sco [5] and γ Peg [6] have been published and those for 10 Lac, α Scl, HD 36959, HD 36960, 114 Tau, 72 Ori, λ Ori, ϕ Ori and μ Col are to be available soon. Goldberg has developed a simple method for extracting absorption coefficients from observed line profiles with no assumptions as to the model atmospheres involved.

Stockholm. Larsson-Leander notes that Sinnerstad, using 75 Å/mm dispersion, has made equivalent-width comparisons with some of the Edinburgh stars. He finds considerable scatter but no systematic deviations.

Utrecht. Houtgast is considering deriving equivalent widths from the Solar Atlas corresponding to lower dispersions by obliterating the records with different apparatus functions. This would permit some estimate of the height of the continuum to be made for lower-dispersion spectra.

Victoria. Wright and Lee have extended their observations of the stars recommended in the 1952 report [7] and their equivalent-width measures will be published in the near future. Miss Underhill is making a study of line intensities in the spectrum of 9 Sge. Wilson has measured equivalent widths in HD 30614 (9 Cam) from seven spectrograms that he had measured previously at Edinburgh [8]. His Victoria measures were made as similar to those at Edinburgh as was practical by reducing all microphotometer tracings to log I and superposing them to form a single mean log I-curve which was then reduced to an intensity curve. Wilson's measures at the two observatories are plotted in Fig. 1. There is no detectable systematic effect and the agreement is entirely satisfactory. However, the scatter is larger than one would expect from common spectrograms and is certainly due to differences involved in estimating the continuum and line profiles.

In considering the measurement of line profiles, it seems that their usefulness as applied to theoretical problems is limited by the large number of variables in a stellar atmosphere. Rotation and turbulence, in particular, are not usually included in model-atmosphere computations yet they may be the principal sources of line broadening. Nevertheless most of the replies to the circular were favourable to the measurement of selected lines in a few stars. Since it seems agreed that the continuous spectrum is difficult to define in the photographic region for late-type stars, it is suggested that for the present the co-operative effort be confined to early-type stars. The following stars have been suggested recently by members of the sub-commission:

Star	α (1900)	δ (1900)	m_v	Type
ζ Cas	0^h $31^m.4$	53° 21′	3·72	B2 V
χ^2 Ori	5 58·0	20 08	4·71	B2 Ia
γ Gem	6 31·9	16 29	1·93	A0 IV
η Leo	10 01·9	17 15	3·58	A0 Ib
ρ Leo	10 27·5	9 49	3·85	B1 Ib

in addition to those recommended in the 1952 report [7], γ Peg, 68 Tau, θ Leo, σ Boo, ι Her and 15 Vul, most of which have rather shallow lines. It would be useful to have equivalent-width measurements of numerous lines in the spectra of the above stars. The question of what lines are suitable for the measurement of profiles might be considered at the General Assembly. Thackeray has emphasized the need for standards for interstellar lines; the K lines in the spectra of ξ Per, 9 Cam and ϵ Ori were recommended for this purpose in the 1952 report [7].

Plaskett has pointed out that the best way to test the photometry at the various observatories is by comparing the calibration devices with a set of standardized filters that have had their transmissions determined by a recognized standardizing laboratory.

A similar project was initiated in Commission 36 in 1935 and efforts will be made to obtain such a set of filters for inter-observatory comparisons. R. Wilson, however, feels that tests of calibration devices can best be done by direct photo-electric measures, because factors other than the calibrating device may influence the observed intensities. Thus, though excellent agreement might be obtained between a rotating sector and a standard filter, the actual intensity ratios in the focal plane of the calibrating spectrograph might be affected by non-parallelism of the slit, scattered light and also possible effects due to the slightly different optical paths of the step spectra.

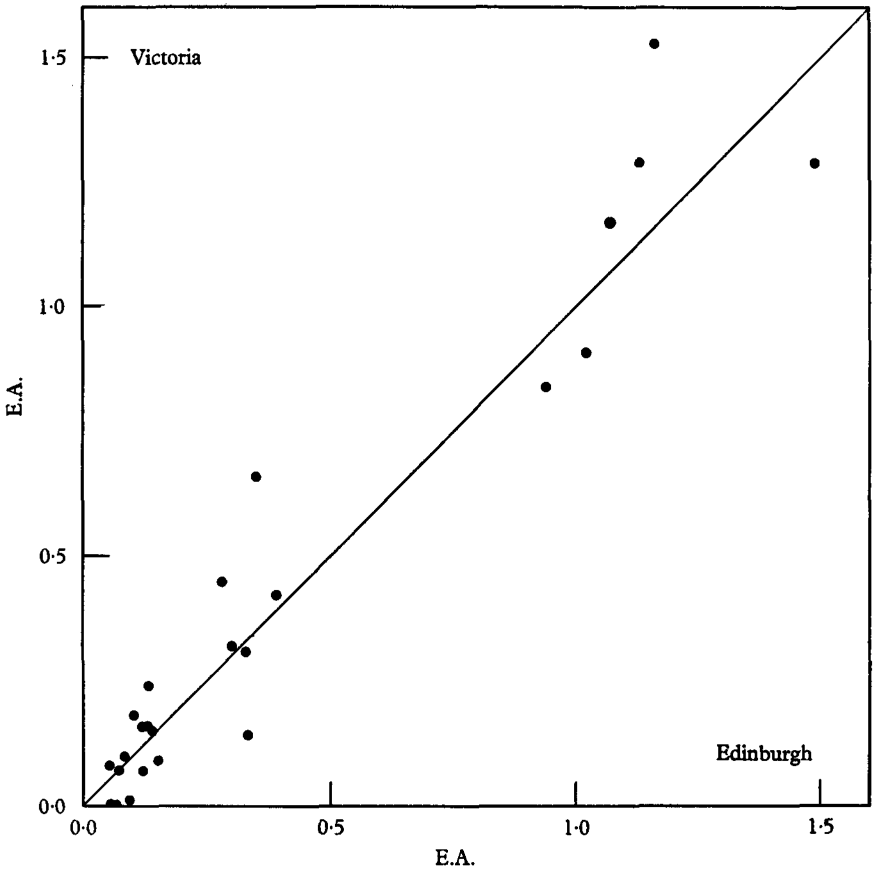

Fig. 1. Comparison of Wilson's equivalent-width measures in the spectrum of 9 Cam, made at Edinburgh and at Victoria.

Several observatories are considering the determination of line profiles by photo-electric methods. However, so far as is known, no results have been obtained with high dispersion, except for the Sun, and the Sub-Commission recommends that every possible effort be made to extend photo-electric studies of stellar spectra to high dispersion.

The stellar continuum remains a problem. Even in early-type spectra, faint lines can be detected throughout the high-dispersion spectrum of many stars and great care must be taken in drawing the continuum. As Greenstein suggested for late-type spectra, the spectrum of a standard lamp or other known continuous source could be placed on each plate but so far as is known this procedure has not been attempted.

It would seem that the work of this Sub-Commission has not yet been completed. Although the Edinburgh, Mount Wilson and Victoria systems, among others, have been found to agree within the probable errors of measurement, more inter-observatory comparisons should be made using both photographic and photo-electric methods. Then, when the observations have been reduced on a uniform scale, the analyses of stellar atmospheres may be considered comparable.

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36*b*. SUB-COMMISSION ON THE THEORY OF STELLAR ATMOSPHERES

Concerning review articles, reference should be made especially to forthcoming volumes of the *Handbuch der Physik*, ed. S. Flügge (Springer-Verlag, Heidelberg) and of *Stars and Stellar Systems*, Compendium of Astronomy and Astrophysics, ed. G. P. Kuiper. V. V. Sobolev published a monograph *Transfer of radiation energy in the atmospheres of stars and planets* (Moscow, 1956).

MODELS OF STELLAR ATMOSPHERES

Radiative equilibrium

The well-known mathematical problems of grey and non-grey atmospheres have been treated under partly new view-points by H. G. Horak and C. A. Lundquist [1], K. Hunger and G. Traving [2], J. I. F. King [3,4], A. Przybylski [6], T. L. Swihart [7] *et al.* R. Wildt [8] has attempted to connect the theory of radiative equilibrium with the concepts of 'thermodynamics of irreversible processes'.

Convective zones. Photospheric turbulence

Recent work has been chiefly connected with the following problems:

(*a*) *Turbulence*: its dependence on depth and its possible anisotropy;

(*b*) *Granulation*: size of the 'smallest' elements—Spectroscopic observations. Very large elements represented by the Ca flocculi and re-detected in turbulence by F. N. Frenkiel and M. Schwarzschild [11].

M. S. Uberoi [26] repeated and extended former work by Grotrian and v. d. Pahlen using the 'moiré'-method. R. R. McMath, O. C. Mohler and A. K. Pierce [14] measured the shift and change in contour of Fraunhofer lines in individual solar granules. Small motions in the solar photosphere are investigated in a series of papers by A. B. Hart [13]. Convection currents in the solar atmosphere produce shifts and asymmetries of Fraunhofer lines, which vary from centre to limb and probably explain the 'limb effect'; cf. E. H. Schröter [19] and H. H. Voigt [28]. Future work should establish the asymmetric line contours on an absolute wave-length scale. Z. Suemoto [24] interprets the centre-limb variation of faint Fraunhofer lines (measured interferometrically) in terms of anisotropic motions.

'What is the size of the smallest granulation elements?' This is a most exciting question. J. Rösch and his collaborators [18] made excellent photographs on the Pic-du-Midi, D. E. Blackwell, D. W. Dewhirst and A. Dollfus [9] from a manned balloon and M. Schwarzschild [20] from a free balloon.

Theoretically A. Skumanich [21] emphasizes the strong tendency towards smaller and smaller elements in a polytropic atmosphere without viscosity and radiative transfer. The latter—which should strongly cut down the small turbulence elements—is investigated by E. A. Spiegel [23], L. Oster [17] and—under somewhat different aspects—by R. G. Giovanelli [12]. W. Unno and K. Kawabata [27] estimate the generation of acoustic noise from the convection in the solar atmosphere.

The viscosity, thermal and electrical conductivity of stellar matter, which are important in connexion with transient solar phenomena, are calculated by F. N. Edmonds [10] and L. Oster [16]; the latter also by S. Nagasawa [15].

Eddies with an unexpectedly large scale of $\sim$25 000 km are revealed in the chromosphere, e.g. by the Ca-flocculi; F. N. Frenkiel and M. Schwarzschild [11] have recently studied probably the same phenomenon by analysing the turbulence spectrum. The origin of this type of eddies is not sufficiently clear.

Also the origin of turbulence in early-type stars, especially super-giants, is not yet understood. Some hope may be attached to an interesting paper by R. N. Thomas and R. G. Athay [25] on temperature gradients and instabilities in the chromosphere. The preliminary problem of distinguishing line broadening by turbulence and by rotation in early-type spectra has been treated statistically by A. Slettebak [22].

Deviations from thermodynamic equilibrium, especially in the chromosphere and in prominences

Deviations from thermodynamic equilibrium concern: (*a*) the field of radiation (Kirchhoff-Planck-formula); (*b*) the population of atomic states (Boltzmann-formula); (*c*) the ionization (Saha-formula); (*d*) the distribution and equipartition of particle-velocities (Maxwell-formula). (*a*) to (*d*) are inter-connected generally in very complicated ways. One must be cautious in the application of simplified 'models' to astronomical reality because even minor features may overthrow the whole picture by 'chain reactions'. How far, for example, can we represent the solar atmosphere by small volume elements with different temperature, etc., which, however, are *locally* in thermodynamic equilibrium? And where do we get *real* deviations from thermodynamic equilibrium? What is due to deviations from the black-body field of radiation which are important also in quiescent atmospheres, and what is due to motions (convection, turbulence, spicules...)? Obviously, low pressure favours deviations from equilibrium. So the chromosphere and prominences are the most studied subjects: reference should be made especially to a great number of papers by R. N. Thomas, R. G. Athay *et al.* Similar problems however occur already in connexion with the higher photospheric layers. A keen analysis of the fundamentals has been initiated by L. G. Henyey and W. Grasberger [33, 32]. The references [29–43] give only a rough picture of what is going on in this field.

ORIGIN OF FRAUNHOFER LINES

Radiative transfer in Fraunhofer lines

Principles. F. N. Edmonds [47] discusses non-coherent scattering in connexion with collisions. On the radiative transfer in lines with incoherent scattering S. Miyamoto and S. Ueno have published numerous papers in *Contr. Inst. Astrophys. Kyoto.* The 'probabilistic' method for dealing with coherent and incoherent scattering problems has been developed by S. Ueno (*ibid.* no. 64*ff.*) and V. V. Sobolev (*Astr. J., Moscow,* **34**, 3, 1957).

J. C. Pecker [53] deals with the contribution of 'scattering' lines toward the blanketing effect. F. W. Jäger [52] published an extensive study of polarization in solar lines.

Calculation of line profiles, curves of growth, etc. D. Barbier [44] discusses the method of weight functions (for weak absorption) relative to others, especially the 'coarse analysis'. H. Hubenet [49, 50] has calculated and compared solar weight functions for λ4000, 5000 and 8000 Å and for different abundance ratios of hydrogen: helium: metals as well as for an analogous three-streams-model. 'General' curves of growth—following the line of previous work by Menzel and Unsöld—have been calculated anew, also for line depths and widths by K. Hunger [51]. J. C. Pecker's generalized weight functions (also for stronger lines) and curves of growth are the subject of numerous papers in *C.R.* and the thesis by H. van Regemorter [55].

Electronic computing of line profiles and equivalent widths is rapidly gaining importance. Concerning programming and similar problems, see: P. ten Bruggencate, R. Lüst-Kulka and H. H. Voigt [45], A. M. Heiser [48] and R. Cayrel [46].

Continuous absorption coefficient

Recent theoretical work on free-free transitions in H has been done by J. M. Berger [56], on absorption from the ground state of Ca I by M. J. Seaton [58]. Experimental work on the H^- continuum in shock tubes has been continued in Chicago and Kiel.

The break near Hβ in early type continuous stellar spectra observed by J. Berger, D. Chalonge, L. Divan and A. M. Fringant [57] is still unexplained.

Broadening of spectral lines

Theory. A general report has been published by I. I. Sobelman [72]. While the semi-classical theories for the limiting cases of purely statistical or purely collisional broadening are fairly simple, intermediate cases and significant application of quantum mechanics at once lead into great difficulties. With charged particles their interaction causes additional trouble.

Broadening of H and possibly He II lines by ions and evt. electrons has been investigated further by H. Margenau and his students [67, 68], by A. C. Kolb [65] and by G. Ecker [62, 63]. The work of all three groups has probably not yet reached the state of astrophysical application. A. Underhill intends to calculate with an I.B.M. 650 the Stark-effect patterns and Verweij-Functions $S(\alpha)$ for all transitions between $n=1$ to 5 and n' up to 18.

Line broadening by quadruple interaction with charged particles (equivalent to taking into account the inhomogeneity of the field) has been estimated independently by I. I. Sobelman [72] and A. Unsöld (*Sternatmosphären*). It would be important to treat the non-adiabatic effects quantum-mechanically.

Laboratory experiments. Experimental work has been continued under the direction of W. Lochte-Holtgreven. P. Bogen [60] made further experiments on the Holtsmark broadening of Balmer lines. A contribution of the free electrons towards the line width is indicated, agreeing qualitatively but not very well quantitatively with theoretical estimates. H. Wulff [74] examined the profiles of many helium lines in a thermal plasma. Also the *Inglis-Teller*-formula could be checked. H. J. Kusch [66] succeeded in measuring, at least roughly, the broadening and shift of Fe I lines by hydrogen atoms and molecules.

Astrophysics. Reference should be made to papers by H. H. Plaskett [70, 71] and R. J. Bray [61]. W. R. Hindmarsh [64] investigated interferometrically the effect of hyperfine structure.

Quite generally in astrophysics effects of this or that physical mechanism appear always mixed with influences of various features of the atmospheric model. It is often difficult to disentangle 'which is which'.

Transition probabilities. f-values

Extensive calculations of transition probabilities, etc. have been published for hydrogen by L. C. Green, P. P. Rush and C. D. Chandler [78] and for helium by E. Trefftz [82]. Measurements for many elements, introduced in quantitatively known (small) ratios into the rods of a copper arc have been made by C. W. Allen and A. S. Asaad [76]. In the Fe I spectrum relative f-values have been measured by J. Aarts, D. Harting and C. J. Bakker [75]. The old problem of the absolute f's for Fe I has been decided in favour of Kopfermann and Wessel by K. Ziock [83] determining electronically the decay time of the resonance fluorescence in an atomic beam without any reference to vapour pressure data. C I, N I, N II and O II have been measured absolutely in high temperature stabilized arcs by W. Lochte-Holtgreven's students.

SPECIAL MODEL ATMOSPHERES AND THEIR FRAUNHOFER LINES

The lists of references [84–113] are far from complete, but might help to give some impression of recent work in a rapidly expanding field of research.

Analysis of individual stellar spectra

'Normal' stars. The B0 V star τ Sco has now been analysed using average values for T, P_e... by A. Unsöld, using a model atmosphere and standard curves of growth by G. Traving (with the same observations) and recently by L. H. Aller, G. Elste and J. Jugaku [100] using a model atmosphere and Pecker's generalized curves of growth (with new observational material). G. Traving [103] in discussing the differences between these three analyses notes the following theoretical points: (1) Unsöld's original g-determination ('coarse analysis') gives too large g's because atoms in deeper layers contribute fully towards producing pressure, but only partially towards producing lines. (2) Lines, like O III..., originating in deep layers only can never get limiting central depths R_c as large as, e.g., O II-lines; that effect is automatically taken into account in the Michigan work, but it can also be dealt with using the standard curve of growth. The differences concerning the chemical composition are mainly due to systematic differences in the measured equivalent widths! These are still the nightmare of all quantitative work in stellar spectroscopy.

The other references [90–103] probably need no explanation.

Stars with anomalous ratios of hydrogen:helium:metals. Attempts to determine these ratios more accurately in 'normal' stars have been mentioned already (e.g. Hubenet [49]). In connexion with cosmogonic problems studies of possibly metal-deficient stars, subdwarfs, stars in globular clusters, some RR Lyrae stars have gained importance. The quantitative investigation of 'strong'- and 'weak'-line spectra by P. Wellmann and the Cambridge astronomers has led into strange difficulties. A few recent papers of theoretical interest are listed [104–110].

Metallic line stars. The anomalous weakness of the Ca II lines in these stars is unexplained so far. We list some recent quantitative work [111–13].

The literature on the interpretation of the spectra of peculiar A-stars (magnetic stars), cepheids and other variables cannot be reported here. These matters are more properly left to other commissions.

ABUNDANCE OF ELEMENTS. NUCLEAR PROCESSES

Summaries on cosmic abundances have recently been published by M. Minnaert [119] and by H. E. Suess and H. C. Urey [120], stressing the view-points of astrophysics and of nuclear-physics and geochemistry. L. H. Aller is writing a book on the *Chemical composition of the universe* (Interscience Press). Further on, the *Geochimica and Cosmochimica Acta* should be mentioned.

In connexion with the spectra of Ap stars, the variations of the $^{12}C/^{13}C$ ratios, the spectral differences between various late-type stars, the two Wolf-Rayet sequences, etc., nuclear processes in the interiors, and partly also in the atmospheres of stars, have been advocated by some astrophysicists. Here it may be sufficient to refer to several recent summaries (with extensive literature references) and to a note by L. Biermann. The possibility of more trivial 'spectroscopic' interpretations should, however, always be considered very carefully.

A. UNSÖLD

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SPECIAL MODEL ATMOSPHERES AND THEIR FRAUNHOFER LINES

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Report of Meeting. 18 August 1958

PRESIDENT: H. Kienle.

SECRETARY: C. de Jager.

The meeting was attended by sixteen Commission members and by many others. The *Draft Report* was accepted without comment.

The problem of the abolition of Commission 36 was discussed. There was a general feeling that the Commission in its present form and with the present large membership should not be maintained. Spectrophotometry is no longer a new technique and most spectrophotometric problems will be discussed in Commissions 29 or 12 on stellar and solar spectroscopy. But a number of members (Kienle, Greenstein, Melnikov, Chalonge and others) felt strongly that in the I.A.U. a place should remain to discuss the fundamental problem of standardization and calibration of light sources, problems beside the common astrophysical problems on stellar spectra and their interpretation. Various proposals were discussed: forming a Sub-Commission of Commission 9 (instruments) or 29 (stellar spectra), or dividing Commission 36 into various sub-commissions. In any case it is clear that such a Sub-Commission should be small, since only few people are concerned with fundamental calibration and standardization problems. After some further discussions a vote was unanimously accepted that this little group expresses its desire to become a Sub-Commission of Commission 29.

STANDARD RADIATION SOURCES

This problem was introduced by Kienle. Experience has shown that a laboratory black body must be the first standard. A very fine secondary standard is the Tungsten lamp. Most Tungsten lamps have radiation temperatures of about 2800° K; hence, to make a comparison of the lamp spectrum with that of a star has always been difficult with the conventional photographic technique, but nowadays, with photo-electric methods, even intensity ratios of 10^3–10^4 can easily be measured. The light source should be constant for hours, the calibration should be constant for years. Among the types studied, the Philips Tungsten lamp (nose type) seems to be one of the best. The filament is 2×8 mm². A difficulty is that the current (15 amps) and voltage (6 volts) should be constant to 10^{-4} to have T_c precise at 10^{-3}.

For the ultra-violet region Chalonge has made a disk of fluorescent powder, illuminated by a mercury arc ($\lambda = 2537$ Å). It gives a continuous spectrum ($T_c > 10^4$ °K) with some gaps. The ratio of surface brightness—Tungsten lamp: fluorescent powder—is about 10^4. Of this fine standard radiation source Chalonge is able to make a dozen or more identical copies that might be distributed around the world. Chalonge remarked that the powder disk is not only useful for absolute measurements but also for the calibration of plates, the luminosity extending from the red to the ultra-violet.

CALIBRATION PROBLEMS

Until recently people have been mainly interested in the wave-length range 3000–12 000 Å, but in the last few years interest has been extended in both directions: the infra-red and the ultra-violet (rockets). For the short wave-length region lamps are insufficient. Zeiss has developed a hydrogen lamp that emits a H continuum (it consumes 30 watts). For the infra-red there are no difficulties with light sources; ribbon lamps are sufficient.

Melnikov has developed a lamp with a filter such that the combination has a colour temperature $T_c = \infty$.

Kienle remarked that the H-lamp also has a colour temperature, virtually equal to infinity.

SCIENTIFIC COMMUNICATIONS

Wrubel showed detailed calculations of line profiles, and stated that he intends to publish an atlas of theoretical line profiles, computed for the Milne-Eddington approximation, with parameters: limb darkening, damping, number of absorbers, all for the two cases $\eta = 0$ (pure absorption) or $\eta = 1$ (pure scattering). The results are also available for interested colleagues in the form of a program for the I.B.M. 650 electronic computing machine.

There is also a project for computing blend profiles on an I.B.M. 704 machine. Allen and Cayrel dealt with similar problems; the latter has developed a sub-routine for line intensity computations on an I.B.M. 650.

Sitnik has developed and investigated a standard light-source consisting essentially of a carbon tube, which emits black-body radiation. The radiation is measured with photo-multipliers and photo-electric cells; $T_c = 1336°$ K between $\lambda = 3100$–13 000 Å.

For the comparison of this standard with the solar spectrum a Tungsten lamp served as a secondary standard. The solar and lamp spectra have been measured between 3500 and 6000 Å with a photo-multiplier (slit width 0·65 Å) and between 5500 Å and 12 500 Å with a photo-resistor cell (slit width 7·3–10·5 Å). For the comparison measurements the secondary source was placed in front of a parabolic mirror.

The measurements have been made at Moscow (Sternberg State Observatory) and are now being repeated at an altitude of 3100 m. In the visual and photographic region they agree with Labs's measurements to within 3–5 %.

Kienle noted that the new measurements of the energy-wave-length distribution of the solar spectrum now being made at three places all agree with one another. They are higher than the old Abbot-Mulders values by 10–15 %. In the visual range the observations of Labs (Pic-du-Midi), Sitnik (Moscow) and Peyturaux (St Michel) agree, whereas in the ultra-violet region there is still a discordance between Labs and Sitnik, as below:

	5000 Å	3500 Å
Labs	$4{\cdot}9 \times 10^{14}$	$4{\cdot}0 \times 10^{14}$ erg cm^{-2} sec^{-1}
Sitnik	$4{\cdot}9 \times 10^{14}$	$2{\cdot}4 \times 10^{14}$ erg cm^{-2} sec^{-1}

Report of Meeting of Sub-Commission 36*a*. 18 August 1958

ACTING PRESIDENT: M. H. Wrubel.

SECRETARY: O. A. Melnikov.

AGENDA

1. Additions and corrections to *Draft Report.*
2. Stars recommended for observation.
3. Objectives of observation.
4. Methods of observation: (*a*) Photographic; (*b*) direct photo-electric photometry.

Numbers in the following report refer to the Agenda:

1. Buscombe submitted a revision of the description of the Mt Stromlo programme; this has been omitted in the final report.

2. Houtgast noted with concern that only stars of early type are on the recommended list. Greenstein pointed out the difficulty of locating the continuum in later types but Houtgast and Minnaert were of the opinion that high-dispersion solar observations could be combined with observations at lower dispersion to provide useful material for intensity standards in G stars. Melnikov reported that experience at Pulkovo indicated this method as very useful. Greenstein and Melnikov thought intercomparison of solar spectra obtained at Utrecht and Mt Wilson, and in U.S.S.R. (Pulkovo, Crimea, Moscow, etc.) would be interesting.

3. It was agreed that publication of line profiles as well as equivalent widths would provide useful material for theoretical analysis, but a number of difficulties arise: expense (Greenstein, Wrubel), correction for apparatus function (Minnaert), location of continuum (Melnikov, Minnaert). Aller suggested focusing attention on some Balmer lines, H, K and λ4227. In lieu of publication, the President of the Sub-Commission might supervise the circulation of selected profiles among observatories. It was emphasized (Minnaert, Melnikov) that profiles must be accompanied by additional information concerning the method used to correct for the instrument and the assumed location of the continuum.

Tracings of σ Bootis (Victoria) and B stars (Edinburgh) were exhibited.

4 (*a*). The question of circulating a standard step filter was discussed. Minnaert described a platinum-on-quartz step filter, that was successfully used in an earlier intercomparison and offered the use of it to the Sub-Commission. Kienle agreed to calibrate it. Greenstein remarked that it would be difficult to use such a filter in his equipment. It was left for the President of the Sub-Commission to determine if a sufficient number of observatories would use the filter.

Brück reported intercomparisons between Victoria and Edinburgh made by Wilson. Greenstein noted that intercomparisons of equivalent widths at Mt Wilson were satisfactory.

4 (*b*). Aller reported on direct photo-electric scanning at small dispersion.

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Report of Meetings of Sub-Commission 36*b*. 18 and 19 August 1958

PRESIDENT: A. Unsöld.

SECRETARY: C. de Jager.

First Meeting. 18 August

A review of the present state of problems concerning solar and stellar atmospheric models was given by de Jager. Certain properties of the solar photosphere of which we were fairly certain are now less certain because of new observational data or of a new theoretical approach.

1. The occurrence of high-temperature fluctuations $\Delta T(\tau)$ in the photosphere, for which the strongest support was given by the hydrogen lines, is less certain since new hydrogen-line computations by van Regemorter [1] and Aller [2], on the basis of Kolb's theory, have given a good agreement between computed and observed profiles.

2. As a rule temperature inhomogeneities have only negligible influence on the resultant equivalent width (Hubenet [3]), thus throwing doubt on the ΔT-values found earlier from Fraunhofer-line computations.

3. Even the current homogeneous models are not completely correct: the new observations of the energy-wave-length curve by Labs and Sitnik, yielding a greater intensity in the visual range, will give at $\tau_0 = 1$ and 0·2 respectively: $\Delta T = 300°$ and 200°. (The immediate consequence is that H-line computations with such a model and with Kolb's theory would give too strong and too broad H-lines: it is again necessary to revise the H-line theory!)

4. Another reason for revising the current models may be the possibility that deviations from local thermodynamic equilibrium have a considerable influence on the emergent continuous radiation of the Sun (Pecker and Schatzman [4]).

In the light of these uncertainties Schwarzschild's new result, giving much smaller average intensity fluctuations in the solar granulation than were assumed before, need not be in contradiction with other data. So the theory of the *solar photosphere* should have some reconsideration, taking further into account: (*a*) The influence of deviations from local thermodynamic equilibrium on the population of the lines; (*b*) the rise in temperature in the low chromosphere (at $\tau_0 = 0{\cdot}001$, T is about 300° higher than at $\tau_0 = 0{\cdot}005$); (*c*) systematic convective motions with velocities decreasing with altitude, and turbulent motions increasing with altitude (Voigt [5]).

The degree of precision of *stellar* spectrographic observations where errors in equivalent widths sometimes rise to a factor of 2 is not yet so high that inhomogeneities and deviations from local thermodynamic equilibrium as great as those occurring in the solar photosphere could be detected: in the Sun these effects change the atomic-level populations by a factor of 2 at maximum. Rocket ultra-violet photometry of stars can hardly give information on their Ly α emission because of the recently discovered veil of scattered solar Ly α light in the light of the night sky [6].

As to the *solar chromosphere* it now seems quite certain that the lower part ($h < 5000$ km) consists of two kinds of elements, with temperatures of 5000° and of 10 000°–20 000° respectively. The spicules of the high chromosphere have $T = 2$ to 6×10^4 °K; there is a steep rise in temperature from the chromosphere to the corona. Deviations of the atomic-level populations from the local thermodynamic equilibrium conditions are considerable, perhaps rising to a factor of 10^4 in the case of the second H-level. Two of the most important problems encountered in an observational determination of the main characteristics of the chromospheric model are those of the elimination of the influence of self-absorption and of deviations for local thermodynamic equilibrium. The first problem can perhaps be solved best with a curve-of-growth method (Böhm-Vitense [7]; Zirker [8]), whereas the elimination of the influence of deviations from L.T.E. are unimportant for He II and He I lines because of the strong dependence of the level populations on T ($N_n \propto 10^{-50\theta}$ or $10^{-20\theta}$ respectively), and is only important for $H(N_2 \propto 10^{-10\theta})$, less so for the metal lines, for which these deviations are probably relatively small.

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DISCUSSION

In answer to a question by Unsöld, Pecker said that the increase of the solar temperature required by the new observations of the continuous spectrum will perhaps largely be compensated for if deviations from L.T.E. are properly taken into account. However (Unsöld), the increased radiation should in any case manifest itself somewhere in a higher $T(\tau_\lambda)$, but not in the whole spectral region (Böhm, Sitnik) since the new observations only deviate from the old ones in the visual spectral region.

Thomas remarked that some of the current applications of earlier non-L.T.E. computations were unjustified and that work done in Boulder after 1948 already stressed the great influence of the chromosphere on photospheric line profiles. Böhm expected that deviations from L.T.E. would be less great in the photosphere than is suggested by Pecker: at $\tau_0 \approx 0{\cdot}1$ the differences between the local radiation field and a Planck function are nearly negligible, and in deeper layers he was certain there are virtually no effects; on the other hand many Fraunhofer lines can only be explained by assuming rather strong inhomogeneities. Pecker found purely empirically $b_n \approx 0{\cdot}5$ for $\tau_0 \approx 0{\cdot}1$, but Pagel has computed the influence of non-L.T.E. on the second H-level populations for $\tau_0 \approx 0{\cdot}1$ and could not find any deviations of b_n from unity larger than by a factor of 2. Thomas was of the opinion that this result should be investigated anew.

Second Meeting. 19 August

The second session started with a review by Minnaert of the photospheric non-L.T.E. problem. Pecker's result should be accepted as an empirical one, and the next point is how it should be understood theoretically.

SCIENTIFIC COMMUNICATIONS

Minnaert discussed the problem of the solar u.v. continuous spectrum. This spectrum can be traced by using spectroscopic 'windows' (Chalonge *et al.*) or, by using the profiles of lines (Weidemann, Rauer), extrapolating the line profiles ($\propto \Delta\lambda^{-2}$) with a refined method, thereby assuming that the influence of faint lines can be represented by a general continuous absorption. Between 3600 and 3500 Å, the Utrecht solar atlas continuum should be at the level 1·30–1·40, a result similar to that expected from the 'window' method.

A change of the ultra-violet continuum will certainly change the photospheric model derived from the empirical data (Unsöld).

Mustel described an iterative method of finding the temperature distribution in a stellar photosphere, based on replacing the Eddington approximation $3K_\nu = J_\nu$ by the exact expression $dK_\nu/d\tau = H_\nu(\tau)/4$. The method has the advantage that for $\tau = 0$ it yields the exact flux $H = \sigma T_e^4$, and it seems to converge rapidly.

In reply to a question by Unsöld, Mustel answered that the method was applied to A0 stars, and that even in a first approximation the deviation from the constant flux did not exceed 3%. Böhm recalled that it is precisely for A0 stars that the differences between the grey and the exact models are not great, so the method should be applied to other stars. Pecker said that in the new method the flux enters directly in the computations; this could be an advantage as compared to other methods.

Sobolev showed an extension to the solution of the integral equation which describes the diffusion of radiation in a plane-parallel atmosphere (case of radiative equilibrium) for an arbitrary distribution of the sources of radiation through the atmosphere. The method can be also applied to the case of true absorption where κ_λ varies with the frequency, and to the case of complete redistribution.

Ueno demonstrated a possible solution of the problem of non-coherent scattering for an arbitrary stratification of a finite atmosphere, assuming complete redistribution. The solution is obtained by the probabilistic method, and makes use of the equation for the transport of radiation. The solution can be obtained by numerical computation.

Pagel and Buscombe discussed the absorption by negative ions. At a wave-length of 6000 Å the cross-section expressed in that of H^- is 1/3 for the OH-ion and 1/6 for O^-; other ions give smaller values. The results might be important for O-rich stars. Greenstein thought the problem of the occurrence of such ions could be attacked by photoelectric spectral scanning. Biberman suggested that the ionization potential for O^- given by Pagel (1·2 eV) should perhaps be increased to 2·2 eV but Buscombe said that this latter value was due to an erroneous earlier determination.