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29*c*. SOUS-COMMISSION DES BANDES MOLÉCULAIRES DANS LES SPECTRES STELLAIRES

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To report on the past three years in stellar spectroscopy has been a pleasant but difficult task. From over ninety members, whose interests in spectroscopy range from the most difficult astrophysical theory to the use of spectra at 30,000 Å/mm. for discovery of reddened B stars, I have received fifty replies. The volume of spectroscopic material published is enormous, and I can mention only that part which individual members have stressed in their communications to me, especially those investigations under way or in print, and plans for future work. I am grateful to the sub-committee chairmen for their separate reports, and to Prof. O. A. Melnikov who has prepared an excellent review of the work in the U.S.S.R. His résumé has been distributed, with detailed references, through the body of my report.

BIBLIOGRAPHY

Publications of general interest which have recently appeared might be briefly mentioned. An excellent bibliographical service is now offered by the Centre National de la Recherche Scientifique, Paris, in its *Bulletin Analytique*, sect. II. A current full abstract service is in the *Journal of Abstracts, Astronomy and Geodesy Section* issued by the Institute of Scientific Information, Academy of Sciences of the U.S.S.R. The latter has full abstracts in Russian, often illustrated and with tables; to date ten numbers with

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5412 abstracts have reached us. An index in Russian and also in the authors' languages is included. The *Astronomische Jahresbericht* is being brought up to date as rapidly as possible. Index volumes have appeared for the *Astrophysical Journal*, Vols. **76–100** (July 1932 to November 1944), and for the *Publications of the Astronomical Society of the Pacific*, Vols. **51–65** (1939–53).

Some books or tables now being prepared should be mentioned. Bidelman has completed a catalogue and bibliography of emission-line stars of types later than B; 1114 stars with bright hydrogen lines and 426 stars with bright H and K are listed, and references are given to all known spectroscopic observations. P. Merrill has completed a monograph on the *Lines of Chemical Elements in Astronomical Spectra*, with a copious bibliography. Swensson is preparing an *Astrophysical Forbidden-Multiplet Table*, $\lambda\lambda$2950–3500, based on predictions from the energy levels given by C. E. Moore, and including transitions with $\Delta J = 0, \pm 1, \pm 2, \Delta L = 0, \pm 1, \pm 2$ (except in a few very rich spectra) and all plausible ΔS. Unsöld has completed his revision of *Sternatmosphären*.

Instrumentation

The large coudé grating spectrograph for the 200 in. Hale reflector has been described by Bowen (1), and has worked well in practice, reaching 15th mag. at 38 Å/mm. The theory of the design of high-efficiency spectrographs is also discussed by him in the forthcoming volume on *Vistas in Astronomy*. The Lick Observatory is planning a large multi-purpose grating spectrograph for the 120-inch. The present coudé at the Mount Wilson 100-inch is being revised, with the addition of shorter focal-length Schmidt cameras, and provision for rapid change of gratings. The 82-inch McDonald reflector has a new grating spectrograph for 4·5 Å/mm. and lower dispersions, and the Victoria spectrograph is being revised. A new spectrograph for intermediate and low dispersions has been built for the Cassegrain focus of the 60-inch at Mount Wilson; it has three gratings on a turret mount, an inverted-Cassegrain collimator, and several Schmidt cameras. It is essentially a small, portable version of the coudé spectrograph, and may be a useful step forward for reflectors of moderate size. Several new slitless spectrographs are being constructed with transmission gratings.

Exposure meters have been proved useful at Palomar, Mount Wilson and McDonald. They use a small fraction of the light that has passed through the slit, and by either photon counting or integrating give a realistic measure of the effect of seeing, transparency, etc.

Fehrenbach reports that twenty low-latitude fields are being measured at Haute Provence for objective-prism radial velocities. The stars are also being classified on the MK (Yerkes) system for type and luminosity, and the colours and magnitudes are being measured at Toulouse by Bouigue. Publication of the first portion of this work is expected in 1955. The Stockholm Observatory is experimenting with objective-prism radial velocities, with the goal of separating the high- and low-velocity stars, which then will be measured spectrophotometrically for luminosity criteria.

I may not have received all information concerning new spectrograph construction in the U.S.S.R., but several new developments are known to me and will be of interest. At the Crimean Astrophysical Observatory the 1200 mm. reflector has been completed, and a nebular and two stellar spectrographs put into operation. Kopylov (2) describes the new instruments, and some spectra are reproduced. Glass optics provide a range in dispersion from 23 to 72 Å/mm. at Hγ. The quartz spectrograph reaches down to λ3400 and has a dispersion of 162 Å/mm. at Hγ. At Pulkovo, Mitrofanova (3) is using a modern high-dispersion spectrograph for the study of both laboratory and solar spectra. In the spark and arc, relative *gf*-values were measured for Fe I, Fe II, Ti I, Ti II and Cr I, with results in agreement with those of King. These were applied to obtain the curve of growth for the Sun, and the excitation temperatures (Fe I, 4750° ± 150°; Ti I, 4575° ± 125°).

The trend set by the success of multicolour photo-electric photometry in detecting high- and low-velocity stars, white dwarfs, reddened stars, etc., has been carried to an

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interesting extreme by Morgan, Meinel and Johnson at Yerkes. A precision Schmidt telescope with an objective prism gives a dispersion of 30,000 Å/mm., and is used to examine photographically the energy distribution from λ7200 to λ3500. Very faint reddened B stars can be recognized, for further study by photo-electric colours or with large telescopes. No spectral features are visible, but the energy distribution in a blue star, as distorted by space reddening, is easily recognized by inspection. After preliminary tests, a 7-inch $f/4$ Schmidt camera of very high resolution is being constructed. A survey of the galactic belt down to 14^m or 15^m is to be made. (*Ap. J.* **120**, 506, 1954.)

At David Dunlap, Hossack (4) has developed an oscilloscopic microphotometer which presents a tracing of a stellar spectrum on the oscilloscope screen. By electronic adjustments two stars are matched approximately, and then quantitative measures of relative intensities of the lines are made for spectral type and luminosity criteria. G and K stars can be classified to 0·1 spectral subclass and 0·1 luminosity class in the MK system. He found a group of G and K giants, spectroscopic binaries, in which the hydrogen lines are excessively strong.

Identifications

Thackeray (5) has studied intensively the high-velocity helium-rich star HD 168476, measuring 206 lines. He I, C II, Ne I, Si II, S II, N I, N II are strong, but oxygen is weak or absent. The star has some resemblance to υ Sgr in the strength of lines with high excitation potentials. Hydrogen is not observed, so low opacity may be involved, as in υ Sgr. The absence of oxygen is typical of results in some low-luminosity stars being studied by Greenstein and Munch (in unpublished investigations of the Humason-Zwicky faint blue stars), where N II, N III are often strong in apparently helium-rich objects, C II, C III seen in one case, but O II and O III not seen. Aller is making a study of the apparently carbon-rich, H-poor star HD 160641, with Munch. The former has made an extensive study of γ Peg, B2·5, with results in substantial agreement with those of Underhill. However, some of the very weak lines are uncertain, and identifications in early B stars are not yet complete. He adds wave-lengths and equivalent widths λλ3545–3973. He has in preparation line lists and identifications for HD 36959 (B1V) and α Sc (B5).

Crespin and Swensson (6), using McDonald spectra, give a list of wave-lengths in the A2ep supergiant 3 Pup (formerly *l* Pup), λλ3120–3354. Lines of the ionized metals are strong; intensities are compared with those in other A and peculiar stars.

Thackeray (7) gives a complete list of emission lines in η Car and RR Tel (a slow nova). The latter has higher excitation, strong lines of O I, O II, O III, while η Car has weak or no oxygen lines. Displaced diffuse H absorption lines may exist in both. The wave-length list extends from λ3677 to λ8863.

Gratton (8) has published accurate wave-lengths and identifications of about 2600 lines, λ4000 to λ5000, in the spectra of the stars α UMa, K0 III, and α Ser, K2 III. This provides material badly needed for the study of typical red giants. A group of stars exists with strong Ba II, Zr II, Y II and ionized rare earths (9). Garstang and Bidelman have extensive wave-length lists, which will be published in part, for these stars; Greenstein has measured 4000 lines at 2·8 Å/mm. in the blue, 4·2 Å/mm. in the red. In spite of the apparent relationship of these stars to the S types, the unstable element Tc is absent. Neutral rare earths were identified for the first time in the S star R And by Bidelman. Merrill and Greenstein are now making an extensive study of identifications in R And, from Palomar plates at its 1954 maximum (4·8 Å/mm. blue, 7·2 Å/mm. red). More complete high-dispersion wave-length lists are needed for stars of most standard types.

Spectral Classification

The Yerkes system developed by Morgan, Keenan and Kellman (MKK) provides a moderate- and low-dispersion, two-dimensional classification which has been extensively used. It is now redefined as the MK system (10). The details are to be discussed in a projected revised edition of the *Atlas of Stellar Spectra*, but some changes are given in the above reference. The dispersions used were 50 or 100 Å/mm. at Hδ; about 350 stars define the stars from O9 to M2, luminosity classes Ia to V. In the same paper accurate B-V and U-B photo-electric colours are given by Johnson for many of the standard stars, providing a fundamental reference list for type and three-colour photometry. Types in the Pleiades, M 36 and NGC 2362 are given, as well as composite HR diagrams and a study of the effect of space reddening on the colour standards. Finally, intrinsic colours, and the correlations between type, colour and luminosity are studied. Morgan is extending his fundamental spectral-type list by about 300 stars which were classified for the new Stebbins six-colour photometry; he has also classified about 1100 blue supergiants. He wishes to stress the importance of developing criteria for classification and luminosity in the red and infra-red regions, both for later-type stars and for the space-reddened stars in distant parts of our Galaxy.

The Stockholm Observatory is studying spectroscopic luminosity criteria on slit spectra, 75 Å/mm. at Hγ. Sinnerstad has developed a technique for isolating the supergiants in his work on the B and A stars, while P. O. Lindblad is studying the later types with material from Lick.

A. N. Vyssotsky wishes to amplify results previously reported in *Trans. I.A.U.* (11). An ambiguity had been found in objective-prism classification of G dwarfs, in that some stars showed both Hγ and the G-band strengthened. Since then, he has found that these stars have a larger velocity dispersion and a larger group velocity than normal with respect to the Sun. The same observation had later been made by Roman (12).

Roman has classified 693 F5–K5 stars brighter than $5^{m}{\cdot}5$ and north of $-20°$ on the MK system. She was able to add a third parameter, the division by kinematical properties, as shown by spectral peculiarities. The G-band and the ratio 4226/4045 increase in stars of moderately high velocity, presumably old population I and mild II stars. A few genuinely high-velocity stars, mean speed 95 km./sec., show extreme CN weakening. A catalogue of 600 high-velocity stars brighter than $9^{m}{\cdot}5$, earlier than M1, north of $-20°$ has been prepared; she is observing slit spectra and obtaining photo-electric colours on the B-V and U-B systems. The most extreme stars of this group are the F-type subdwarfs, discussed below.

Feast and Thackeray report that in K stars, λ3905, a subordinate line of Si I is enhanced by 50% in dwarfs as compared to giants. This parallels the strengthening of λ5183, Mg I, in dwarfs, also a line of moderate excitation; both change in the opposite direction from most excited lines (E.P. $< 2{\cdot}6$ volts) which are usually weakened in dwarfs.

The complications recently discovered in the spectra of G and K giants are described by Keenan, who proposes a new suggestion on classification technique in the appendix to this report (p. 404).

Herbig is studying dM and dMe stars, using 15 Å/mm. in the range λ5200–λ6750. Of twenty-five stars so far observed, eight have Hα emission, five may have He I, λ5876, and one has Na I emission. The Hα emission sometimes shows a narrow central absorption indicating cooler gases above the region producing the emission line. He hopes to develop more detailed criteria for the study of the dM stars.

The penetrating power of the infra-red spectral region has been well demonstrated by the objective-prism surveys at the Warner and Swasey Observatory. In the near infrared a 2° prism gives 3400 Å/mm. at the A-band. In ten minutes, 10^{m} infra-red stars are reached; the space reddening is substantially decreased and the red giants and supergiants can be detected to large distances. A catalogue of 271 carbon stars, of which 222 are new, is given by Nassau and Blanco (13) in addition to 384 late M stars, 31 new S stars and 89 faint supergiants.

The development of photo-electric scanning of stellar spectra has continued, with high-dispersion experiments at McDonald, and a low-dispersion survey by Whitford and Code at Mount Wilson. Until this promising technique is carried further, possibly with non-scan image-tube methods to economize on light, most important results in spectral classification are being obtained by spectrophotometry. The precise observations of gradients and Balmer discontinuity by Barbier and Chalonge have been extended by Chalonge and Divan to a three-dimensional spectral classification of types O to F. They use the gradient in the blue, ϕ_b, λ_1 the wave-length, and D the magnitude of the jump. The normal stars fall on a surface in this three-dimensional space. But RR Lyr, subdwarfs and population II stars fall off this surface and can be detected spectrophotometrically. This successful method, having an extra parameter, is more sophisticated than the photo-electric three-colour method, which also shows that in the U-B, B-V plane the weak-line stars and white dwarfs fall off the normal curve. The possibility of multicolour photo-electric stellar classification has been carried further by Strömgren, who uses narrow-band interference filters, measuring line intensity as well as ϕ and D. The classification accuracy is greater than is possible spectroscopically. With the growth in our appreciation of the complexity of the apparent abundance variations, it is probable that a multi-parameter spectrophotometric technique will be as necessary as a three-dimensional spectroscopic classification. It seems probable that there are variations in the H/metal, the H/He, and possibly C/N and C/H ratios, and that for various T_e and g, these effects will appear both spectroscopically and spectrophotometrically. Which method will be most precise and most economical of time remains to be explored.

Applied Spectral Classification

Extensive surveys for various purposes are being carried out. I will list them by institutions.

At Abastumani, an extensive survey of the spectra and luminosities in Selected Areas is under way. *Bulletin* no. 15 contains 176 B and A stars in S.A. 20, 22, 23, 25, 26, 41; in addition 336 B and A stars in S.A. 17, 19, 24, 38, 39, 46–51, 62–67 are available, and Kalandadze has a catalogue in the Press for 425 G and K stars in S.A. 16, 19, 20, 22–26, 30, 38, 39, 41, 44–48, 50–52, 62–67. A paper on the luminosities of 137 B8–B9 stars at high galactic latitude is in the Press, and *Bulletin* no. 14, 1953, contains spectral characteristics of the B8–B9 stars used for photo-electric colour standards.

At Case, the 24-inch Schmidt has been used for a variety of survey programmes. A 4° prism gives 383 Å/mm. at Hγ. The galactic equator programme is to cover from 333° to 201° longitude in a belt 12° wide. The following are complete: (1) F supergiants to 9·0 m_{pg}. (2) Ten fields each 12 square degrees classified down to 12·3 m_{pg}, luminosities down to 11 m_{pg}. So far 19,000 stars have been classified. Several of these fields have been already published in the *Astrophysical Journal*. (3) Spectra in the Harvard C-regions, in progress.

At David Dunlap, 1880 radial-velocity stars later than G0 have been classified on the MK system by Halliday and Creeper. Halliday has determined space motions, and used Hossack's oscilloscopic microphotometer for luminosity classes. He finds a minimum in the luminosity function at $M_v = +2$ (subgiants infrequent).

At Harvard, Hoffleit has been working on (1) the classification of fainter stars on objective-prism plates taken with the ADH telescope, especially A stars to the plate limit; (2) luminosity estimates (14), which are possible for fainter stars than previously; (3) with Lippincott (15), the spectra of the brighter B5 stars at 50 Å/mm.; (4) spectral types and luminosities in the Carina emission nebula and in Sagittarius, at 70 Å/mm. Wade is studying the early stars between 250° and 355° longitude, apparently responsible for excitation of Hα emission regions. For these stars photo-electric colours will be available. This group of programmes on the structure of the southern Milky Way is particularly important in view of the paucity of our information there.

The peculiar A stars in a Milky Way zone, found on Case objective-prism spectra by Nassau, are being studied by Slettebak at Perkins, using slit spectra. Even at 383 Å/mm. the peculiar A's can be recognized by the strength of $\lambda\lambda$4077, 4130, 4177.

Lindblad reports on the progress of the Stockholm spectrophotometric classification of faint stars, to $m_{pg} = 13·5$. Ramberg is concentrating on the Milky Way A and B stars, and Elvius on Selected Areas.

According to Haro, he and his collaborators, L. Munch, Gu. Gonzalez, Gr. Gonzalez, Iriarte and Chavira, have been making extensive surveys with the Tonantzintla Schmidt, on a variety of discovery and classification projects (16): 2139 stars have been classified as belonging to the OB group of high-luminosity objects. These publications include positions and finding charts, and studies of surface distribution. These stars, more than 50 per cent of which are in southern declinations, even reaching the Carina region, are important for studies of spiral structure and of O-associations. (The work on emission stars is reported elsewhere.)

According to Schalén, a general survey of the Milky Way is in progress at Uppsala. (1) Results for the region longitude 60° to 80° $9 < m_{pg} < 10$ have been published (17). (2) A region in Taurus, down to $m_{pg} = 12$ has been studied by Adolfsson (18). (3) The Lindblad spectrophotometric criteria have been investigated by Westerlund (19), and measures of spectra and colour obtained.

At Yerkes and McDonald, Roman is obtaining slit spectra in selected areas from latitude +45° to −40° and down to $m_{pg} = 12$, in certain areas.

The Southern Hemisphere

The expansion of astronomical activity in the southern hemisphere is perhaps the most important international need, and it is pleasant to report on some items from our colleagues in the south. An informal sub-commission, headed by Thackeray, is interested in the problem of spectroscopic standards in the southern sky. They have no formal report at present; part of their goal was to supplement Joy's (20) list by stars accessible to southern observers, which has been done. They urge that future fundamental classification lists emphasize stars accessible from the south. The importance of avoiding systematic differences between northern and southern classification standards is obvious.

Thackeray and Feast have classified 150 B stars at 49 Å/mm., on plates taken for radial velocity; they used three luminosity subdivisions. Gratton has observed 100 southern stars for standard types, and more will be added. He suggests emphasis on stars near the equator, for cross-calibration in both hemispheres and hopes that a large number of stars will be provided on both the Yerkes and Mount Wilson systems. His own work has been experimentally based on the MK standards and on colours and magnitudes provided by Stoy.

Bidelman (21), at Lick, has classified the Chilean spectra of southern high-luminosity stars. With K. Böhm he has classified southern peculiar A and F stars from the same material. At the Radcliffe Observatory, Code and Houck obtained spectrograms of 220 early-type stars at a dispersion suitable for classification on the MK system. The colours and magnitudes of 118 southern OB stars, together with classifications assigned in collaboration with W. W. Morgan, have been published (*Ap. J. Suppl.* no. 14, 1955).

The Radcliffe programme includes a study of: AE Aqr, AG Car, GG Car, Proxima Cen, W Cru, S Dor, AL Vel, AR Pav (an interesting P Cyg eclipsing star, intrinsically variable, with symbiotic and nebular characteristics). Spectra of individual stars in 47 Tuc and in the Magellanic Clouds have been obtained; including a number of P Cygni stars. Feast found the central star in the 30 Dor nebula to be of O type, with H and K interstellar absorption lines produced by gas in the Magellanic Cloud, and He I, λ3889, in absorption in a circumstellar nebula (as in the Trapezium stars). Feast discovered T Ara to be a new Li I star, in his work on 59 southern N stars. He also showed the luminosity of the S star π^1 Gru to be that of a normal giant by classifying its dG visual companion.

Classification in Clusters

The high accuracy of photo-electric photometry has resulted in a recent emphasis on colour rather than spectral measures in clusters. These results fall more properly in other commissions and I will limit myself to a brief listing of spectral investigations in progress, as reported to me.

Roman classified 54 stars in the galactic cluster NGC 752. The main sequence from

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G0 to F2 is capped by subgiants and one giant of types F2 to F6; eight late-type giants and one A0 star are found. NGC 752 is one of the oldest of the galactic clusters and the stars belong to the 'weak-line' group. Deutsch finds the F stars to have normal spectra for their colours and luminosities. Deutsch has studied IC 4665, which resembles the Pleiades, but has a quite different distribution of rotational velocities. In NGC 663 the most luminous stars are of class Ib and although their spectra are normal, the Balmer jump is abnormally strong, in agreement with W. Becker's photometric evidence. Deutsch finds that in the Taurus and Coma clusters metallic-line stars simulate supergiants on the basis of line criteria. Many have apparent abundance differences similar to those found by Greenstein in τU Ma, but the abundance anomalies are not the same in all. In NGC 457 Deutsch classified 20 stars earlier than A0; the B giants show Balmer emission. Merle Walker has measured photo-electric magnitudes and colours.

Globular cluster stars have been the subject of a concerted study by the Mount Wilson and Palomar spectroscopists. Wilson and Coffeen (22) derived a mass of $3{\cdot}3 \times 10^5$ M☉ for M92 from the internal radial-velocity dispersion, with an uncertainty estimated as a factor of 2 or 3 (22). Deutsch will classify at low dispersion and partly at 38 Å/mm. the red giants in twelve of the brightest clusters, an extension of the work reported in the 1953 Paris conference on spectral classification; M3 and M13 showed spectra like high-velocity giants near the Sun; M15 and M92 have very much weaker lines. Greenstein has obtained several spectra of the brightest red giants in M13 and M92 at 18 Å/mm., the highest feasible dispersion (exposures 8 to 15 hours with the 200 in.). The M92 spectra are very peculiar; they are clearly not F stars (as earlier classified at low dispersion), but have very weak lines. Unexpected anomalies exist like the strength of VI lines of zero excitation. A suspicion exists that the M92 stars, greatly distended and probably with low surface gravity, may be partly 'shell' stars.

Münch will attempt to observe the blue stars in globular clusters. The horizontal-branch stars (M=0) will be difficult objects (about $15^m{\cdot}5$). A few B stars exist brighter than M=0; they must have a different evolution, presumably being well-mixed, than the red giants and horizontal-branch stars. An example is Barnard no. 29 in M13 which seems to be B2p. It has very sharp H and He I lines, very weak Mg II, but a luminosity of $-1^m{\cdot}6$, more than one magnitude below the main sequence for its spectral type and colour.

An important use of stellar associations, when the reality of the physical connexion is certain, is to provide calibrations of stars of high luminosity. As an example, Bidelman has studied the space distribution of supergiants later than B, based on classification and discovery lists from the Case programme. By ascribing stars to various associations or spiral arms, the luminosities may be obtained.

Be and Shell Stars

From Prof. Melnikov's excellent review of work in the U.S.S.R., I abstract some of the highlights. Many aspects of the Be star and P Cyg problem have been studied; O. D. Dokutchaeva (Sternberg Astr. Inst.) has surveyed the observational and theoretical status of the problem. Colour temperatures for 36 Be stars were measured, 28 for the first time. After correction for space reddening the Be and B stars had similar energy distributions. Anomalously low temperatures are rare. Larger axial rotation distinguishes Be from B stars. At Sternberg the colour temperature variations of γ Cas were studied, and the Balmer decrement in AG Peg measured and analysed theoretically. Mustel, Galkin and Kopylov studied γ Cas spectrophotometrically at Simeis. They give a rotational $v \sin i$ of 330 km./sec., spectral type of B1, as of late 1952. The line broadening of the underlying hydrogen lines is mainly caused by interatomic stark effect. The question of the origin of narrow hydrogen and ionized metals absorption lines in the spectra of γ Cas and Pleione during one observational period was studied by V. G. Gorbatzky (23). These lines may originate in the extended shell at great distances from the border of the star, owing to an increased radiation beyond the Lyman series. The radiation pressure causes further on an expansion and scattering of the shell, as a result of which a disappearance of the narrow lines is observed.

Heard has followed 53 Be stars at David Dunlap over a period of sixteen years. The following objects proved to have variable spectra: MWC 23, 29, 49, 61, 76, 164, 278, 292, 307, 310, 312, 317, 320, 331, 332, 336, 346, 347, 350, 360, 361, 366, 371, 376, 381, 383, 394, 395, 402, 407, 409.

Gratton has followed the spectral variations of AG Car which changed from A2e in 1949 to B5e in 1953.

Merrill (24) has summarized his results on shell stars. On high-dispersion Mount Wilson spectra L. Searle (Princeton) is studying 1 Del, HD 33232, 193182 and 195407. Greenstein found that MWC 603, an eleventh magnitude star at moderately high galactic latitude, has a very rich emission-line spectrum; Tifft has measured several hundred ionized metallic lines, and He I, [O III], [Ne III]. Deutsch announces that HD 161261, in IC 4665 is a shell star.

Roman (25) finds a high-velocity star, +67° 922, to have a late-type G absorption spectrum with strong H and He emission. Variability of the spectrum has been discovered and the peculiarities of the absorption spectrum described by Miss Roman.

An extensive study of shell stars has been made by Underhill (ζ Tau, 48 Lib, 14 Com, V 367 Cyg), and her results have been published in *Contributions from the Dominion Astrophysical Observatory*. She will continue studies of shells at high dispersion. The star ζ Tau may be a spectroscopic binary. An interesting result on which more observations are planned is that the Hα emission in shell stars is wider than expected and suggests chaotic or stream motion, or turbulence in the outer parts of the shells (26). She is also studying the composite spectrum of HD 50820, whose components are of types B2e and K1 II.

Swings (27) has reviewed the problems of identification and interpretation of forbidden lines of iron and other metals in various stages of ionization. The conditions under which [Fe I] might appear and its possible presence in the Sun are discussed by Swensson (28). The predictions by Swings concerning the infra-red lines of [Fe II], [Ni II] and [Fe IV] have been confirmed by Thackeray. Swensson (29) lists the expected lines of [Cr III], [Mn III], [Co III]; only [Ni III] has possibly been identified as yet, in novae, the Orion nebula, and in Z And. He is observing PGC 1985, studying variations of the new forbidden lines in the ultra-violet. The Liège group will continue studies of ρ Cas, Z And, CI Cyg, RW Hya, XX Oph, AG Peg, AX Per, HD 45677, μ Cen. The spectrum of BF Cyg, 1947–50, has been described by Swings and Swensson; it shows emission lines of H, He I, He II, C II, C III, N III, Si II, Si III, Si IV, Fe II, and many forbidden lines of the ionized metals.

Feast and Thackeray find H and K emission to be quite common in dK stars, and list ten new southern objects. Popper is studying the long-term variation of the emission-line intensities in dwarfs. O. C. Wilson has found a remarkably close correlation between the strength of H and K emission, in G to M stars, with luminosity. From $M=+7$ to $M=-6$ the emission widens monotonically with increasing brightness. Presumably the velocities of turbulent or prominence motion increase as the surface gravity and mean density in the stellar envelope decreases (in agreement with the turbulent motions in the reversing layer).

Magnetic Fields

H. W. Babcock has published a list of stars showing strong magnetic fields (30) and a detailed study of the magnetic and spectral variations of HD 188041 (31). Strong, coherent fields have been found only in the peculiar stars and spectrum variables of types A and early F, and in a few M-type giants. Spectrum variations occur only in some of the periodic magnetic variables; the largest amplitudes occur for periods from 4 to 10 days. Non-uniform variations of field occur in HD 188041 which has a periodic spectral variation. A varying field near 3000 gauss exists in VV Cep, type cM2e. Because of the laborious nature of the measurements required to determine field strengths Babcock is experimenting with direct photo-electric measurements in the spectrograph. A standard 'template' will be moved along the stellar spectrum and a phototube measurement made to determine the position of coincidence of stellar and template lines. Deutsch is continuing his study of the peculiar A stars, for determination of period, line widths and the geometry of the relevant oblique-rotator models.

M. and G. Burbidge have made a detailed study of α^2 CVn on McDonald coudé plates. The curves of growth seem normal and the major difficulties are connected with blending in the rare-earth lines and the high excitation potential of some important elements. They find that Pb I may be present, and that the rare earths and La, Ba, Pb are increased in abundance over normal stars by factors of 100 to 1000. They are studying theoretical mechanisms of the possible nuclear processes at the surfaces of a magnetic star, if accelerated particles cause spallation reactions, or produce neutrons to build heavy elements from the lighter and normally more abundant ones. The abundances should be inversely proportional to the neutron-capture cross-sections; since Eu, Dy and Gd have large low-energy cross-sections, and are present, there is some difficulty. However, for the other stable magic-number nuclei, they predict high abundances, as observed.

Subdwarfs and White Dwarfs

The possibility of radical differences in composition between old and new stars has been emphasized recently, and the quantitative work of Chamberlin and Aller on F subdwarfs is being expanded by Aller and Greenstein. A most interesting survey of the kinematic, colorimetric and spectral properties of F subdwarfs is given by Roman (32). These have extraordinarily weak lines, and a large ultra-violet excess, due partly to the weakening of the normally very strong resonance lines. The galactic orbits are extremely peculiar with a mean eccentricity near 0·9 and little systematic galactic rotation. They represent one of the purest samples of population II.

Greenstein is studying eighty subdwarfs, A5 to G8 at 18 Å/mm., to 11·5 m_{pg} at Palomar, to provide a more complete spectroscopic description. A provisional, purely excitation-temperature classification has been made which should be nearly unaffected by abundance changes. At a given type three degrees of line weakening appear to be distinguishable; ordinary weak-line stars have a space-velocity dispersion near 70 km./sec.; stars of large weakening have 210 km./sec. and extreme weakening, 330 km./sec. The latter two groups average 1·5 mag. fainter than the population I main sequence.

In the earlier types a large and important region of the HR diagram remains unexplored spectroscopically, i.e. O, B, A subdwarfs, pre-novae, hot components of SS Cyg stars and of symbiotic stars. The study by Joy of AE Aqr should be mentioned here. Humason (33) has obtained low-dispersion spectra of the Humason-Zwicky stars, some of which seemed to be white dwarfs. Greenstein and Münch have investigated a group of these HZ stars, of mean type B7, 12th magnitude, at the galactic pole. They find a moderate velocity dispersion, ± 48 km./sec., and a luminosity (from a few proper motions only) in the range 0 to +2, i.e. at least 1·5 mag. below the main sequence. These are probably like the globular cluster, horizontal-branch stars, and the spectra are not very abnormal, except for small axial rotation. An interesting hot subdwarf is HZ 44, an 11th mag. O star, with strong He I, He II, N II and N III and weak H, O II and C II. HZ 1 and HZ 3 are much more extreme stars, at the 13th mag.; H is very weak, He II, Si IV present; these are probably close to the white dwarfs. The star +28° 4211 is very nearly a white dwarf, with shallow weak H and strong He II (34).

Luyten (35), in a most important summary, gives spectral types of 44 white dwarfs from McDonald and Mount Wilson spectra, 165 to 390 Å/mm. He bases a classification on the H-line widths. In addition to the so-called continuous spectra and the F stars he finds two helium-rich white dwarfs. These objects may be viewed as positive proof of thermonuclear exhaustion of H as the nuclear fuel in stars. Luyten's work is a major step forward in spectroscopy of white dwarfs since pioneer work twenty years earlier. Because of the efficiency of the 200-inch spectrograph, Greenstein (36) has been able to

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observe about twenty white dwarfs at 38 Å/mm., down to $14^m.5$. From the peculiarities already noted, it is clear that the problem will be difficult, and that more parallaxes and photo-electric, multicolour photometry are needed to obtain a correlation of the spectra and other properties. Luyten has noted that 'continuous' spectra appeared in both blue and yellow stars, and that the He-rich stars were not outstanding in either colour or luminosity. Among some of the types of white dwarfs found, Greenstein lists (*a*) relatively sharp-line stars, e.g. L532–81; (*b*) former DC blue stars with broad, but extremely shallow H, about 10% deep, like HZ29, HZ43; (*c*) AC +70° 8247, a blue DC star with shallow band-like unidentified absorption lines; λ4135 has a depth of 15%, other possible lines are shallower; (*d*) He-rich stars, L930–80 and L1573–31 have very broad lines underlying displaced shell lines He I, λλ3889, 3965 of the type that appear in the Orion nebula; (*e*) 'composites' He II and shallow late-type features, Ca I, Ca II and the G-band; these may be unresolved doubles, a late-type and an O subdwarf; (*f*) V Ma 2 (= Wolf 28) is an F-type white dwarf with very broad Fe I lines in the ultra-violet, enormous pressure broadening, and shell lines, sharp and of large negative velocity in H and K of Ca II. The existence of shells was proved in five helium-rich subdwarfs and white dwarfs, and in the F-type white dwarf; it must have important consequences in the evolution of these stars and possibly in the theory of the formation of the elements.

Popper has measured the radial velocity of 40 Eri B, a normal hydrogen white dwarf. From the velocity of 40 Eri C, a dM star, he finds a relative red shift of 21 km./sec. in 40 Eri B. This agrees well with the predicted value of 17 km./sec. based on the mass and radius he deduces for 40 Eri B, and on the theory of general relativity.

T Tauri and Hα Stars in Nebulae

G. Haro at Tonantzintla has made extensive discovery searches for emission-line dwarfs in dark nebulae. He lists 255 Hα stars within 3·5 square degrees centred on the Orion nebula, with the greatest concentration near the Trapezium. He has studied their variability and surface distribution (37). With collaborators, he lists 98 objects near IC 434 and 69 in the Taurus field where Joy had first found these objects. The highest surface density of these stars is in an Hα emission region somewhat similar to the Horsehead nebula (38). Haro and Terrazas (39) have studied rapid light variations and flares of emission-line stars. Deutsch plans to observe the spectra of late-type stars in the Orion nebula, particularly the nebular variables, using 38 Å/mm. dispersion.

Herbig has developed a slitless spectrograph with transmission grating at the Lick Observatory, permitting discovery of Hα emission in stars of $m_{pg} = 19$ with the 36 in. reflector. In NGC 2264, a nebulous cluster, 84 Hα objects were found, 14^m to 19^m; slit spectra show them to be T Tauri stars (40). In and around IC 348, a part of the ζ Per expanding association, sixteen objects, $16^m.5$–$19^m.5$ were discovered (41). In both the above, late-type dwarfs are found in the same groups as the O and B stars; some evidence of late-type Hα stars was found in the expanding association in Lacerta. Other O associations in obscured regions are to be observed. Herbig comments that since about 140 T Tau stars have been observed with slit spectrograms, more attention should be paid to the study of typical objects at high dispersion. He found that in four of the brightest, the absorption lines are diffuse at 10 Å/mm., due either to rotation or large-scale turbulence (42). A rough classification of the bright-line dwarfs in nebulosity is as follows:

(*a*) T Tauri stars, types F8 to M, late-type spectra with strong emission lines.

(*b*) Objects like −6° 1253, strong hydrogen lines, with higher excitation emission lines than (*a*). These all have associated reflection nebulae.

(*c*) Abnormal stars above the main sequence like BF Ori and FU Ori.

(*d*) Mainly bright lines, with continuum invisible, like the objects near −6° 1253.

Herbig and Walker point out that there is a definite tendency for T Tauri stars of types later than K5 in a cluster like NGC 2264 to lie progressively further above the main sequence, reaching 2·5 mag. by dM2. If the T Tauri stars are being currently formed by gravitational condensation, they should first appear as cool stars, not in a steady state, and then approach the main sequence. Henyey and others at Berkeley are exploring this problem of non-steady state contractional equilibrium configurations, using high-speed computing machines. The stars follow tracks starting above and to the right of the main sequence, as observed, remaining on them longer periods for the smaller masses (which eventually become the fainter main-sequence stars).

Spectroscopic Binaries

Struve and collaborators have studied the stars ϵ Aur, λ Tau, β Per and other objects at higher dispersion. The sub-giant components of Algol-type variables proved to be entirely different from normal subgiants, or those in wide visual binaries. It is possible that they have lost appreciable mass in evolving, due to the close proximity of a denser primary.

Underhill will study the radial velocities of visual binaries with periods ranging from 15 to 40 years. The following stars will be on her programme: ϵ Hya, 10 UMa, β LMi, α UMa, HD 126128, ζ Her, β Del, 85 Peg.

Hynek plans a detailed study of 200 spectrum binaries, composite stars, to provide magnitude differences, radial velocities, etc. He is planning a study of the B stars brighter than the fifth magnitude in the wave-length region $\lambda\lambda$ 8000–8750, at 500 Å/mm. Any red components of spectrum binaries, and of eclipsing stars, show well in this region.

Humblet, Mannino and Swings are studying the intensity variations and profiles in the Of stars. Miczaika (43) has studied the Of plus O9 double-line binary, $+40^\circ$ 4220. The components do not seem to obey the mass-luminosity relation; the system is an important one like 29 CMa, since it is also an eclipsing variable.

Deutsch (44) has found that α Equ is a double-line spectroscopic binary, gF8+A3, with approximate but anomalous mass ratio of 1/3·9, and a period of 98 days. There is an apparent suppression of the lines of the A star, an effect first noted by Struve (45) in Capella, and also by Wright (46). Deutsch will also observe spectroscopic binaries α HerB, α PscB, HD 190275.

During the 1951 eclipse of 31 Cyg Underhill studied the Fe I chromospheric absorption lines. There is evidence that continuous absorption of ultra-violet radiation by the envelope of the K star dims the B star three or four days before occultation begins. Complex structure in the chromospheric K line of 31 Cyg was studied by McKellar and his collaborators (47). Work on the problem of 31 Cyg is being continued. The star 32 Cyg was observed during its 1952 eclipse by Wellmann and Weston, who found a period of 1148 days, spectral types K5 Ib and B2 V. They find that the primary eclipse is a grazing one.

Turbulence and Rotation

In collaboration, Huang and Struve (48) have published four papers on the effects of rotation, large-scale turbulence, small-scale turbulence and prominence-like motion on the line profiles of stars. Expected profiles for various distributions of the macroscopic motions have been worked out. The effects predicted can best be studied by a relation which connects the line widths and the equivalent widths. Large and small eddies can be studied separately (where the size is in units of the thickness of the reversal layer). The general conclusion, based on the observation of supergiants, is that in the most luminous stars mass motion with spherical symmetry, perhaps a field of prominences surrounding the star, produces a large-eddy line broadening, and that there may exist a stratification of velocity with depth. This emphasis on the importance of line-profiles as against the use of equivalent width alone is an important one and represents a growing trend in stellar spectroscopy. It is made possible by the use of high resolution spectrographs. The relation of line-width versus equivalent width is, however, very sensitive to experimental error. In supergiants later than F0 the blends and the uncertainty of location of the continuum will seriously affect the results. The method seems best suited for the study of early-type stars.

The α Sco system, an M supergiant with a hot companion, has been studied by Struve. However, no particular extension of the supergiant envelope was found there; in α HerA, a supergiant M5 star, Deutsch has found an extraordinary extension of the envelope of the supergiant which seems to envelop α HerB, a spectroscopic binary at a projected distance on the plane of the sky of 1000 astronomical units from the supergiant. Sharp stationary lines from zero volts excitation potential of Ca I, Ca II, Fe I, Na I are found superposed on the moving lines of α HerB. These sharp envelope lines had previously been found by Adams in α HerA. Enough mass flow seems to occur in the supergiant envelope so that evolutionary changes in its mass might occur in a relatively short time.

Struve has been studying the spectra of fifty visual binary stars, a field too long neglected. These binaries are in a sense the most frequent and simple clusters, and evolutionary trends therefore can be most easily seen. In many systems the brighter component is a subgiant, and if in the spectral type range F0 to F8, the brighter star is often rotating, while the secondary has sharp lines. There seems to be no curve-of-growth anomalies, but Struve suspects there may be some abnormality in the relation between colour and spectral type. The fact that the primary is rotating is consistent with an evolution to the right from the main sequence of an originally hotter and more rapidly rotating earlier type primary, while the secondary has hardly evolved at all.

A comprehensive study of the frequency distribution of rotational velocity has been made by Slettebak at Perkins Observatory. His work includes 179 stars, B8 to A2 (49a), 185 B2 to B5 stars (49b), 250 A3 to G0 stars (50). The programme was to cover generally the stars brighter than fifth magnitude and north of $-15°$. The dispersion was 28 Å/mm.; the lines used were λ4471 for B2 to B5, λ4481 for B8 to F0, λ4071 for F2 to G0. MK types and luminosities were assigned to the stars. Slettebak finds that down the main sequence rotation has a maximum at B5, decreasing gradually, till at F0 an abrupt drop occurs. For early types, B1 to A2, main-sequence stars have greater rotation than giants; at A3 to A7 the rotations are the same, but at F0 to G0 the giants and subgiants have greater rotations than the dwarfs. Peculiar and metallic-line A stars and supergiants showed somewhat lower rotations, although other investigators have found a high percentage of binaries in the metallic-line stars.

The question is still unresolved as to whether the broad and shallow lines of the O- and early B-type stars are explained completely by rotation. The work of Struve and Huang indicates that a decision between macroscopic turbulence, rotation and other causes of line broadening will be difficult. Work on Mount Wilson coudé spectra is in progress on this topic, and Slettebak will also study these early types.

Herbig and Spalding have studied rotation in 656 stars of types F0 to K5 on the MKK system, using 11 Å/mm. dispersion. They find that through spectral class F rotation diminishes, but that some stars still have $v \sin i$ 20 km./sec. up to spectral-type F8 V and even to G0 III or IV. At a given type, between F0 and G0, giants and subgiants have greater rotation than dwarfs. No significant differences are seen between strong- and weak-line stars in the pattern of rotation. This important information on the properties of stars in the Hertzsprung gap is supplemented by the study by Oke and Greenstein (51). They determined accurate rotational velocity for stars in the A and early F types, especially giants. They find surprisingly large rotations in the A and F giants, as did Herbig and Spalding. The current theory of evolution of stars with appreciable exhaustion of hydrogen predicts that type A main-sequence stars will become F giants. This explains why there is still appreciable rotation, since the smaller original stars were of earlier type, and therefore at originally large rotations. The amount of reduction of $v \sin i$ by the expansion was computed by Oke and Greenstein. Thus evolution to the right from the main sequence seems confirmed by the rotation. Evolution directly upwards from late F or G dwarfs is impossible because the original objects would then not have been sufficiently rapidly rotating.

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A narrow spectral range, types B1 to B3, includes the majority of these objects. According to Struve, at B3 the luminosities are those of main-sequence non-variables, while at B1 they are 1·5 mags. too bright. A period-luminosity relation exists, with periods near six hours at B1·5 and periods of the order of 3·5 hours at B3. The velocity curves show very strong discontinuities on the rising branch of the light curve. In BW Vul and in σ Sco the lines double at maximum radial velocity. The component at larger positive velocity fades out and the shortward component gains strength, causing a 'still stand' on low dispersion. Finally a new violet displaced component takes over as the intermediate velocity component fades during the rising branch of the velocity curve. Similar discontinuities probably exist in other objects like 12 Lac where doubling was seen in 1950. Beat phenomena have been found in 16 Lac, β CMa, ν Eri, but not in all objects. Period changes have been found which range from 3 sec./century in BW Vul to 1 sec./century for β Cep. Other stars may have no change, β CMa, ν Eri, δ Cet, 12 Lac. Struve suspects that if there were systematic long-continuing evolutionary trends a star like γ Peg would take 10^6 years to go from spectral type B3 to B1, possibly following a $P\sqrt{\rho}$ law. Collaborating with Struve in these problems have been McNamara, Huang, Kung, Williams and Father Bertiau. The 60- and 100-inch telescopes at Mount Wilson and the telescopes at Lick have provided most of the observational material. Greaves, Baker and Wilson find that the Balmer lines in β Cep vary in strength during the period, especially Hα. Independent work on some of these same stars has been done at Victoria by R. M. Retrie and G. J. Odgers.

ASTROPHYSICAL THEORY

Much work connected with stellar and solar atmosphere models is reported in other commissions. Only a few investigations having more direct relation to spectroscopy will be mentioned here.

Studies of the temperature distribution in the solar atmosphere have been carried out by E. Böhm-Vitense (52, 53) and K. H. Böhm (54), leading to a more detailed model of the temperature distribution in the Sun. Non-coherent scattering is taken into account by Böhm in his study of the centre-limb variations of strong and weak lines. His model still requires temperature fluctuations in the outer layers and deviations from local thermodynamic equilibrium (55). Priester has studied the abnormal excitation of transitions in a multiplet which may coincide with other strong lines. In the Sun, the chromosphere and some giants and dwarfs, no effect is found, which can be interpreted as proof that the lines are formed dominantly by a simple 'absorption' scheme and that incoherent scattering plays only a small part. The effectiveness of coincidence-excitation in nebulae or T Tauri stars reflects the strong departure from equilibrium in these objects.

V. V. Sobolev (56) reports on a new method in the theory of scattering of radiation. He uses the probability of emission at a given point into certain directions, a function of the properties of the medium, but not of the sources of emission. Then, given the source distribution, a solution of the scattering problem is obtained by integration. The emission-probability integral and functional equations are derived; within a constant, it proves to be the B (τ) for the radiation in a medium illuminated by parallel light rays. Other problems, including redistribution in frequency and time dependence, can be solved in a similar way. Sobolev (57) also investigated non-coherent scattering, including fluorescence. Computations were made of central intensity and line-profiles for a strong line in the Sun, and its centre-limb variation. Sobolev finds better agreement with observations in the non-coherent case.

Sliusarev (58) has studied the difficult question of the effect of free electrons on the structure of atmospheres of hot stars when both absorption and scattering processes contribute to the opacity.

Atmospheric models have been derived for B and O stars by Underhill and Mac-

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Donald (59). The strength of the He II lines in O stars is discussed (Liège Symposium volume) and Underhill finds a low ratio of He/H in agreement with Neven. She is continuing low-dispersion measures of equivalent widths in O and B stars in clusters, to establish luminosity criteria and to study the relation between O, Of and WR stars. Unsöld, as mentioned below, disagrees with the recently derived low He/H ratio.

The Holtsmark theory of the hydrogen line-profiles has been re-examined extensively. Underhill (60) applied it to O9 stars. Melnikov (61) has determined the ionization temperature for stars in which the Balmer lines reach their maximum strength, spectral type A2 on the Harvard system. He gives a temperature of 9000° for the maximum.

Aller has worked in collaboration with Turner and Kolb at Michigan, who are studying the radiation from shock tubes in hydrogen. Temperatures of 10,000° to 20,000° are reached, and strong broadened Balmer lines observed. The observed profiles differ from those predicted on a simple application of the Holtsmark theory (62). The measures of T and P_e in the shock tube are thought dependable; they believe the simple Holtsmark theory and the Inglis-Teller formula therefore need revision, and that the electron densities in stars will have to be changed, when derived from the hydrogen lines. An approximate theory has been developed based on the Michigan results, indicating that the line-broadening function is shallower in the core and more extended in the wings than the Holtsmark function. This theory assumes Lorentz-Weisskopf broadening by electrons about the shifted position given by the Holtsmark Stark broadening, dominated by the protons.

Experimental measures over a wide range of temperature, gases and electron density are being carried out in shock tubes. In a different technique, the line broadening has been studied at Lochte-Holtgreven's laboratory. Earlier, Jurgens (63) at Kiel had reported agreement with the Holtsmark theory. Unsöld and Kivel report that the effect of electrons on Stark broadening seems to be small as compared to that of ions. Because of the importance of the line broadening in the interpretation of H and He abundances in hot stars, this new field of 'experimental astrophysics' is of the greatest importance.

Aller and his collaborators have made an intensive attempt to derive model atmospheres, using machine computation, and curves of growth from observational material, for hot hydrogen- and helium-rich stars. Milligan and Aller (64) use a new convergent method of fulfilling the flux-constancy condition, including blanketing by lines and the Lyman continuum; they find a steep temperature gradient near the surface.

A detailed study of line strengths in the H and He lines in seven B1 stars has been made by Greaves, Baker and Wilson at Edinburgh, using the ingenious method described in *Publications of the Edinburgh Obs.* **1**, no. 2. Quantitative effects of increasing luminosity include the weakening of $H\alpha$, $H\beta$, $H\gamma$ and strengthening of other lines. The intensity gradient along the He I series changes, $\lambda\lambda$5876, 6678 being weakened in dwarfs, weaker than higher series members and falling off any single curve of growth. In π Aqr (B1 V), λ5876 shows weak emissions. Cyclical transitions may be operative, although collisional and Stark broadening also is operative on the higher series members.

A. A. Nikitin has studied extensively a group of problems related to the appearance of lines of high excitation potential. The helium problem is discussed for the solar chromosphere (65), for absorption on the solar disk (66) and for metastable lines in stars and nebulae (67). The oxygen lines in the Sun and stars have been studied (68). He has made a detailed study (69) of the transition probabilities and energy levels of Ca II, to compute populations and the strength of permitted and forbidden lines in various sources.

Stellar Abundances

There have not been many detailed abundance analyses published, but much time has been devoted to critical examination of the methods and to the link between nuclear reactions and observed abundances. Considerable work is in progress on normal and peculiar stars.

Traving, Hunger and Weidemann, working with Unsöld, have made a detailed analysis of the effect of temperature and pressure stratification on the abundance determinations ('fine' analysis) in 10 Lac, τ Sco, α Lyr and the Sun. New models in the non-grey atmosphere case are derived, the T_e and g are determined from the spectra; the ratio H/He is low, like that first given by Unsöld in τ Sco, and in contradiction to the high ratios given by Neven and Underhill. Voigt (70) has made a 'rough' analysis of 55 Cyg, a supergiant B2 star, with results similar to those of Unsöld in τ Sco.

Aller and Munch are analysing the hydrogen-poor star HD 160641; Aller and Greenstein are studying the early-type, faint, carbon-rich, absorption-line star HZ 15. Two metallic-line stars are being investigated by Miczaika; with Greenstein he has measured equivalent widths of 500 lines in 15 Vul, and with Deutsch 300 lines in 8 Com. The abundance differences are less pronounced than in τ UMa. Mustel and Galkin, using the Crimean 1200 mm. reflector, have been studying the metallic-line stars observationally and theoretically. They investigate the line-profiles of Hα and compare them with normal stars. The relative intensities of cores and wings seem to be normal in metallic-line stars. They point out that Greenstein's mechanism of resonance ionization of certain ionized metals by electron transfer to protons would require anomalous ionization of hydrogen at certain layers, and that this would be noticeable in the core/wing ratio and is not found. This very interesting approach to the problem of metallic-line stars has been published in *Publications of the Crimean Observatory* (71). In a second paper (72) they study α Gem B, which has the line profiles of a giant star rather than of a dwarf. (This is in agreement with other lines which give these objects a pseudo-supergiant appearance.) They assert that the metallic-line stars deviate two magnitudes from the main sequence and that this deviation increases with increasing differences between the types given by the Fe and Mn lines as compared to that given by the Ca II lines. This apparently high luminosity for α Gem B is not confirmed by the parallax (0".072), which puts it near the main sequence if the hydrogen-line type is used. Nikitin (73) has discussed problems of the composition of stars and nebulae.

Gratton has made an analysis of the relative abundances of the elements in five K giants. By using a differential method, remarkably accurate results are obtained. He found, relative to the mean of the metals Ti, V, Cr, Fe, Ni, that the hydrogen abundance was higher by about 60% in the high-velocity stars, and that most other well-determined metals had the same abundances, within about 10% in all stars (1953 Liège Symposium). He found lower C, N, O abundance in the high-velocity stars, the opposite of Schwarzschild's results. Greenstein's work on the G stars has progressed slowly. All measurements and rough analyses are completed for eight stars. The blending and the uncertainty of location of the continuum even at 2·8 Å/mm. are functions of luminosity, and there are considerable systematic differences between the measured equivalent widths, and those measured at Victoria (see Commission 36, on Spectrophotometry). In addition to the normal and high-velocity stars studied, two peculiar objects have been investigated by J. Humblet (Liège), the G-subgiant HD 18474 which has extraordinarily weak CH and CN, and 31 Aqu, a '4150' star, with abnormal apparent strength of the higher bands of the λ4215 system of CN.

Schwarzschild is analysing the composition of sixteen K giants of both high- and low-velocity groups.

Bidelman has reviewed the properties of the hydrogen-deficient stars and of the R, N, and S stars in the Liège symposium volume. He points out the weakness of C^{13} in the H-poor stars. A general review of the effects of thermonuclear reactions on abundances is given by Greenstein in the same volume, who stresses N^{14} as an abundant end product of the carbon cycle.

Several lines of evidence point to the recent production of heavy elements in at least some stars, e.g. the carbon stars, the S types (rich in heavy elements and Tc), the Ba II stars like ζ Cap, the high-velocity CH star, HD 26, etc. If elements are formed in the interior and later can be observed at the surface, or if they are formed at the surface, a wide new field of possibilities is opened.

Hoyle (74) made an interesting detailed study of the various element-building processes in exhausted stars of large mass and high temperature, which become supernovae, and thus ultimately increase the average heavy-element content of the Galaxy. The detailed predictions of the equilibria between He^4, Be^8, C^{12}, O^{16} and Ne^{20} are given in the temperature range 140–200 million degrees, although in some cases the nuclear data are not sufficiently well known. Side reactions leading to other elements are discussed. The heavier elements are treated more tentatively, in the range 600 to 2000 million degrees.

G. and E. Burbidge are working on the effects of surface magnetic fields which may produce heavy elements in magnetic stars, i.e. permitting a star to alter its composition without catastrophe. If stars can form heavy elements in a collapsed interior region, and subsequently mix these with outer layers, and without an explosive catastrophe, a new process suggested by A. G. W. Cameron (Chalk River) is most significant (75). Since C^{13} is produced in considerable quantity by the carbon cycle, the process C^{13} (α, n) O^{16} makes large numbers of neutrons at only 85 million degrees. Enough are so provided to increase substantially the number of 5th and 6th period elements, including Tc, by multiple capture on iron-group elements. This interesting possibility for explaining S-type stars may also provide a way worth exploring, to begin with a universe of pure hydrogen and end with He, C, and the heavy elements, without necessarily invoking the neutron-capture theory of Gamow, Alpher, and Herman. It explains incidentally the apparent heavy-element deficiency of the oldest population II stars. The subject of the effect of nuclear reactions on stellar abundance is an important and growing one. It will be important for spectroscopists to pay increased attention to determinations of abundances, or even upper limits for undetectable elements, in those cases where the nuclei are sensitive to various processes.

Proposals for Consideration by Commission 29

Information centre for stellar spectra

Paul Merrill proposes that a project financed by the I.A.U., with possible governmental assistance, at some observatory or department, might maintain a card catalogue listing for each star all published spectroscopic material. It would provide by mail on request a set of references for each star. The cards kept up to date might also include current lists of velocities, spectroscopic binaries, supergiants, white dwarfs, etc. For spectra, such a centre might perform the same service as is now available for variable stars.

P. C. Keenan comments on the above that the Perkins Observatory, Delaware, Ohio, U.S.A., has started a card-index file of published references for individual stars. The stars are ordered by right ascension and the data include a brief description of the contents of each paper. The spectral type, peculiarities, velocities are tabulated as well as any published illustrations or microphotometer tracings. Several thousand stars are included, complete to 1954, and down to the BD mag. limit. Some early papers in inaccessible journals are omitted. References to a few long catalogues or bibliographies are also omitted. The index could be made more complete and the service supplied to astronomers throughout the world on their request if an extra half-time assistant were available. Keenan believes that the Perkins Observatory could undertake completion and supervision of the catalogue together with the service to astronomers for information, if the I.A.U. could provide 1500–2000 dollars a year. If the I.A.U. wishes the information centre established elsewhere, the Perkins Observatory will be glad to loan the card index for copying.

Information centre on composite spectra

J. A. Hynek of Ohio State offers to set up at the Perkins Observatory an information centre on stars with composite spectra and will co-operate with others interested in this cosmogonically important group of objects. He would appreciate being notified as to stars with composite spectra found, for example, in objective prism spectroscopic surveys.

Recommendation on spectra of comets

Biermann wishes to draw attention, also to members of Commission 29, to the importance of distinguishing between the spectra of molecular ions and those of neutral molecules in the spectra of comets. This results from the fact that these two kinds of molecules will be influenced in quite different ways by solar activity, the ions being sensitive particularly to corpuscular solar radiation. In particular it would be useful to photograph future comets in such wave-length ranges that from the pictures themselves structures consisting of ions may be distinguished from structures consisting of non-ionized molecules. If this could be done for faint comets, it might eventually become possible to trace the influence of solar corpuscular radiation and to find out its intensity also in very high heliocentric latitudes.

Recommendations for increased effort

Swings recommends that more stellar spectra be observed in both the photographic and bolometric infra-red regions. Underhill emphasizes the importance of the $\lambda 5000$ to $\lambda 7000$ region of spectra for almost all types. The composite spectra containing early-type and late-type stars can well be separated there; spectra are not too crowded even in G and K stars in that region, and interesting lines are found in the O-type stars.

It has been suggested that insufficient photometric data is available for certain kinds of interesting and peculiar objects, such as the Of, Be, symbiotic and N stars. What is desirable may be monochromatic or narrow-band photo-electric magnitudes and colours of such objects, including the variation with time in the case of variable stars.

Revision of the Commission structure pertaining to stellar spectroscopy, spectrophotometry, and spectrum variables

Unsöld, in a letter to your commission President dated 2 December 1954, says that it would be very desirable to have at the Dublin meeting a discussion of the possibility of division of I.A.U. membership among commissions which would better represent the present status of research and its separation into different fields of interest. In *Trans. I.A.U.* Vol. **8**, p. 400, Swings discusses the difficulty of the proper definition of what subjects properly belong in the report of Commission 29. He lists the following commissions with which spectroscopy has a good deal to do: 24, 34, 42, 36, 14, 30, 40. L. Gratton, in two thoughtful letters dated 24 September and 1 December 1954, has expressed similar questions as to the degree with which the commission structure division now corresponds to the actual division of interests among working scientists in the various fields. Such a question is very much too large for a single I.A.U. commission to decide. In my own case I have been, in particular, unable to make a proper separation between functions of Commission 29 on stellar spectra and Commission 36 on spectrophotometry, nor in all cases to decide whether a theoretical investigation can be directly relevant to stellar spectra, solar spectroscopy, or spectrophotometry (which is needed for most theoretical studies). I hope that commission members will have some suggestions to make on a more rational distribution of membership.

Other proposals

At various times in the last two years your chairman has received suggestions that various lists would be useful. A discussion of some of these at the commission meeting might be desirable.

1. Current lists of objects on which members are making long-term investigations, to be distributed regularly.
2. Lists of existing but unpublished spectra of variable stars.
3. List of metallic-line stars.
4. List of spectral standard stars for southern observers.

5. An atlas of high-dispersion standard spectra on a spectrophotometric basis, extending the Hiltner-Williams Atlas.
6. Completion of atlas of spectra of molecular bands.
7. New edition of the *Yerkes Atlas of Stellar Spectra* on an enlarged scale.

JESSE L. GREENSTEIN
President of the Commission

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APPENDIX

A SUGGESTION FOR CONSIDERATION BY COMMISSION 29

Classification of Stars of the Giant Branch, G5 to K3

The bands of CN, particularly those with heads at $\lambda 3883$ and $\lambda 4215$, have long been known to show a positive luminosity effect and have been employed in the estimation of spectroscopic absolute magnitudes (1). More recently, however, it has been established that stars of a given spectral type and absolute magnitude show a real dispersion in the strength of their CN bands. This is not a random scatter, but is correlated with the space velocities of the stars in the sense that the percentage of stars with abnormally weak CN rises with increasing luminosity (2). Weak CN bands thus appear to be a characteristic of 'population II' stars, and extreme examples of the weakening are found among the members of globular clusters. On the other hand, a number of stars with unusually strong CN bands are also known, and these have sometimes been designated as '$\lambda 4150$' stars, though different observers have been somewhat inconsistent in using this last term (3).