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29*a*. SOUS-COMMISSION DES SPECTRES DES ÉTOILES VARIABLES

PRÉSIDENT: Mme C. H. Payne-Gaposchkin.

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

PRÉSIDENT: P. Swings.

MEMBRES: MM. Dobronravin, Feast, Fehrenbach, Herzberg, Junkes, Keenan, R. B. King, McKellar, Nevin, Phillips, Rosen, Wurm.

INSTRUMENTS

Perhaps the most striking tendency of the last few years is the rapid expansion of moderate size spectroscopic observing facilities in Europe and, fortunately, also in the southern hemisphere. New telescopes of about 1-m aperture, equipped with objective-prism or slit spectrographs, are now providing interesting results; in addition, older telescopes have been adapted to newer problems. A new objective-prism Maksutov camera of 70-cm aperture is in use at Abastumani. The telescope has focal ratio *f*/3, but has an additional secondary focus with 10·5-m effective focal length. The objective prism, made of light flint, goes down to wave-length 3500 Å, and gives a dispersion of 166 Å/mm at Hγ. The field covered is 5° in diameter. In addition at the secondary focus a grating slit spectrograph is provided giving dispersions of 23 Å/mm and 83 Å/mm. Gratton reports the extensive use of a 42 Å/mm grating spectrograph at Bosque Alegre, and construction of a lower dispersion instrument, possibly to reach 14^m. A small Schmidt camera has been finished, for eventual use with an objective prism. At Canberra, a 2-prism Zeiss spectrograph has been finished for the Newtonian focus of the 74-inch, to provide dispersions of 100, 145, 200, 290 Å/mm at Hγ. It will be used for velocities, spectra, luminosities and exploration of the interstellar lines in southern B stars. Swings reports a new objective-prism Schmidt telescope of 40–60-cm aperture, and 7° angle; a 95-cm Schmidt is to be built for the Belgian Congo, for spectral classification and a Be star survey of the southern hemisphere. In France, the expansion and international use of the facilities at Haute Provence has been notable. Bouigue, at Toulouse, has built a low-dispersion spectrograph for red stars and a new grating instrument for the near infra-red. Bappu reports new facilities at Naini Tal, in India; a 22-inch reflector should soon be in operation, with a low-dispersion spectrograph. He has successfully used interference filters on a 10-inch refractor to measure photo-electrically the variations of strong emission lines. At Merate, for the 1-m reflector, a 35 Å/mm blazed grating spectrograph uses an inverted-cassegrain collimator and a Schmidt camera. This combination is becoming popular for a relatively compact, all-reflexion spectrograph, adapted to slower focal ratio primaries. Japan has funded construction of two 36-inch reflectors and a new 74-inch reflector for spectroscopic work is under construction by Grubb Parsons, for completion in 1959. A new 3-prism ultra-violet spectrograph with quartz-fluorite optics and $f/1$ and $f/2$ folded Schmidts is in use at Michigan for faint objects. The Palomar nebular spectrograph has now been frequently used for stellar spectroscopy; at 180 Å/mm well-widened spectra to 16^m and unwidened to $17^m.5$ have been obtained in globular clusters and extra-galactic nebulae.

Spectral scanning at the telescope is developing rapidly; scans with low resolutions down to 10^m are possible at many institutions. These fill an important gap between multi-colour photo-electric photometry and the difficult high-resolution scan. David Dunlap Observatory reports resolution up to 6 Å, to $7^m.5$, with a few minutes scan time. They are studying energy distribution of standard stars, including variables, and measure equivalent widths of strong lines. Bappu has both a rapid-scan spectrophotometer and a 1-prism monochromator. Dobronravin has been active in developing a photo-electric spectrometer at the Crimean Astrophysical Observatory. Code has carried out an extensive scanning programme on stars, and some extra-galactic nebulae. A very high-resolution spectral scanner for line intensities and profiles has just been installed at the 100-inch coudé at Mount Wilson. Kuprevitch has studied the problems of seeing-compensation in spectral scanning, and gives examples of records obtained as a function of zenith distance and aperture.

Development work has been carried out by Babcock on a new 'spectrum-template' instrument to permit photo-electric measurement, at the telescope, of stellar velocities and magnetic fields. A photographic template, of a standard star, traverses the spectrum of the programme star. A photo-electric cell with a Fresnel field lens observes the coincidence of the standard and programme star.

Abt and Weitbrecht are converting a normal transmission microphotometer to an automatic direct-intensity machine. They use an electronic function-generator which can be pre-set to represent the calibration curve as a series of segments of varying slope. These transformation devices are now commercially available at moderate cost.

Miczaika reports instrumental developments at Harvard. The 61-inch reflector has been largely rebuilt and will be used with an ultra-violet prism spectrograph; plans are being made for a modern grating spectrograph at the cassegrain focus. Mertz has developed an interferometric technique to record photo-electrically the Fourier transform of the spectrum; with a 24-inch reflector a preliminary survey showed differences between stars of various types, the Orion nebula and Comet Arend-Roland.

IDENTIFICATIONS AND ABUNDANCES

The surveys of identifications in high-dispersion spectra of standard stars still remain to be done; their need by workers in stellar spectroscopy cannot be over-stressed. A survey of an S star has been carried out by Merrill and Greenstein. The 'barium' star ζ Cap has yielded a list containing 4000 lines. Keenan is studying cool stars in the red and near infra-red. But the normal middle- and late-type stars remain essentially untouched for many years. Actually there has been more interesting progress in the identification of molecular bands than of atomic lines. The growing interest in peculiar stars, in part originating from new theories of nucleogenesis, has led to search for elements sensitive to nuclear reactions. Tc has been found in S and certain C stars; other unstable elements are not present. The Burbidges have searched spectra of a Ba II star HD 46407 for all spectroscopically accessible rare elements. A tentative identification of Dy III is given. In HD 46407 the light elements were normal and Sr, Y, Zr, Nb, Ru, Ba, La, Ce, Pr, Nd,

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Sm, W were overabundant by factors of 5 to 30. All definitely overabundant elements have either closed neutron shells or can be reached by a neutron-capture chain with 10^1 to 10^5 years between successive captures. The analysis of a magnetic star, type Ap, yields different results, since Eu is overabundant and cannot be reached in a slow neutron capture process; in α^2 CVn and HD 133209 Si, Cr, Mn are enhanced with La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Pb enhanced by 200 to 2000. The Burbidges and Fowler suggest surface reactions initiated by high-energy protons accelerated in magnetic fields. The existence of He^3 is suspected in a magnetic B star, 21 Aql. The existence and abundance of Pb, the end-point of neutron-addition processes, is a very critical point in these theories. A very complete review by Burbidge, Burbidge, Hoyle and Fowler of new theories of nucleogenesis has appeared in the *Reviews of Modern Physics*. Biermann has re-discussed the surface production of elements in the upper strata of active magnetic atmospheres as caused by ion-acceleration. He finds the required physical conditions to be even more restrictive than do Fowler and the Burbidges.

The identification of atomic lines in C stars remains an important need; their separation from molecular lines is difficult. The strength of rare earths in S stars has been confirmed by Keenan and Teske; Teske has studied the line spectrum of FU Mon, a star related to both the C and S sequences, and finds ZrO, YO, CN strong and Li, La, Y enhanced. A survey of Li in G to M stars and of Be II in A and F stars is being carried on by Bonsack; Li is seen in R CrB and Be II in α^2 CVn. Surprising strength of Li and the rare earths is noted in a T Tau star by Hunger.

Kleman has reproduced in the laboratory the Merrill-Sanford bands, strong in late-type N stars. It seems probable that the SiC_2 molecule is responsible. The five bands with heads near λ 10 500 in late M stars like R Leo and R Cas have been attributed to VO. The puzzling emission lines found by Merrill in χ Cyg near minimum have been identified as AlH by Herbig. These are strongest in certain S-type variables.

Aller and Jugaku have completed a study of wave-lengths and equivalent widths in γ Peg, $\lambda\lambda$ 3545-6700. Swings is studying early-type stars, with particular reference to Fe III and other doubly ionized metals. He urges the importance of high dispersion in the near infra-red.

Greenstein has given profiles and wave-lengths of the unidentifiable Minkowski bands in the white dwarf, AC + 70°8247 and of a new band at λ 4670 in two cooler white dwarfs, L 879–14 and W 219. Extensive wave-length tables in the hot O sub-dwarfs have been prepared by G. Münch and Greenstein. They identify highly excited lines of Ne II and essentially all lines of N III given in *R.M.T.*; N IV is strong in some of these objects, e.g. +25°4655 and +75°325. Spectrophotometric measures of the continuum by J. Berger, which indicated that σ Ori E appears to be helium-rich were confirmed by Wallerstein and Greenstein on slit spectra. A detailed analysis will be carried out at the Institut d'Astrophysique in Paris. In Italy a good number of abundance analyses have been attempted at moderate dispersion. Mannino studied the composition of HD 168957 and γ UMi, and has observed four other early-type stars. Taffara will use line strengths in θ Leo, μ Her, α Cyg and α Per to compare Asiago 40 Å/mm results with those of other observers. Casati and Hack at Merate have analysed the Ap 'silicon' star HD 34452; they find normal abundances except for Mg and Si. Model-atmosphere computations hardly change their results. They are now working on ϵ UMa. A general programme on bright Ap stars is under way at Merate. Hack finds that 34 Å/mm is sufficient for stars earlier than F, from her results on α Per as compared to other high-dispersion work. She has made a rough analysis of an O9 star with strong N III, HD 188209, and used both a rough and model-atmosphere model for ν Cep, A2 Ia. Metallic-line stars, 15 Vul and 8 Com, have been analysed by Miczaika *et al.* They find low P_e and opacity, and large turbulence. Hack has studied other Am stars, θ Cep, ξ Cep, ζ Lyr A, ω and 88 Tau, μ Ori; investigators agree that Am stars show deficiencies, in varying amounts, of Ca, Ti, Sc, Zr, Mg, V. Miczaika and Wade report that a more elaborate analysis of the turbulence in 8 Com gives 6·9 km/sec and 5·4 km/sec for the velocities of the small- and large-scale eddies.

Aller and collaborators plan to carry out analyses of early-type stars using the method of Elste, Jugaku and Aller as applied to τ Sco. Their list includes: 114 Tau, τ, λ, 22 and 42 Ori, 14 and α CMa, HD 36959, 36960, ϕ Scl, μ Col and 10 Lac.

If nuclear reactions occur at the surface of magnetic stars, Ap, positrons will be formed and produce the short-lived element positronium, in very low abundance. Infra-red coudé spectra of β CrB by Deutsch verify that the Balmer series of positronium does not in fact appear. Hack made a quantitative analysis of β CrB. She finds that Mg, Ca, Sc, V, Ni have normal abundances, Ti and Fe are overabundant by a factor of 7, Cr by a factor of 30, and Sr and Zr by 40 and 90. The rare earths are overabundant by a mean factor of 1000, while Ba shows only a factor of 4.

Greenstein and Keenan studied sixteen stars, G 4-K0, luminosity classes II–III to III–IV, mostly on 3 and 4·5 Å/mm Mount Wilson plates; in seven out of eight high-velocity stars, metallic lines are slightly weaker, CH the same and CN much weaker than in the standard stars. A logarithmic deficiency of $-0{\cdot}2$ for metals, and $-1{\cdot}00$ for CN is required. One, υ^2 Cnc, is normal, and must be a high-velocity population I star. Two apparently carbon-poor stars, HD 18474 (originally studied by Humblet) and HD 166208 are discussed. HD 30297 has also been reported by Morgan and Nassau to be a member of this group. Hack compared η Boo with ζ Her A, both G0 IV, on 20 Å/mm spectra from Merate. She believes that the 'weak-line' star is not weak in metals, but rather has higher strength of CH. The latter criterion is useful also, at low dispersion, for K giants, and she proposes it, rather than the metallic lines, as the discriminant of population type.

Mustel and Kumajgorodskaya of the Crimean Observatory, however, studied eight stars of types G0 to K0, strong- and weak-line stars from Roman's list, at 36 Å/mm. At G0, equivalent widths were 20% greater in the strong-line than in the weak-line stars of the same type and luminosity. The curves of growth showed shifts not explainable by changes in excitation. By type K0 the tendency is reversed. Their result disagrees with that of Hack, and conforms to the results of visual classification.

Wellmann has studied at 8 Å/mm two F 8 stars, HR 7955, F8 IV, weak lines according to Roman and θ Dra, F8 IV, strong lines, Roman or F 8 IV–V, Morgan. He tried to obtain a quantitative confirmation of the 'weak-line' effect and found instead that the neutral metallic lines were the same but that the ionized lines were 15% stronger in θ Dra. The CH band was stronger by 13% in HR 7955. He concludes that θ Dra is actually F 8 III–IV and that its apparently greater line strength is a luminosity effect. The shift of one whole luminosity class is somewhat unexpected, considering the accuracy of the MK system. In 1955, Wellmann had made a similar comparison of α CMi, F 5 IV, strong lines with 110 Her, F 5 IV weak lines. He found, however, that in 110 Her CH was strengthened by a factor of nearly two and lines of both neutral and ionized metals strengthened by 10–12%. No detailed abundance analysis was made. Schwarzschild and collaborators analysed a group of high- and low-velocity K giants and found only one high-velocity star with pronounced and two with slight, weakening of the metals, although the strengthening of CH is definite for most high-velocity stars. It is not easy to draw any general conclusions on abundances in high-velocity, or 'weak-line' stars on the basis of the rather conflicting evidence. Stars selected as extreme in CN deficiency by Greenstein and Keenan do have weakened metallic lines; they do not show a CH enhancement. Deutsch and others have suggested that comparison of the measurements of absolute strength of lines on high dispersion with those on lower dispersion, or with the visual estimates of line strength or weakness is very dangerous. For example, on low dispersion, all weak lines blend to form a depressed continuum; if the number of active atoms is reduced, the continuum will rise, and equivalent widths of strong lines will actually increase and the deduced changes in 'abundance of metals' will be incorrect. In the sense of this argument, only such features as the G band of CH, H and K, hydrogen lines, if strong, and possibly λ4227 of Ca I would have strong-line behaviour on dispersions of less than 3 Å/mm in K giants; essentially the location of the continuum is a problem which becomes intractable if, at the given dispersion, the number of lines contained in a wave-length region equal to 3–5 times the resolving power becomes greater than unity. It is apparent that much more careful and elaborate observational work is needed, at the highest possible resolution required by the spectral type, before this important question can be settled.

Fujita has studied the late C stars, U Cyg and V Aql, and identified the C_2 and CN bands in the visual and infra-red. Atomic lines of lowest excitation potential have great strength, and the resonance line of K I is the most sensitive indication of temperature in carbon stars. Excitation temperature from atomic lines in WZ Cas, U Cyg, U Hya, V Aql, RY Dra correlate well with their classification on the C system. Fujita, Yamashita and Nishimura have made a preliminary study of the M, S and C stars, especially for the behaviour of atomic lines and the Merrill-Sanford bands.

Several analyses of high-velocity sub-dwarfs are under way. Reduced blanketing by weakened absorption lines has a serious effect on the colours of these stars. An ultra-violet excess correlates well with space velocity, and probably with distance below the main sequence at types F and G. Quantitative analyses of HD 84123, 106223, 161817, λ Boo and 29 Cyg were carried out by the Burbidges; some of these high-velocity stars showed abundance deficiencies in Mg, Ca, Fe, Sr, Ba, especially HD 106223, while HD 84123 seems normal.

A large and valuable set of fifty theoretical model atmospheres has been made available by the work of de Jager and Neven, at Utrecht and Uccle, in part computed on an IBM-604. The monochromatic fluxes are given for T from 4000° to 25 000° with $\log g$ from 1 to 5. In addition the behaviour of various important lines is computed, in considerable detail for the Balmer lines and He II, and roughly for seventy-eight lines with less well-known physical parameters. Lines of interest include H, He I, He II, C II, C III, N II, N III, O I, O II, O III, Mg I, Mg II, Si I, Si II, Si III, Si IV, Ca I, Ca II, Sr I, Sr II. It will be very interesting to see even rough comparisons of theory and observation over the spectral sequence from O to K. Other interesting model calculations testing effects of the convective zone were made by Przybylski, using Planck mean opacities of H and H^-; he computes the variation of Ca I and Ca II line strengths on two assumptions, (*a*) that in the convective zone the transfer is largely by radiation, or (*b*) by convection. Hack studied the same effect using opacities by Miss Vitense, but computing the continuous spectrum and the Hδ profile, and extending the calculations to the super-giant stars. Both conclude that observations suggest that (*a*) is correct, i.e. transfer is still largely by radiation, except for super-giants.

SPECTRAL CLASSIFICATION

Various generalizations of the idea of two main stellar populations or sub-systems are probable on kinematic and on spectroscopic grounds. Whether there exists a continuous transition between sub-systems of various degrees of flattening and other parameters, such as age or chemical composition, is not yet known. Spatial or velocity co-ordinates alone are insufficient. For working spectroscopists the best procedure will be an attempt to add a third dimension to present two-parameter classification schemes, as well as the development of techniques for recognition of population characteristics in spectra of stars in unusual regions of the H.R. diagram. Morgan has discussed the recognition of the halo population near the sun. The extreme weak-line F stars and the RR Lyr stars of longer periods have common characteristics. Certain F to K semi-regular variables of high luminosity are kinematically like the extreme weak-line group and also have weak metallic lines; they resemble globular-cluster giants. The sub-luminous O stars are recognizable by wide Balmer lines with a steep intensity decrement. The intermediate population is more difficult, although the late M giants of the disk can be segregated.

Morgan has studied the highly composite spectra of groups such as globular clusters and galaxies. Those clusters that belong to the galactic halo have integrated spectra like extreme weak-line F stars. But globular clusters of the galactic disk have spectra which in the blue and violet are dominated by G and K stars which do not have peculiar spectra. Deutsch has obtained a number of spectra of red giants in seventeen globular clusters, largely at 38 Å/mm. Very weak lines are found in NGC 5053, 5466, 5897, 6341, 7078, and

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stronger lines in NGC 5272, 5904, 6093, 6121, 6205, 6218. He reports that two red giants in NGC 7789, which had been reported as a globular cluster, show normal population I giant characteristics. Roman finds that the colour-magnitude diagram of high-velocity stars in her catalogue resembles that of the old galactic cluster M 67, and not that of globular clusters. Spectroscopically, also, even the most extreme of her high-velocity stars are less peculiar than the globular cluster giants. The very-high-velocity star, HD 232078, found by Preston and Bidelman is one of the few K 3 II field stars with weak CN and Hα emission. Helfer and Wallerstein will include it in their study of Palomar 18 Å/mm spectra of stars in M 13 and M 92, and compare it with a K 3 II member of the galactic cluster M 41.

With Mayall, Morgan has studied spectra of the brighter galaxies and attempted to construct their idealized H.R. diagrams. The Sc, SBc and Irr systems contain a number of A and F stars, but most systems of types Sb, Sa and E owe most of their light to giant K stars. A smooth progression exists relating dominant stellar population and nebular form. Mayall and Morgan note that the brightest elliptical nebulae in the Virgo cloud have broader lines than in M 31. The line width correlates well with luminosity within the Virgo cloud. Thus a possibility exists for a large programme of spectroscopic parallaxes of galaxies.

Attempts to establish quantitative luminosity criteria are being made. At Stockholm for early-type stars, Sinnerstad, and for later types, P. O. Lindblad are using measured intensities on slit spectra for stars of known luminosity on the MK system. Low dispersion, objective-prism spectra are used by Lodén for population criteria. Sinnerstad believes that the hydrogen lines show a discontinuity between giants and super-giants. Several interesting quantitative classification techniques have been developed by Kopylov at the Crimea. Using O 5–O 8 stars in associations, and measured equivalent widths of the hydrogen lines, he finds a good correlation in types O 4·5–O 8·5, and a less pronounced and different correlation for the later group O 8·5–O 9·8. He is now studying a two-dimensional quantitative classification for 220 O 5 to B 7 stars, using measured strengths of lines employed in the MKK system; the high accuracy of $\pm 0^{m}_{.}2$ to $\pm 0^{m}_{.}3$ is expected. Oke, at David Dunlap, using 33 Å/mm slit spectra, has developed a luminosity classification with errors of $\pm 0^{m}_{.}3$ for F 5 to K 1 stars of $M > 0$. He measures central absorptions, and takes averages over a number of sensitive line pairs. Applications are to some peculiar stars, e.g. λ4150 or weak CN types, and the possible construction of an H.R. diagram for such objects. Mustel, Galkin, Kumajgorodskaya and Boyarchuk have measured equivalent widths of absorption lines in the range λ4000 to λ4400 (72 Å/mm), in eighty-one stars of types F 0 – K 5, with known parallaxes. A rough MK class, by inspection, was used to obtain a smoothed run of measured line intensities and ratios. An improved mean spectral type was then obtained by averaging results from various lines, and the calibration curves improved. The authors believe that the errors of their second approximation are considerably less than of their initial visual estimates. The spectrum-luminosity diagram so constructed showed a scatter which they interpret as the intrinsic dispersion in this relation. Searle is observing the high-velocity dwarfs and sub-dwarfs from Miss Roman's catalogue, brighter than 9^{m}. He hopes to construct the H.R. diagram for population II. His work is to be supplemented by photo-electric scans for measurement of ultra-violet excess in the high-velocity stars brighter than $7^{m}_{.}5$. A programme of spectral scans, and measurements of line intensities for line-blanketing, and the effect of lines on colours, is being undertaken by Melbourne at Mount Wilson. Late-type stars are being studied in the blue and yellow, at low dispersion, by Keenan, to classify small-amplitude variables of types K, M and S. The two-dimensional classification of long-period variables at maximum, M 0e to M 5e, by Keenan suggests that there are genuine luminosity differences within this group. The infra-red survey of cooler stars to 10^{m} at Warner and Swasey is completed in a belt $\pm 6°$ in latitude and from 333° to 202° in longitude. Nassau, Blanco and collaborators give 8000 M 5–M 10 stars, and a list of M 2 to M 4 BD stars is in preparation. Reddened early M super-giants are detectable on objective-prism surveys. A list of carbon stars brings the number to 700, and a total of seventy S stars were found, using the infra-red LaO band. The new large Schmidt at Hamburg, 80–120 cm aperture, is provided with an objective prism which gives 580 Å/mm at Hγ; this instrument provides a welcome expansion towards faint stars. A preliminary survey by Slettebak and Stock gave a list of 1000 high-luminosity stars down to $13^m.5$. The OB stars could be classified in three groups from the Balmer lines, and the A, F and G super-giants from the Balmer lines and the appearance near the series limit, and the K line.

Regional surveys of spectra are not as numerous as could be desired. Some are reported elsewhere in connexion with studies of galactic structure. Bidelman has classified sixty-two Praesepe stars on the MK system. Slit spectra between 8^m and 12^m in Selected Areas are being observed by Miss Roman; T. Elvius and Bartaya are continuing work on Selected Area programmes. At Abastumani, spectroscopic absolute magnitudes of 824 B and A stars have been obtained in forty-four selected areas by Bartaya. Kalandadze gives luminosities for 425 G and K stars in twenty-six selected areas. A general programme of spectral classification of stars in the near neighbourhood of the sun has been undertaken by a group of Soviet observatories. Kharadze and Apriam-ashvili have covered 200 square degrees in the Rift of the Milky Way. Vashakidze and Bartaya give spectral classes for stars in 'stellar chains', associations and in regions of diffuse nebulosity. Ramberg has studied spectrophotometrically a field in Lacerta. Mrs Herman and collaborators are continuing the observation of Be stars brighter than 7^m. The growth of spectroscopy in the southern hemisphere is very exciting and encouraging. M. L. Woods gives a MKK classification of the brighter southern stars, and Mrs de Vaucouleurs has classified 366 B, A, F stars brighter than $6^m.5$ on the MK system. Gratton is classifying stars brighter than 10^m near η Car, with special attention to emission-line objects. Hoffleit has been studying slit spectra of southern stars, with spectroscopic parallaxes for a group in Carina. She is also using ADH objective-prism plates for studies of galactic structure, and the relation between stars and diffuse nebulosity. Landi and Gratton have spectra in the Large Magellanic Cloud; 30 Dor is remarkable in that nothing is visible, either in absorption or emission, except interstellar Ca II. A general survey of peculiar stars $< 9^m$ has been started by Bertaud, of Meudon, using 60 Å/mm. This will include Ae, Ap and Am stars, of which 130 have already been obtained. The programme will use thirty nights per year for several years. Many surveys of peculiar (Ap) and metallic-line (Am) spectra are under way. At the Radcliffe Observatory velocities of 189 southern OB stars, and classification on the MK system were obtained by Feast, Thackeray and Wesselink; this project will be continued. The bright stars in the Magellanic Clouds, observed by Feast and Thackeray, are F and G super-giants, reaching -9^m, mostly slowly variable in light. The H.R. diagram curves upward to the right as in h and χ Persei. The brightest absorption O stars are 2^m fainter visually. Feast is observing spectra of the cepheids in both clouds; he finds that W Men is an R CrB star, with $M = -5{\cdot}4$, consistent with the luminosity of R CrB and δ CMa. Thirty members of 47 Tuc were observed at 49 and 86 Å/mm; the lines are relatively strong. The cluster contains long-period variables, non-variable M stars and probably a late B star, which would be the brightest member. Kinman is observing individual stars in other southern globular clusters for velocity and spectral type. Feast has shown that the classical cepheids, U Sgr and S Nor are members of M 25 and NGC 6087. Spectra in the clusters NGC 3293, 6067, IC 2994, M 25 and NGC 6087 were obtained by Thackeray and others. Slettebak and collaborators are obtaining objective-prism spectra at Warner and Swasey to 8^m, with slit spectra at Perkins (110 Å mm). So far 262 stars have been observed, of which forty-nine are Am and fifteen Ap of the Si, Cr and Sr types. M. and R. Jaschek of La Plata have studied northern Am stars and are now obtaining slit spectra at 40 Å/mm of stars south of $-30°$, and with $m < 8$. They hope to survey a large number of A and early F stars to see whether there is a smooth transition between Am, Ap and normal stars. Lavagnino is also studying the Ap stars.

The spectra of visual binaries are much neglected; each binary is a miniature cluster, and because of their large number, they should permit refinement of concepts of stellar evolution hitherto based on galactic or globular systems. The frequency of spectroscopic and visual binaries as a function of population type is not known. Slettebak is observing

200 visual doubles for velocity, rotation, spectrum and luminosity; this should provide luminosity calibration for various types of peculiar stars, separations > 4″, $m < 7{\cdot}5$. I hope that photo-electric colours for these systems, and a similar programme of spectra and colours in the southern hemisphere, will be carried out. Archer observed radial velocity differences between components of southern visual binaries, α Cen and ADS 6914 showed significant differences. Miss Roman has obtained spectral types of one or both components of sixty-three eclipsing binaries. Spectra of close, interacting binaries are discussed elsewhere.

In an Appendix to the last report of Commission 29 (*Trans. I.A.U.* **9**, 404) a notation for indicating abnormal intensities of CN bands in G 5–K 3 giants was suggested by Keenan. In the proposed notation the spectral type and luminosity class would be followed by the symbol CN and a number indicating the band strength, positive if the λ4215 band is stronger than normal. Since the Commission encouraged the preparation of a list of standard stars with differing excesses or deficiencies of CN, the following short table was prepared by Keenan in the hope that it will be useful to observers. It is limited for the most part to stars for which the estimated strength of the CN bands has been checked by photometric measurement. The check data were either the magnitude of the break in the spectrum at the λ4216 head as measured on small-scale Perkins spectrograms, or total absorptions of individual bands determined from Mount Wilson coudé plates. The absence from the list of stars with only slight cyanogen excess (CN + 1) is due to the fact that CN strength increases so rapidly between luminosity classes III and II for types G 8–K 2 that it is extremely difficult to be sure that a slight error in luminosity is not responsible for the apparent discrepancy in such stars.

Strong CN	Normal CN	Weak CN
α Ser K 2 III CN + 2	κ Gem G 8 III	γ Psc G 7 III CN–1
HD 112127 K2$^+$ III CN + 2	ϵ Vir G 8 III	ϵ Dra G 8 III CN–1
HD 104998 K 0 III CN + 3	70 Peg G 8 III	HD 2901 K 2 III CN–1
	η Cyg K 0 III	δ Lep G 8$^+$ III CN–2
	ξ Dra K 2 III	BS 6853 G 9 III CN–2
		48 Her K 1 II–III CN–2
		HD 6833 G 8 III CN–3
		BS 6152 G 8 II CN–3

EARLY-TYPE AND SYMBIOTIC STARS

Shallow and weak lines are common in hot stars, and are most elegantly studied (until photo-electric scan techniques are developed) by an 'impartial' method such as developed at Edinburgh by Greaves, Baker and R. Wilson. Mean spectra are obtained by averaging many smoothed tracings; weak lines, and even more strikingly, very shallow broad lines, become visible. Mean spectra are now available of five B1 super-giants and five dwarfs, with the statistical grain fluctuation down to 1%. Seddon and Wilson found slowly variable, weak Balmer emission in β Cep stars. Wilson's spectrophotometric luminosity classification of sixteen stars of types O 6–B 0 uses the line ratios He I $\lambda 4472 + \frac{1}{2}(\lambda 4144 + \lambda 4388)$ /He I $(\lambda 5876 + \lambda 6678)$; He II $\lambda 4686$/He II $(\lambda 4200 + \lambda 4542 + \lambda 5412)$ and C III $\lambda 5696$/C III $\lambda\lambda$4647–51. The criteria are consistent and prove insensitive to temperature over this range of types. Line profiles of forty-three O 5–B 2 stars were measured by Slettebak at 10 Å/mm. It proved impossible to distinguish, from profiles, between rotation and large-scale turbulence or stream motion. Additional line widths in 110 stars were estimated visually, for statistical study. Slettebak believes that the O 5–O 8 stars and the high luminosity O 9–B 1 stars have large-scale atmospheric motions, largest for the brighter and hotter stars. Rotation is almost universal in the dwarfs. Ivanova used spectrophotometric gradients and line intensities to study the physical properties of stars in the Orion association.

Mannino has taken 106 spectra of the Of stars HD 108, 34656, 188001, 190429 N, 190864, 192639 at Asiago. When studied in collaboration with Humblet, these objects show variable emission-line intensity for most lines. The programme, started in 1953, will be continued. The binary Of star, 29 CMa, is being followed by Struve and Sahade. R. Wilson has studied the behaviour of the emission lines in Of stars spectro-photometrically; He II λ4686 and N III $\lambda\lambda$4634–42 persist to Bo Ia. The emission features are composite, a central core superposed on a faint, broad band, up to 60 Å wide. Such widths suggest that the Of mechanism is related to that in the Wolf-Rayet stars. Miss Underhill has studied the C III emission in O stars, the origin of the λ5696 line, as well as the general problem of emission lines, in Of and WR stars. She is not convinced that Of stars have very high luminosity, but believes they must have extended envelopes. She believes that λ5696 is caused by ionization from an excited level of C II, by He II λ304. She confirms the great width of emission wings found by R. Wilson. Bappu has used hydrogenic transitions discovered by Edlen in C IV, to obtain excitation temperatures in WC stars; lines occur at $\lambda\lambda$5471, 4229, 3567, 3450. He finds $T_{exc} = 49000° \pm 10000°$ for HD 192103 (WC 7) and $27\,000° \pm 8000°$ for HD 184738 (WC 8). Bappu and Sinhal have measured the variation of line profiles and intensities with phase in the WR binaries HD 193576, 193928, 214419. In the latter all lines vary in phase, in the others considerable differences exist.

γ^2 Vel, studied by Sahade, may be a spectroscopic binary. λ4686 has sharp emission, sometimes with a shortwards absorption core, superposed on broad Wolf-Rayet emission. A He I shell is indicated by λ3888, which sometimes shows several components. Structure within He II emission is found in V 444 Cyg and changes position cyclically. Streams of matter leave the WR star towards the O component, with deceleration outwards.

An unusual star is reported by Thackeray, HDE 326823 in which the emission He I lines are detected. The patrol of spectral variations of important Be stars continues. The main types of interest are variations of V/R ratio, changes in level of ionization, relative strength of permitted and forbidden lines, and relative strength of the early- and late-type continua in symbiotic objects. McLaughlin has concentrated on velocity and V/R variations in B stars, $\delta > -20°$, $m < 5{\cdot}5$. Forty years are covered for HD 20336, β^1 Mon and π Aqr. The changing intensity of hydrogen lines and their shortward satellites in υ Sgr, is being studied by Kumar, and by Hack. Aller will obtain ultra-violet spectra of Z And, BF Cyg, CI Cyg and AX Per. Bloch and Tcheng Mao-Lin, working at Haute Provence survey the ultra-violet to the red regions of Z And, T CrB, BF Cyg, CI Cyg, AG Peg, AX Per, RY Sct, FR Sct. They report a progressive drop in colour temperature in Z And and a rise in the level of ionization, as shown by the presence of [Ca VII] and [Fe VII]. Also at Haute Provence, Bertaud has obtained spectra of twenty-eight shell stars, seven composites, V 568 Cyg and AG Peg. Gauzit is following AX Per, Houziaux HD 19507, Hack ζ Tau, Larsson-Leander γ Cas, ρ Cas and AG Peg, Mannino the spectral variation of HD 218393 (1951–57), Taffara π Aql, γ Cas, b_2 Cyg and Pleione, Underhill 48 Lib and HD 50820. A high-velocity symbiotic star, MWC 603 studied by Tifft and Greenstein shows an interesting dependence of emission-line sharpness on excitation. Cowley reports that $+37°2318$ has a variable spectrum, K 2–B 5. It has P Cyg Hα, and probably is variable in light, 10^m–11^m5.

Boyarchuk has used the thin-layer approximation to evaluate the number of excited neutral hydrogen atoms, log N_{02} H for nine Be shells. The optical thickness proves large for early members of the Balmer series. In most Be stars he finds the Lyman continuous absorption to be near unity, and the physical dilution about 0·1. The masses of the shell are about $10^{-10}\ M_{\odot}$.

In the southern hemisphere long-term surveys of Be stars are only beginning and it is to be hoped that interesting new objects will be found. The Radcliffe survey of long-period variables by Feast may reveal peculiar emission and symbiotic objects; other stars to be studied there include AR Pav, BL Tel and AI Vel.

Huang and Struve have studied the spectrum of Maia, the only sharp-line B star in the Pleiades. The temperature estimated from Fe I/Fe II differs from that given by He I. The composite spectrum can be understood if Maia is a rapidly rotating star, seen pole-on.

RED GIANTS, CHROMOSPHERIC PHENOMENA AND LOSS OF MASS

Quantitative analysis of the cooler stars will always be difficult, and restricted to studies at high dispersion. The wide variety in apparent composition in the M–S–C type differences, and the appearance of molecular bands of otherwise rare elements suggest that order-of-magnitude studies might be sufficient if the problems of molecular equilibria could be solved. In recent investigations attention has been paid to phenomena in non-variable stars that were first recognized in variable and composite stars—i.e. extended chromospheres, systematic velocity differences between atoms of different excitation potentials, stream and shell lines and loss of mass. The red giant or super-giant seems to represent a turning-point in stellar evolution, and variability may represent a temporary phase; from this point of view, variable and non-variable stars should be discussed together. Loss of mass, long stressed (in hot stars of high luminosity) by Soviet astrophysicists, has been proved important for the red giants. The evolutionary fate of red giants is not known, and if they evolve downwards and to the left in the H.R. diagrams of clusters, some should be found at intermediate stages.

RW Cep, an extremely luminous G or K super-giant, with small variation in light, was studied by Merrill and Wilson. It shows a complex interplay of emission and absorption features (the latter broad, up to 80 km/sec) with emission lines, of peculiar intensity ratios, dominating in the ultra-violet. Stream, shell and chromospheric effects exist. The M super-giant μ Cep, studied by Yamashita, gave a micro-turbulence of 9·3 km/sec. Double absorption lines appear in many systems, as higher resolution is used. R And, at its 1956 maximum, showed double lines, separation 23 km/sec, not all of them resonance, in the infra-red, according to Merrill and Greenstein. Double lines in ρ Cas have been studied in detail by Bidelman and McKellar; the strongest Fe I lines are double, separation 34 km/sec, the weaker ones show only the longward component and single lines of other elements have the same velocity as the longward component. Even strong lines, from highly excited states, remain single. Some emission phenomena alter the separations of components of Ba II and Na I, so that both an emission envelope, and a two-stream absorbing envelope exists. Slight line doubling is observed in the classical cepheid X Cyg by Kraft. During variations near maximum Greenstein found that the R CrB star RY Sgr showed double lines separated by 40 km/sec, and the D lines displaced by −200 km/sec; a drop of 4 magnitudes in 1957 produced D line emission of P Cyg type.

The mass loss of α Her has been computed by Deutsch in a very important paper. The displaced lines visible in both α Her A and its spectroscopic-binary companion, α Her B, provide an estimate of space density in the enormous expanding envelope. Circumstellar lines were found in a variety of late-type stars. He applies this rate of loss to a study of the evolution of M giants from main-sequence stars, using the Schwarzschild-Sandage-Hoyle evolutionary models, and concludes from the number of M giants that M giants would suffice to produce the total number of dead stars of population I. About one-half the present mass of interstellar gas then could once have been inside the hot cores of old, dead, red giants. Deutsch has searched in K and M giant spectroscopic binaries for stationary central absorption reversals in Ca II emission, and found them so far in η Gem and RR UMi. Rublev (Odessa) studied theoretically (based on work by Sobolev) the ejection of matter due to radiation pressure, with a special application to o Cet. Mustel derives the mass lost by the Sun as 10^{18} gm/year. This topic has been discussed by several Soviet astrophysicists, some of whom have questioned Biermann's derivation of the amount of corpuscular radiation of the Sun. Mustel finds that the Hα line in escaping gas, even near early-type stars, may be too weak for detection, and points out our lack of knowledge of the mechanism of escape of atoms from stellar atmospheres.

More extreme versions of the line-doubling and shells of red giants are found in super-giants, spectroscopic binaries, emission-line and symbiotic stars. Obviously, low densities and surface gravity favour the production of circumstellar clouds. We still are uncertain as to whether all symbiotic objects are two independent stars. Evidence now favours duplicity as the explanation of emission lines, and of detached absorption satellite lines in binaries in which one star more than fills a Lagrangian surface. While some of these stars are eclipsing variables, the spectroscopic studies largely concern the nature of the envelope.

Among single stars, the super-giants of types A and F have been frequently studied. In such objects the spectrum is relatively simple, showing broadened lines in absorption, with very weak Hα emission in some stars. Variability of line profiles may occur, possibly connected with macro-turbulence or stream motions. Abt's velocity measures confirm the suspicion that A and F super-giants are largely velocity-variables (see, for example, the older measures at Lick on α Cyg) and velocity catalogues have often indicated variability for super-giants. Abt finds roughly periodic, small-amplitude variations, probably connected with pulsation. These obey the $P\rho^{\frac{1}{2}}$ law, except for the M giants, with a parameter, Q, close to that for classical cepheids. He suggests that most stars with $M_V < +1$, to the right of the main sequence, are variables. Line profiles in A and F super-giants, classes Ia, Ib and II measured by Abt are explained by micro-turbulence plus rotation. The rotation is compatible with but smaller than that predicted by evolution on a Sandage-Schwarzschild model; some mass loss or non-rigid-body rotation is possible.

A new chromospheric phenomenon has been discovered by Wilson and Bappu, in single stars of types G, K, M with emission H and K lines. A remarkably precise correlation exists between the widths of H and K in late-type stars and the luminosity. Velocity-widths measured at 10 Å/mm are sufficiently precise to give luminosities, independent of spectral type, temperature and therefore of surface gravity, with errors not exceeding $\pm 0^m\!.5$. Absolute magnitudes are almost linear in the logarithm of the width. No theoretical explanation has yet been advanced, although it has been known that macro-turbulent velocities increase with luminosity. The driving forces of convection, combined with the lower surface gravity, suggest that chromospheres should become extended and even more massive in super-giants, as they do, but no obvious explanation of precise constancy of their velocity dispersion has been suggested. Wilson is continuing this programme in the Hyades and Praesepe to refine the method and evaluate the intrinsic scatter. An H.R. diagram of stars of G, K, M types, and known $B-V$ colour, in the solar neighbourhood show the great range in luminosity of the brighter population I stars, some traces of the sub-giant branch, and the main sequence. Wilson suggests that this method applied to a late-type visual binary above the main sequence would yield the parallax, and if the orbit is available, good masses for stars otherwise poorly known could be obtained.

In the binary star case, much more complex chromospheric phenomena have been extensively studied; atmospheric eclipses, streams, emission-line rings etc., bring us close to the problems of the variable stars. A newly discussed composite spectrum, that of 5 Lac, consists of an A 0 secondary and a K 5 super-giant with an expanding shell, according to Hynek and Stanger. In Plaskett's massive star, HD 47129, Struve, Sahade and Huang find an expanding envelope containing both the O-type primary and later secondary. The envelope itself produces an absorption O spectrum, variable with aspect; the secondary has variable line intensities, and there is complex structure in Hα. Abhyankar finds broad complex emission in λ4686. The classical case of β Lyr, in which light variation also is a factor, has been studied by Struve, Sahade, Huang and Zebergs, who have prepared an atlas of its spectrum, and made a comprehensive study of all velocity data. Orbital elements were obtained on an IBM-701 computer. An expanding shell displays several absorption components, especially in metastable He I λ3888, and streams produce satellite lines. The B 8 primary is in a late stage of evolution near a more massive, under-luminous secondary. The third body in the Algol system has now been recognized; it is $1^m\!.8$ fainter than the primary, and probably of type A or F. Sahade finds Hα strongest at phase 0·25 and absent at conjunctions, indicating matter streaming out of the secondary. A third body has been found in λ Tau, and stream motions produce a velocity difference between H and He I; U CrB also shows the latter anomaly. A more extreme shell is found in W Ser, by Struve, Hack *et. al.* where the absorption-line spectrum comes from the expanding shell. The underlying star has rotationally broadened lines, but may resemble α Per. It loses matter at high velocities.

The filamentary, cloudy nature of the envelope is revealed during atmospheric eclipses. This very active field must be studied in the detailed original publications. A partial list of investigators interested in some of these objects may be useful: ζ Aur, Struve, Larsson-Leander; ϵ Aur, Groth, Hack, McKellar; AO Cas, McNamara; VV Cep, Deutsch, Larsson-Leander, McLaughlin and Perry, Wright; 31 Cyg, McKellar, Petrie, McLaughlin (the next eclipse effects are predicted for late September 1961); 32 Cyg, γ Per, δ Sge, McLaughlin. High resolution has added new detail to our knowledge of atmospheric eclipses. For example, in 1956, VV Cep showed well-resolved double lines of Ti II split by 50 km/sec, and by 30 km/sec for other metals. Wright and McKellar discuss whether emission could cause the apparent doubling, but prefer a combination of emission and absorption in discrete clouds in stream motion. In 1957, emission became stronger, but during totality, the emission showed only in some lines and could not have produced the doubling observed in 1956. Circumstellar lines with an expansion velocity of 20 km/sec may also be present.

Struve, Hack, Pillans and Sahade have studied ϵ Aur extensively in and before eclipse. The lines are double, the shortward component produced in the shell of the invisible I star. The excitation temperature is very low, and metastable lines of Mg II and Si II are missing. Both stars have extended gaseous envelopes and streams, probably irregular and filamentary in shape flowing through each lobe of the inner velocity surfaces, from star to star. (Wright and Kushwaha believe that their Hα observations confirm this suggestion.) During eclipse certain lines passed through three separate clouds in the I star, as demonstrated by the lines tripling. The electron density could be estimated as $10^{11}/\text{cm}^3$ in the shell, enough to produce continuous opacity during eclipse. A large ultra-violet excess would be required in the F star, to produce the ionization; possibly the I star is a shell of turbulent clouds surrounding a relatively small star of earlier type. Hack finds that, if the hydrogen ionization in the shell is controlled by dilute radiation of the B star, Rayleigh scattering and H^- opacity become negligible. The opacity of the shell during eclipse is then electron scattering. Irregular condensations also were found in the chromospheric eclipse of ζ Aur by McKellar and Butkov. Strong ultra-violet lines showed asymmetrical structure two weeks before contact. A ring of Hα emission was found in RZ Sct, by line-doubling near eclipse. Thus evidence is fast accumulating from these complex systems, that 'levitation' of extended, filamentary chromospheres, producing absorption and emission lines, is common. The effects of magnetic forces and shock waves should not be neglected, although theoretical work now largely concentrates on ejection through lobes of the zero-velocity surfaces. Not all stars with envelopes are binary systems; the discrete nature of stream velocity in single stars with double lines suggests a physical process leading to a 'terminal velocity' which can be maintained for long periods of time.

MAGNETIC STARS

Babcock will publish a detailed catalogue of the results of eleven years observing of magnetic stars, using the differential analyser for Zeeman effect. Polarity, field intensity, stellar velocity, spectral peculiarities and line widths are included. He has found eighty-nine stars with coherent magnetic fields, sixty-five stars mostly with broader lines that probably have fields, and fifty-five sharp-line stars that do not have fields (none of the latter are Ap). He has examined 112 other stars with lines too broad to show a field. Of the magnetic stars, sixty-eight are Ap with sharp lines, six Am, three M giants, two S giants, one a weak-line sub-dwarf, and RR Lyr. Most sharp-line stars of type A with fields can be understood as pole-on rapid rotators, and are above the main sequence. A few sharp-line A stars without field are probably slow rotators, and are on the main sequence. He suspects that magnetic fields are ubiquitous in other parts of the H.R. diagram, but A stars because of rotation and convection show the strong, coherent fields. All fields are found to vary, mostly in irregular fashion. Only six are periodic, and these are large amplitude, nearly symmetrical reversers. He favours a hydromagnetic oscillator model.

Deutsch, who has preferred the magnetic-rotator model has made a detailed study of HD 125248, period 9·3 days, Ap, with synchronized changes in field, line strength and width and velocity. He has analysed his and Babcock's plates for a ten-year interval and found a velocity variation of 1620-day period caused by orbital motion with 7 km/sec amplitude. The orbital motion can then be removed. Three residual-velocity curves are required for groups of elements whose variations differ in phase and amplitude. The end-result of a harmonic analysis will be a map of the abundance irregularities and the patches of magnetic fields, on the star's surface.

Surveys for Ap stars fainter than 6^m, and observations of Ap stars for periodic spectral variation if it exists, are needed. Babcock urges that more observers who have available a dispersion of 10 Å/mm undertake the measurement of magnetic fields.

HALO STARS, WHITE DWARFS AND NOVAE

Photographic, photo-electric, and spectroscopic surveys have opened up a new field of study, that of intrinsically faint blue stars. Instrumental advances in Schmidt cameras and the three-colour photo-electric system have permitted discovery and colorimetric classification of some of these, but full realization of the variety of objects present waits on spectroscopic study. Only a few of these objects are $< 10^m$; the body of those known is between 13^m and 18^m. The proper motions by Luyten, together with his photographic colours, expanded the list of white dwarfs enormously. He has also published lists of very faint blue stars, observations of which are under way at Cordoba; Iriarte and Chavira give 817 blue stars $< 17^m$ in 1360 square degrees, with estimated colours earlier than *f*; Feige surveyed 48-inch Schmidt plates in both polar caps and gives 111 very blue stars $< 15^m$. Spectra and colours of 22 Feige stars by Greenstein show two white dwarfs, one hot sub-dwarf, and the balance probably peculiar O, B and A stars; Münch finds one to show extraordinarily strong He II. Photo-electric colours range from $-0^m.37$ to $+0^m.10$ on the $B-V$ scale. Some very blue stars show only Balmer lines, and even a large Balmer absorption discontinuity. Many of these blue stars must belong to the 'halo', but from spectroscopic evidence not all can be 'horizontal-branch' stars. The weakness of Ca II and Mg II near A0 is very striking. Of twenty-four Humason-Zwicky stars so far observed, nine are white dwarfs, three are hot sub-dwarfs, nine are 'halo' objects and three appear normal. An objective-prism survey by Slettebak using the Hamburg low dispersion gives 250 B, A and early F stars fainter than the BD limit. He plans to observe some slit spectra. The hot sub-dwarfs are a new class; Münch and Greenstein list HZ 1, HZ 3, HZ 38, HZ 44, Feige 46, HD 127493, BD $+25°4655$ and $+75°325$ (found by T. Elvius). The temperature of the latter is very high, H weak and broad, He II/H large, He I strong, N III and even N IV strong. Gould, Herbig and Morgan classify it as O5p with very strong He II and N IV. Sinnerstad estimates $T = 60\,000°$, which seems high. A theoretical analysis by Münch using He II, H, N II, N III and N IV lines in $+75°325$, HZ 44 and BD $+25°4655$ is under way. These objects are the hottest known absorption-line stars; their luminosity is about $+3$ to $+5$.

The white dwarfs have been classified by Greenstein and a spectrophotometric description of forty is in press. Several new types are recognizable; some show He II strong, others He I, others Balmer lines, and a few have metallic lines. Essentially continuous spectra exist, and in two types unidentifiable broad absorption bands. A recurrent nova, WZ Sge, was shown to be a white dwarf. Spectrophotometry of seventeen hydrogen white dwarfs has been carried out by B. T. Lynds. The dependence of the strength of $H\gamma$ on colour in normal DA stars, according to both Lynds and Greenstein is unusual. It has a strong maximum, with small scatter near $B-V=0$, but by $B-V=+0{\cdot}2$, the hydrogen lines have essentially disappeared. Another anomalous feature is that the He I stars are not necessarily bluer than stars that show Balmer lines, and no white drawf shows both H and He I; He II and H co-exist in two stars. Space velocities are rather high, and a statistically interesting K term will need good velocities for at least twenty-five white dwarfs. Several new visual binaries have been found, all wide pairs. The H.R. diagram of the white dwarfs is fairly narrow, and a preliminary temperature calibration gives nearly constant radius from $M_v = +10$ to $+15$, about $0{\cdot}013 R_{\odot}$, i.e. 9100 km; if $\mu_e = 2$, the mass is $0{\cdot}56\odot$, and the central density $2{\cdot}6 \times 10^6$ gm/cm³.

There have been no bright novae, and detailed studies of spectroscopic developments are confined to work by McLaughlin on V 528 Aql (1945) and DK Lac, which resembled Nova Aql 1918. He has suggested an explanation for the change of emission-line profiles in Nova Aql 1918 during its oscillatory phases. He reports that T CrB showed essentially constant velocity, discrete absorption components. Thackeray has followed the slow development of RR Tel towards higher stages of ionization. In 1957 [Fe VI], [Ca V], [Ne IV] strengthened while [Fe II] weakened. He wishes to classify η Car as an ultra-slow super-nova, which reached -13^m at its 1843 maximum. Feast has observed the spectral development of Nova Haro-Herrera (1954). Kraft is working on the eclipsing binary Nova DQ Her and has also confirmed the binary nature of T CrB, a recurrent nova. After ten years, nebular lines are weak except for [Ne IV]. T CrB is a double-lined spectroscopic binary of $227^d\!\!.6$ period; Hβ emission can be reconstructed from tracings, by subtracting the gM3 absorption features. Semi-amplitudes are 33 km/sec for the blue, and 24 km/sec for the M star. The large cool envelope of the gM star which overfills the zero-velocity surface may transfer matter to the hot component, as occurs in the U Gem stars, according to Kraft and Crawford. The luminosities of the blue components of these systems at minimum are all similar, near $+4$ to $+6$, well above the white-dwarf range. Huang has suggested that all novae are binary stars, and that the binary nature, and transfer of mass, are the discriminants between placid and catastrophic evolution in dying stars. Greenstein has observed a number of old novae at 180 Å/mm; emission-line intensities of H, He I, He II, and widths show great variety, and are not uniquely dependent on interval since the last outburst. The spectrum of Nova Q Cyg 1876 is nearly continuous; Nova Oph 1848 shows the highest ratio of He II/H; Nova Per 1901 has stronger lines and higher excitation than Nova Aql 1918. Nebular lines persist only in Nova DQ Her (1934) and Nova Pup (1942). A continual post-nova ejection process seems likely. No duplicity, absorption lines or bands were found. A new evaluation of the luminosities of the nuclei of planetary nebulae, by Shklovsky, shows that some approach white dwarfs in luminosities, and that thirteen have $M > +6$.

An elaborate theoretical study of the structure of nova shells has been made by Mustel, on the basis of the predominantly double nature of emission bands, the 'doubling' in the ejected shells, when they become visible, and the detailed ring structure observed spectroscopically. The forces are magnetic and may produce deceleration of ejected gas, entangled with the field. Mustel gives a model of the ejected rings and cone-like configurations, especially for Nova Aql 1918; the field should have had a strength of 1900 gauss. Bajenov has obtained the relative and absolute brightness of about forty emission lines in Nova Her (1934), during a period of two years. The Balmer decrement is given as a function of time.

T TAURI AND FLARING STARS

Soviet astronomers have taken a strong interest in this field; a symposium at Bjurakan in 1956 was devoted to the observations and theoretical interpretations of T Tau and Herbig-Haro objects. The proceedings have just appeared in a volume entitled 'The Non-Stable Stars' (published by the Academy of Sciences of the Armenian SSR, Erevan). This contains reports on observational progress in spectrophotometry of the continua, and the nature of the light and spectral variation of T Tau and other types of flaring stars such as UV Cet, SS Cyg. The discovery of duplicity in several members of the last class indicates that close pairs of dwarf stars may show violent interaction. The interaction between dust and gas clouds and the T Tau stars, the importance of magnetic fields, and the possible existence and evidence for a 'pre-stellar' state of matter were discussed theoretically. The existence of polarization in the stellar continuum, and in

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reflexion nebulae suggests the need of more extensive observation of polarization phenomena. Non-thermal effects may be required in these early stages of star formation.

In this connexion recent observations have particular interest. Hunger's work on Li I and the rare earths suggests abnormal abundances of elements produced by either spallation reactions, or neutron-capture processes. Condensed magnetic energy of interstellar gas may lead to acceleration processes during the contraction phase. However, Böhm working on NX Mon believes that the ultra-violet excess may be explained by Balmer lines and continuum, with self-absorption. Stratton urges observations of polarization in stellar and nova spectra. Mirzoyan has made an extensive study of AG Dra, giving both emission-line intensity ratios and spectrophotometric energy distributions. The latter show a very large ultra-violet excess starting near $\lambda 4000$.

There are now about 1000 T Tau stars, mostly discovered (largely from emission lines) at Lick, Tonantzintla and Mount Wilson. Herbig is attempting to derive the rate of formation of these stars in the Galaxy. M. Walker and others have found many of these objects in young clusters, photometrically through light variation and their location in the 'sub-giant' region of the H.R. diagram. Herbig reported that the absorption lines in T Tau are broad. When his observations of line width are interpreted as caused by rotation, his statistics indicate that if the stars move left, towards the main sequence, they have velocities consistent with the normal rotational velocities for stars at their terminal spectral type. Walker noted that some G and K 'sub-giants' in the NGC 2264 H.R. diagram had broadened lines (confirmed for no. 92, K0 IV by Greenstein, with high dispersion). HD 117555, Gpnn, near the galactic pole, possibly a 'runaway' T Tau star, has greatly broadened lines, strong Ca II and Hα emission. Greenstein finds that the profile and strength of Hα varies from night to night; the emission is 1000 km/sec wide with a broad central reversal. Stecker (Michigan) plans to observe R Mon, T Tau and RY Tau in the ultra-violet.

A K-type flare star, $+1^\circ 1522$ is reported by Münch, Münch and S. Gaposchkin; a number of lists of Hα emission stars have appeared from Tonantzintla; Haro has studied extensively the relations between T Tau and UV Cet stars.

Joy reports a flare of UV Cet on 7 October 1957, amplitude about $1^m.5$ and 15 min duration. The emission lines of H and He were widened and strengthened, and the continuum also was enhanced. His discovery of the spectroscopic-binary nature of the more complex flaring stars of the U Gem class, SS Cyg and AE Aqr, has had important theoretical consequences in the dynamic interpretation based on theories developed by Kopal and by Kraft and Crawford. It seems possible for interchange of matter to seriously affect the luminosity of a small, denser companion of a star that fills the zero-velocity surface. The flares may then be connected with turbulent motions of infalling material, or with magnetohydrodynamic effects. No polarization was observed in SS Cyg at maximum light.

Dolidze has made spectrophotometric measures of fourteen non-stable stars; Kharadze and Bartaya are undertaking a programme of spectral photometry of the T Tauri stars including HK Aql, V 733, BY And. Preliminary results on HK Aql suggest that this is not a T Tauri star.

RECOMMENDATIONS FOR DISCUSSION

1. A possible unification of Commissions 29 and 36, with a revised sub-commission structure, is under consideration. Many members have urged this, and responses to the circular letter sent by Oosterhoff will be useful.

2. At the Dublin meeting the Perkins Observatory bibliography of stellar spectroscopy was discussed, without action. Several members have re-opened this question, and I have ascertained that Keenan is still interested in maintaining such an information centre, for international use. Funds and personnel are lacking, and for action to obtain these our commission must make a recommendation to the I.A.U.

3. Slettebak and Stock urge an extension of the MK standards to fainter stars, 10^m to $13^m.5$, OB and A types, as an aid to galactic research based on objective-

prism surveys. Bappu recommends a new MK spectral atlas, or at least a reprint of the older MKK atlas.

4. Thackeray urges the publication of an atlas of standard stellar spectra, at about 40 Å/mm, to permit transfer of accurate classification systems to the southern sky, and to permit classification of spectra obtained for radial velocity at typical medium dispersion.

5. Hoffleit suggests the usefulness, for classification of low-dispersion spectra, of an atlas of 'pseudo-tracings', such as was given by Nassau and van Albada, to cover a wide range of types and wave-lengths, to show features visible at dispersions from 20 to 400 Å/mm. Such a project could be carried out with quite modest instruments.

6. Objective-prism surveys leading to discovery of interesting or rare objects have sometimes been carried out for statistical purposes. Working spectroscopists, however, must consider such objects as 'lost' if no maps, charts or positions are given. Many members have brought up this point; marked charts could be at least privately circulated, if publication costs are too great. If co-ordinates are given, positional accuracy of $0\overset{\prime}{.}5$ is needed, especially in crowded fields.

7. The quantitative interpretation of high-dispersion stellar spectra, including measurements of wave-lengths and equivalent widths, identifications, curve-of-growth analysis, model-atmosphere analysis, proceeds slowly, even if the spectra are available. M. Burbidge suggests that the Commission encourage straightforward analyses of chemical composition of a wide variety of stars. Trials of the synthesis of complex spectra on electronic computers have also been suggested. Molecular equilibria have been computed by de Jager and Neven for a variety of H/C/N/O abundances, yielding concentrations of CN and CH for different temperatures and pressures. Extensions to other molecular species, together with laboratory data, are badly needed. We should discuss plans for enlarged exchange of material, either by direct communication between individuals, or if necessary through the next Commission President.

8. The problem of spectrophotometric atlases of standard stars has been repeatedly discussed. The *Utrecht Atlas* of the solar spectrum is extremely useful in almost all phases of astrophysics and the uses of atlases for other stars might be considerable. Your President must admit that the enormous cost of such a two-colour, very high-quality, ideally convenient format has proved very discouraging. It seems impossible to obtain the horizontal background and continuum, accurately registered, fine réseau, and standard wave-length and intensity units, in an atlas which might have few users. I would appreciate opinions as to (1) how many users an atlas might have and (2) whether the more economical presentation used by Migeotte *et al.* and by the Michigan group in their infra-red solar atlases is sufficient; these are on a linear, but not constant, intensity scale, and have only a few wave-lengths marked. (3) Actual copies of microphotometer tracings might be circulated to individuals, on request, at cost, using ozalid or xerographic methods, if the total number of users proves to be small.

9. Hack suggests expansion of co-operation and exchange of material between larger observatories and astronomers of other countries who lack suitable equipment. Gratton states that progress in study of spectra in the southern hemisphere is hampered largely by lack of staff. Loan of material would not be easy unless observers could visit such places as Cordoba and themselves co-operate in observing programmes. Gratton hopes to have such visitors from the north in 1958. Fujita suggests a more far-reaching plan, since astronomers from many nations lack not only modern equipment, but even funds for travel. Fujita suggests that an international centre be established to which large observatories transfer their older spectra, and where astronomers could obtain material without the need of travel or even application to the original institution. Such a centre would obviously be difficult to establish and administer; the need of most institutions to keep one spectrum of each object, to provide themselves with a 'reference library', would greatly reduce the available material. Speaking purely for my own institution, I can mention that 5100 spectrograms are now on loan to twenty-seven astronomers in the United States and 900 spectra (mainly at high dispersion) to sixteen astronomers in

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thirteen countries outside the United States: twenty-nine astronomers from other institutions used Mount Wilson or Palomar equipment in 1954–55. I quote these figures mainly to suggest that international co-operation does exist, and can be still further expanded to bring more closely together the scientists of the entire world.

J. L. GREENSTEIN
President of the Commission

29a. SUB-COMMISSION ON THE SPECTRA OF VARIABLE STARS

The province of the spectra of variable stars is continually widening and its limits are growing more indefinite. This is the result of our growing conviction that variability tends to mark certain phases of a star's career, and that these phases may at some stages be more conspicuously revealed by variations of one type (e.g. changes of brightness) and, at other stages, by variations of another type (e.g. changes of spectrum or variations of magnetic field).

The current report is thus presented in eleven sections, which are arranged in what now appears to be a rough evolutionary order.

T Tauri stars and T Tauri-like stars

Studies in this fertile new field of variable star astronomy have made it clear that T Tauri stars are to be found in the very youngest galactic clusters. The galactic cluster NGC 2264 was found by Walker [1] to contain faint T Tauri stars, and Walker [2] finds similar results for NGC 6530, associated with Messier 8. This work is supplemented and confirmed in spectroscopic studies by Herbig [3], who finds 'T Tauri-like stars' in the neighbourhood of Messier 8, Messier 20, and Simeis 188.

The physical condition of the T Tauri-like stars is approached by Böhm [4], who interprets his study of the spectra of the brightest Herbig-Haro objects and finds that the exciting process is not accretion-heating. This conclusion, however, is questioned by Hoyle [5]. Herbig [6] measures line widths for T Tauri-like stars and concludes that they are consistent with axial rotation. A study of NX Monocerotis by Hunger and Kron [7] reveals high polarization of its ultra-violet light (recent work has thrown doubt on the reality of this effect), and rapid fluctuations in the ultra-violet; NX Monocerotis is in NGC 2264.

Dr L. H. Aller reports:

For a number of years systematic observations of T Tauri, RY Tauri and R Monocerotis were carried out with the 37-inch reflector. The then available spectrographic equipment was not ideally suited to this problem as we were able to cover only the ordinary photographic range. Very recently, the completion of the new ultra-violet spectrograph equipped with an $f/1$ and an $f/2$ camera has opened up new possible lines in the photographic and astronomically accessible ultra-violet region. Mr Theodore Stecher plans to use this instrument in an intensive study of T Tauri stars and their associated nebulosities. Particular emphasis will be placed on the ultra-violet continua and problems of line variations.

Super-giants of early type

The spectrum of the luminous S Doradus in the Large Magellanic Cloud has been described by Smith [8]; it has bright lines with sharp violet components for the first four Balmer lines; the H line obscures the fifth, and the sixth and seventh are weak absorption lines; the H and K lines (apparently not interstellar) are abnormally intense. The Balmer decrement is steep.

A spectroscopic study of S Doradus has been published by Wesselink [9]. During a gradual fading in light (1954–55) emission lines of Fe II appeared. The minimum does not agree with Gaposchkin's ephemeris and the star should not be regarded as a regular eclipsing variable.

A study of the spectrum of P Cygni with high dispersion was published by Adams and Merrill [10].

The β Canis Majoris stars

This distinctive and limited group of stars is currently of great interest. Mathews [11] has discussed 53 Piscium, of spectral class B 3 V and absolute visual magnitude $-2\cdot0$, which thus lies at the edge of the group, near the Main Sequence. Böhm-Vitense and Struve [12] have determined equivalent widths for γ Pegasi; Sahade and Struve [13] note incipient emission in the Hα line of β Cephei. Münch and Flather [14] find that 53 Arietis belongs to the class.

Dr McNamara of Brigham Young University reports:

We anticipate making a study to determine the relative frequency of the β Canis Majoris variables among the sharp line B-type stars. This study will be made to test the hypothesis that all B 1 and B 2 stars (proper luminosity class), with rotational velocities below a certain critical value, pulsate.

We also have a programme whose aim is to determine the position of the β Canis Majoris stars in the H–R diagram. We have accurate equivalent-width measurements on the $H\delta$ and $H\gamma$ lines of these stars. These equivalent widths will be used to obtain absolute magnitudes from a calibration of the equivalent widths and absolute magnitudes of the stars in the clusters NGC 2362, M 36, and the h and χ clusters in Perseus. The absolute magnitudes are from Johnson's photometric observations, and the majority of the equivalent widths have been determined from low dispersion spectra obtained at the Mount Wilson Observatory.

William Buscombe, of the Commonwealth Observatory, reports:

In addition to σ Scorpii, H. Gollnow has obtained radial velocity curves for several short-period cycles of the star β Crucis, simultaneously with photo-electric measures of the light and colour variations by A. R. Hogg. As part of a world-wide study co-ordinated by A. van Hoof, observations of the radial velocity variation through several 3-hour cycles for θ Ophiuchi have also been obtained. The amplitude varies in different cycles between 5 and 20 km/sec, apparently as the result of beat oscillations in the stellar atmosphere.

A. D. Thackeray, of the Radcliffe Observatory, reports:

Pagel [15] has investigated several southern stars for β Cephei variations. Short-period variations of radial velocity were found for β Crucis, τ^1 Lupi, and α Lupi. Van Hoof [16] has added to the already extensive discussion on the mechanism of the β Canis Majoris stars.

The magnetic variables

Several new investigations of magnetic variables have been published or are in progress. Babcock [17] discusses HD 71866, and reports [18] that RR Lyrae has a variable magnetic field.

Armin Deutsch reports as follows:

The Aop star HD 125248 reverses its magnetic field with a period of 9·3 days, and shows synchronous changes in line strength, line width, and radial velocity. Superposed on this 9·3-day cycle, there is another, much slower radial-velocity variation. From coudé spectrograms accumulated over a ten-year period, including many by H. W. Babcock, it has now been found that the secondary velocity variation is due to Kepler motion in an eccentric orbit about an invisible companion. The period of this motion is about 1620 days, and its amplitude about 7 km/sec, or more than twice that of the 9·3-day cycle.

When the orbital velocity variation is removed from the observations, these may now be combined to yield mean velocity curves which are believed to represent the motions due to rigid rotation with a period of 9·3 days. One such curve is required for the lines of Eu II, Gd II, and Ce II; a second for the lines of Cr I and II; and a third for the lines of Fe I, Fe II, and Ti II. By a kind of harmonic analysis, it has proved possible to derive a rigidly-rotating configuration which reasonably well satisfies all the observations of this star. Existing observations of α^2 Canum Venaticorum are being discussed with the same theory. The end-result of this harmonic analysis will be a unique map of the abundance irregularities on these stellar surfaces, and of the associated magnetic fields. (Proceedings of the 1956 Stockholm Conference on Electromagnetic Phenomena in Cosmical Physics, in press.)

Deutsch [19] has discussed the variations of the lines in the spectrum of 56 Arietis. Concerning this star, W. Bonsack reports as follows:

The variability of the spectrum of the Aop star 56 Ari was discovered by Deutsch. A series of grating spectrograms at 40 Å/mm were taken, at Deutsch's suggestion, during six consecutive cycles of variation to investigate the velocity variations of these lines. It was found that the variable lines showed velocity changes related to the intensity changes in the manner demanded by the rigid rotator model. Five Si II lines and four unidentified lines vary synchronously in velocity as they do in intensity; these variations differ in phase from the similar variations of the He I line at λ 4026. The observations are insufficient to define the secondary variation in He I noted by Deutsch. The range of velocity variation (approximately 120 km/sec) is reasonable, being about equal to the equatorial velocity of a normal Ao dwarf rotating with the period of the spectral variations (0·73 day). The hydrogen lines show a small variation in velocity (10–15 km/sec). An unexpected result is that the mean velocity of each hydrogen line, averaged over all the plates, is significantly different, being greater for the higher members of the Balmer series. These results are now in press.

Babcock [20] has published a valuable catalogue of magnetic stars.

The classical cepheids

New light is thrown on the status of the classical cepheids by the discovery that several are members of galactic clusters. The existing material is summarized by Kraft [21]; compare also van den Bergh [22].

Bright lines of Ca II have been noted in further cepheids by Jaschek and Jaschek [23]; a summary is given by Kraft [24]. Livio Gratton reports that Jaschek finds that the radial velocity curve of l Carinae has changed considerably since the beginning of the century. Kraft also discusses the discovery of double lines in the spectrum of X Cygni.

Sergei Gaposchkin reports that he has obtained in 1956–57 at Mount Stromlo Observatory (Australia) over thirty spectra of β Doradus, over thirty spectra of l Carinae, and over fifteen spectra of κ Pavonis simultaneously with photometric observations of the whole variation of light. Few spectra are in the red region.

The dwarf cepheids

Several members have been added to this interesting group. Eggen [25] finds that δ Delphini (A 7 III) has a period of 0·13505 days, and probably resembles δ Scuti; Struve, Sahade and Zebergs [26] determine a velocity curve and confirm the period.

The star ρ Puppis, found by Eggen [27] to vary with a period of 0·141 days, seems to belong to the group with less variable light-curves. The velocity-curve has been determined by Struve, Sahade and Zebergs [28].

William Buscombe writes:

From recent observations of ρ Puppis, covering two complete cycles, together with older published data, the exact period 0^{d}140 881 43 is found to fit all radial-velocity measures, with amplitude $2K = 11$ km/sec. At most phases, particularly near maximum light, the lines of H and Sr II show abnormally large velocities of recession. The phase of maximum radius occurs just after minimum light, and there appears to be no appreciable variation of effective temperature.

AI Velorum was observed intensively in 1955 and hundreds of spectra, now under measurement, have been obtained by Gratton, Platzeck and Lavagnino.

Variable red super-giants

It seems likely that large red stars tend to be surrounded by shells or circumstellar envelopes. The existence of such an envelope around α Herculis has been demonstrated by Deutsch [29].

Spectral peculiarities in *Betelgeuse* have been shown by Adams [30] to be associated with a shell, and Adams and Merrill [31] pointed out an expanding shell about the very luminous variable star RW Cephei.

Long-period variables

Studies of several long-period variables have been published, or are in press. Feast continues to study those in the southern hemisphere. Merrill [32] examines the spectrum of R Hydrae near minimum. Herbig [33] has identified the emission-band spectrum of AlH in the minimal spectrum of χ Cygni.

Merrill [34] calls attention to the three long-period variables that are known to have companions, and commends to the notice of observers a list of seventeen more, whose wide, flat minima suggest that companions may be detectable.

Armin Deutsch reports:

The spectrum of *Mira* has been found to exhibit a number of remarkable changes from cycle to cycle. As compared with the spectra of ordinary M giants, the absorption features in *Mira* tend to be the most nearly normal at bright maxima. At most faint maxima, however, the atomic absorption lines are strongly suppressed, especially in the region of the Ti O bands. As the star fades, the intensities of many of these lines change in opposite directions after maxima of these two kinds. The effects are extremely complicated, but often very large. Presumably they are principally stratification effects, but as yet they are not well understood.

The companion of *Mira* has been observed visually at each of the last four minima, in roughly the same configuration as at all other reliable observations. These observations require the abandonment of a period near fourteen years, as has been suggested by Parenago. Evidently the motion is very slow, and the mass of the system low. Another long-period variable with a visual companion is X Ophiuchi. Rapid changes in the shell of *Mira* B were observed again at the last minimum of the long-period variable. There is some reason to believe that the hot blue star is really a white dwarf which shines by accretion-heating in the circumstellar envelope of the M super-giant. If so, the blue star is likely to become a nova.

Deutsch adds that recent spectrograms of the spectrum of the companion of X Ophiuchi confirm that it is a K sub-giant, which is much less luminous than an ordinary K giant. The systems of *Mira* Ceti and X Ophiuchi, he adds, are likely to be extremely old stars.

A three-dimensional system for classification of the spectra of red stars is advocated by Merrill [35], with parameters that represent temperature, the ratio of oxygen to carbon, and the heavy metal abundance.

P. C. Keenan reports:

In order to meet the need for a classification of *Mira* variables in two dimensions—luminosity and temperature—low-dispersion spectrograms of a number of the brighter ones are being compared. On plates taken with the shortest cameras on the 2-prism spectrograph on the Perkins 69-inch reflector or the new grating spectrograph on the Mount Wilson 60-inch reflector (linear scales 80–100 Å/mm), ratios of several lines in the blue region suggest that there are real luminosity differences between some of the variables observed. Twenty-nine stars have now been classified, but several years will be required to obtain homogeneous types near normal maximum brightness for most of the brighter *Mira* variables in the northern sky.

Semi-regular red variables

P. C. Keenan reports:

Low-dispersion spectrograms covering the blue and yellow regions are being used to classify the small-amplitude variables of types K, M and S. This programme is an extension of earlier work done at Yerkes and Perkins. This year particular efforts are being made to obtain good samples of those with relatively early type (K 0–M 2) and those with very late types (M 7 and M 8).

Attention is turning to the study of the red and infra-red spectra of red variable stars. Studies of FU Monocerotis in the red have been published by Teske [36], and Miller [37] has examined the spectral variations of S Ursae Minoris in the micron range, with special stress on the changes of the VO, λ 10 500 bands. The peculiar and anomalous spectrum of ρ Cassiopeiae has been found by Bidelman and McKellar [38] to display doubled lines. Deutsch reports the continued study of this star. The presence of technetium in the spectrum of 19 Piscium, as reported by Merrill [39] opens up interesting possibilities in the study of the spectra of red stars.

Sergei Gaposchkin reports that he has obtained in 1956–57 at Mount Stromlo about forty spectra of L_2 Puppis, a semi-regular long-period variable with strong emission lines; at the same time photometric observations were made. Few spectra are in the red region.

Red flare stars

The extremely faint star, the red companion to BD $+4°4048$, which has an absolute visual magnitude about $+19$, has been found spectroscopically by Herbig [40] to be a flare star.

The symbiotic variables

A new member of this interesting list has been discovered spectroscopically by Cowley [41], and its light-curve is determined by Mumford [42].

Study of the symbiotic variables continues. L. H. Aller writes:

Observations of CI and BF Cygni, Z Andromedae, and AX Persei have been made at Mount Wilson and at Ann Arbor. A short account of the observations of AX Persei and CI Cygni made with the 60-inch at Mount Wilson was published in Vol. 18 of the Liège Proceedings. Further observations of these stars are being carried out at Ann Arbor with the new ultra-violet spectrograph equipped with quartz-fluorite optics. Our interest in these stars has been largely stimulated by their possible import in connexion with theories of stellar evolution. It is possible that some stars of this type may represent incipient planetary nebulae, although I am inclined to the belief that the formation of an actual planetary may proceed in a more orderly fashion, the earliest stages being represented by objects such as IC 4997 where William Liller and I have found a variation of the intensity ratio of [O III] 4363 to Hγ.

Marie Bloch reports that she and Tcheng Mao-Lin are continuing the study of AX Persei, Z Andromedae, AG Pegasi, BF Cygni, CI Cygni, and T Coronae Borealis.

Variables in clusters, RR Lyrae stars

The study of these stars, both in and out of globular clusters, is continuing. W. Bonsack reports from California Institute of Technology:

Grating spectrograms at 80 Å/mm have yielded radial velocity curves for the stars SW And ($P=0.442$ day), DX Del ($P=0.473$ day), DY Her ($P=0.149$ day), and DH Peg ($P=0.255$ day). The former three stars have light curves of Bailey's type *a*, while the latter has a type *c* variation. The observations were spread through a 15-month period, and include parts of widely separated cycles for each star. The spectrograms have internal probable errors of 2–5 km/sec, and define velocity curves to within the accuracy expected, except that the results for DH Peg would agree better if a slightly longer period than the latest published photometric period were used. The velocity curves of SW And and DX Del resemble reflexions of their light curves, and have amplitudes of about 70 km/sec. The velocity curve of DY Her differs considerably from a reflexion of its light curve, being asymmetrical in the opposite sense—a rapid rise to maximum velocity followed by a gradual decline. Its amplitude is about 30 km/sec. The velocity curve of DH Peg has a rather broad maximum, a fairly rapid decline to minimum, and a gradual rise. Its amplitude is about 25 km/sec. At the time of maximum radius, the spectra of SW And and DX Del resemble closely F 8 III standards on the MK system; DY Her is similar to F 4 III, and DH Peg to A 7 III. The spectra at other times are earlier, but the hydrogen and ionized calcium lines do not give the same classes as the remaining lines. Neither the spectra nor the mean velocities of these stars place them in population II.

Mr Wallerstein, also from California Institute of Technology, reports:

I worked primarily on M 5 no. 42, M 5 no. 84, and TW Cap. At maximum light the metallic lines for both M 5 no. 42, and TW Cap are double. The lines of no. 84 appear very broad but not double; in all probability they are actually double but not quite resolvable at 20 Å/mm. The velocity curve of no. 42 is similar to W Vir but with a slightly smaller amplitude. The velocity curve of TW Cap is also similar but the scatter is considerable, probably due to poor repetition from cycle to cycle. No. 84 has an interesting velocity curve. You will recall that Arp found that no. 84 is an RV Tauri star. The velocity-curve alternates also in that after a deep minimum the new rush of gas is delayed, i.e. the fall in the velocity-curve occurs late; and after a shallow minimum the fall in the velocity-curve occurs early. The total difference is about 8 days of the 26·5 day (half) period.

The spectra of these stars are peculiar and difficult to classify. All three stars get as early as A 5 or A 6, luminosity I b–II, just before maximum light. Near maximum distention they reach their latest spectral type, about F 5 I b–II. λ 4481 of Mg II is always too weak for the assigned spectral type. TW Cap shows a marked weakness of the Fe II lines; this is also noticeable in M 5 no. 84 but hardly noticeable in no. 42. It seems unlikely that this is a luminosity effect since Ti II and Sr II are normal for luminosity class I b or II. On the other hand for W Vir Sr II is weak when compared with Fe II and Ti II, which give it a luminosity class of I b.

I also classified a few plates that I got of M 2 no. 11, M 10 no. 2, M 3 no. 154, AL Vir, UY Cam, and UY Eri. There really seems to be no definite period-spectrum relation. One point of interest that turned up is that, of the cepheids in clusters that Arp found to lie on the uppermost line of the period-luminosity diagram, all have spectra close to A 5 just before maximum light; while those lying on the lower two lines are about F 0 just before maximum. This shows a real difference among stars of different luminosity and same period, but does not say that the lines are discrete.

The three stars M 5 no. 42, no. 84, and TW Cap show hydrogen emission during the rising branch of the light curve, but the emission is not nearly as strong as in W Vir. Last spring Kraft found helium emission on some old plates of W Vir taken by Sanford.

Armin Deutsch writes:

A velocity-curve for the 1·3-day Cepheid XX Virginis ranges from 0 km/sec at minimum light to -75 km/sec at maximum. The dispersion was 40 Å/mm; emission lines or double absorption lines were not observed.

The SS Cygni stars

The important discovery that SS Cygni is a spectroscopic binary with a period of 0·276244 days, and a dG 5 companion, was announced by Joy [43].

The peculiar explosive star AE Aquarii, shown by Joy [44] also to be a spectroscopic binary, is being further studied. Dr Armin Deutsch reports:

The irregular, explosive variable star AE Aquarii has been observed spectroscopically at the 100-inch telescope simultaneously with photo-electric observations by Walker. Spectrograms have been obtained when the star was at normal brightness, and during three explosions that endured an hour or more and reached peak amplitudes in the ultra-violet of more than two magnitudes above normal brightness. These spectrograms indicate the emergence of a strong ultra-violet continuum during explosions. The absolute strengths of the Balmer lines also increase, but by a smaller amount than the hot continuum, during an explosion. The ultra-violet continuum may possibly be synchrotron radiation; a few inconclusive attempts have been made to detect polarization in the focal plane of the spectrograph.

Super-giant eclipsing stars

The astrophysical problems presented by eclipsing stars make it difficult to draw the line between them and the intrinsic variables, despite the fundamentally geometrical cause of their variations of brightness. The super-giant eclipsing systems, with their atmospheric eclipse phenomena, continue to attract the attention they merit. The problem of analysing the envelopes physically has been discussed by Underhill [45]. ϵ Aurigae has been much studied during the recent eclipse; reference may be made to the published papers by Struve [46], and by Struve and Pillans [47]. Two eclipses of ζ Aurigae have been observed and discussed spectrographically by McKellar and Butkov [48].

The newly-discovered member of the group, AZ Cassiopeiae, has been shown by Sahade and Struve [49] to display atmospheric eclipses of unusual type. The system of VV Cephei has continued to excite interest; the spectral type and luminosity have been discussed by Keenan and Wright [50]. The pre-eclipse spectrum and the spectrum during totality have been discussed respectively by Wright and McKellar [51] and by McKellar, Wright and Francis [52]. 'The spectrographic observations agree', reports McKellar, 'with photometric data in placing first and second contacts about 1956 June 29 and July 29 respectively. Third contact should occur about mid-October 1957. High-dispersion spectrographic observations of VV Cephei are being continued at Victoria.'

Armin Deutsch reports:

Coudé spectrograms have been obtained during the chromospheric eclipse of VV Cephei. It appears that some chromospheric lines of Ti II were already present in the far ultra-violet more than four years before the beginning of the photometric eclipse in July 1956. The chromospheric lines differ in structure from one element to another, the lines of Ti II being systematically the most complex. During totality, the spectrum showed the following features: (*a*) in the far ultra-violet, strong emission lines from low levels of Fe II; (*b*) turbulent broadening of the absorption lines which exceeds that in α Orionis; (*c*) circumstellar absorption cores in strong zero-volt lines, but much weaker than in α Orionis; (*d*) emission lines of [Fe II] and [Ti II].

McKellar and Petrie [53] give a general discussion of the ζ Aurigae-like system, 31 Cygni. Their work suggests a shorter period of 3781 $\pm$ 8 days. Hence spectrographic observations of eclipse effects should start by late September 1961. A mass-ratio $m_1/m_2 = 1{\cdot}9$ is deduced. A set of dimensions and other physical quantities describing the system is given. The second component of 31 Cygni is discussed by Wright and Lee [54]. Wellmann [55] publishes a discussion of the system of 32 Cygni.

A. D. Thackeray reports that the minimum of AR Pavonis (P Cyg, regular eclipsing) in July to September 1957 was well observed and scattered observations made at other phases. The star FR Scuti, a possible super-giant binary that displays bright lines of hydrogen, helium and ionized iron, and forbidden lines of Fe II, Fe III and O III, is described by Bidelman and Stephenson [56]. Marie Bloch reports that she is observing this star. Thackeray also reports that the super-giant binary system BL Telescopii is being studied at Pretoria.

Miscellaneous eclipsing stars

The spectrum of U Coronae Borealis has been discussed by Struve, Sahade and Huang [57]. McNamara reports:

Duane R. Aston and I have made a new spectrographic study of the eclipsing binary U Cephei from plates secured with the new 60-inch Cassegrain spectrograph of the Mount Wilson Observatory. The elements derived from the radial velocities are similar to those that have been obtained previously. The velocity-curve is unsymmetrical, leading to a value of the eccentricity considerably different from the zero value found by photometric observers. The radial velocity-curve is not only unsymmetrical when determined from the He, Mg, and Ca lines. At the critical phases when, according to Struve and Hardie, absorption by a gaseous stream distorts the velocity-curve, the lines other than hydrogen give essentially the same velocity. We can detect no modification in the structure of these lines on microphometer tracings at these critical phases. In view of this result, we feel that a closer examination of Struve's hypothesis of absorption in a gaseous stream to explain the unsymmetrical velocity-curve of U Cephei is in order.

Spectra of the Hα region of U Cephei reveal that the Hα line of the brighter component varies in appearance with phase. The majority of the period, the Hα line has a well defined core, but near phases corresponding to one-quarter or three-quarters of the period, the Hα line becomes very weak. We believe that this change in the appearance of the line may be due to emission filling in the centre of the line. If this interpretation is correct, the gas giving rise to the emission must be concentrated between the two stars and hence visible only near the elongation phases of $0{\cdot}25P$ and $0{\cdot}75P$.

The third component of *Algol* has been investigated by Struve and Sahade [58], who find it of spectrum A to F and luminosity class IV or V. Buscombe reports that an orbit is being obtained at the Commonwealth Observatory for ζ Phoenicis on the basis of spectrographs of 1954–55 and earlier Lick observations. McNamara reports:

During the last year and a half, I have secured a series of high-dispersion spectrograms (dispersion 10 Å/mm) of the eclipsing binary RZ Scuti. Of particular interest is the resolution of the hydrogen lines into a double set of absorption lines immediately following mid-eclipse. The stronger set of lines originates in a slowly rotating ring of hydrogen gas surrounding the B 2 component, while the weaker set originates at the same level as the helium and magnesium lines. This interpretation of the line doubling can be demonstrated to be correct from line-profile and Doppler-displacement arguments.

The failure of the H lines to follow the pronounced straight-line trend of the rotational disturbance displayed by the other star lines in RZ Scuti can now be easily understood. The H-line measurements made previously on small dispersion plates have always referred to the strong stationary shell lines rather than the weak underlying star lines. Our measurements of the weak underlying H lines show that they participate in the straight-line trend of the rotational disturbance displayed by the other star lines, such as the helium and magnesium lines. These observations, therefore, strongly confirm the hypothesis advanced by Struve that surrounding the brighter component of RZ Scuti is a slowly rotating shell of hydrogen gas.

Observations of the Hα line in RZ Scuti have also proved to be interesting. Emission lines flanking the Hα line have been detected. The intensity of the Hα absorption line also changes with phase. Also, spectra of the B 2 component obtained just as it emerges from eclipse taken in different cycles reveal that the width and intensity of the absorption line changes from cycle to cycle.

The perennially interesting W Serpentis is discussed by Sahade and Struve [59]. Deutsch reports a current study of UX Ursae Majoris and VW Cephei, and Gratton indicates that GG Carinae is under observation.

Sergei Gaposchkin reports that he has obtained in 1956–57 at Mount Stromlo many spectra of γ Velorum, 29 Canis Majoris, τ Tauri, υ Sagittarii, ζ Puppis and η Carinae. Some spectra are in the red region.

CECILIA PAYNE-GAPOSCHKIN
President of the Sub-Commission

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29*b*. SOUS-COMMISSION DES BANDES MOLECULAIRES DANS LES SPECTRES STELLAIRES

MISSIONS ESSENTIELLES DE LA SOUS-COMMISSION

Le premier rapport de la Sous-Commission 29*b* a été soumis au Congrès de Zurich par Dr A. McKellar. La Commission avait pour but essentiel d'encourager la préparation des tables et atlas de spectres moléculaires, ainsi que de susciter des recherches dans les domaines plutôt négligés de l'astrophysique moléculaire et de la spectroscopie des molécules d'intérêt astronomique. Pour le Congrès de Dublin, nous avons fait rapport sur les tables publiées jusqu'en 1954; à notre connaissance, rien de nouveau n'est paru depuis lors; il semble bien d'ailleurs que les besoins actuels soient couverts.

L'Atlas de spectres d'oxydes diatomiques dont s'était chargé le laboratoire de spectroscopie de la Specola Vaticana est pratiquement terminé; il aura déjà été utilisé par maints chercheurs avant l'Assemblée Générale de 1958.

Le Père Junkes à qui revient la majeure partie de cette œuvre, commencée par notre très regretté Collègue, le Père Gatterer, mérite les vifs remerciements et compliments de la Sous-Commission. Dans le cadre de ce travail, B. Rosen et ses collaborateurs, notamment J. Swensson, S. Hautecler et C. Lemaître, ont examiné critiquement toutes les données spectroscopiques concernant 44 oxydes diatomiques et étudié en détail les spectres de ceux d'entre ces oxydes dont la connaissance semblait peu satisfaisante. C'est le cas en particulier des oxydes de Ba, Ca, Cr, Cu, Hf, La, Sr, Ti, V, Zr et des oxydes de toutes les terres rares. Toutes les données spectroscopiques nouvelles seront publiées prochainement. Le programme suggéré par la Sous-Commission à Zurich a donc donné lieu non seulement à la publication d'un Atlas désiré par de nombreux astronomes, mais encore à l'obtention de nombreux résultats spectroscopiques nouveaux et à la matérialisation d'une coopération intime entre plusieurs observatoires.

Les laboratoires 'fidèles' de spectroscopie moléculaire ont continué à être très actifs. De nouveaux, parfois suscités par la Sous-Commission, se sont créés. C'est ainsi, pour ne citer que le dernier né, qu'un laboratoire consacré aux spectres d'intérêt astronomique est en voie d'installation à la nouvelle Université du Congo Belge à Elisabethville (Prof. J. Genard et Dr L. Haser). Dans plusieurs laboratoires, d'efficaces instruments nouveaux destinés aux spectres moléculaires ont été installés, notamment chez G. Herzberg à Ottawa (plusieurs appareillages nouveaux), T. E. Nevin à Dublin (réseau dans le vide de 3 mètres) et B. Rosen à Liège (réseau dans le vide de 3 mètres). A Berkeley, on a commencé à employer les machines électroniques pour le classement des spectres moléculaires compliqués. On y a aussi commencé des déterminations de durée de vie sur les états moléculaires excités au moyen de systèmes de miroirs tournants permettant l'obtention de spectrogrammes résolus dans le temps.

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Enfin, le président de la Sous-Commission a organisé en 1956, un Colloque International consacré aux 'Molécules dans les Astres'. Dans le volume contenant les communications, les sections relatives aux molécules stellaires (y compris le soleil) comprennent près de 200 pages; il faut y ajouter une section de 160 pages relative aux travaux récents de laboratoire sur les molécules d'intérêt astronomique.

En plus des exposés généraux introductifs contenus dans le volume du colloque de Liège, plusieurs monographies ont été publiées, notamment par P. C. Keenan [1] et par P. Swings [2].

L'intérêt dans le domaine couvert par la sous-commission a donc été vivace durant les dernières années.

QUELQUES PROGRÈS IMPORTANTS DANS LES IDENTIFICATIONS

B. Kleman [3] a reproduit en laboratoire les bandes de Merrill-Sanford qui sont intenses dans les étoiles N avancées. Ces bandes ont été obtenues dans un four à tube de carbone contenant du silicium. Il semble bien que la molécule responsable soit SiC_2, qui est donc la deuxième molécule triatomique stellaire, s'ajoutant à C_3 trouvée dans les mêmes étoiles. Le résultat de B. Kleman apporte une identification cherchée vainement depuis longtemps, aux bandes de Merrill-Sanford.

La séquence de 5 bandes dégradées vers le rouge, avec têtes en $\lambda\lambda$ 10459, 10484, 10510, 10547 et 10566 observée dans les étoiles M avancées comme R Leo et R Cas a été attribuée à VO [4].

Les énigmatiques raies d'émission observées dans la variable χ Cygni près du minimum de lumière ont pu être attribuées à la molécule AlH par G. Herbig [5]. Seules sont observées les raies de rotation provenant de certains nombres quantiques de rotation bien définis; la sélectivité résulte d'un phénomène de prédissociation inverse très pur. Les mêmes émissions de AlH se retrouvent dans d'autres variables à longue période, comme R Cyg et TUMa, près du minimum [6]. L'identification trouvée par Herbig apporte une contribution importante à notre connaissance du mécanisme d'émission dans les variables à longue période; elle rend un intérêt nouveau aux phénomènes de luminescence chimique imaginés autrefois par K. Wurm [7] pour expliquer certaines raies d'émission des variables à longue période.

Le continuum attribué à la molécule C_3 a fait l'objet de nouvelles observations en laboratoire et dans les spectres stellaires; quoiqu'il paraisse assez probable que la forte opacité violette des étoiles N avancées soit due au continuum de C_3, ceci n'est pas encore certain [8].

Enfin, la raie interstellaire λ 3143·22 a été attribuée par M. W. Feast à la molécule CH [9].

QUELQUES RÉSULTATS D'OBSERVATION

Soleil. C. E. Moore et H. P. Broida [10] ont revu les identifications des raies de rotation de CH, OH et CN. G. Righini [11] a déterminé le rapport des abondances de ^{12}C et ^{13}C en partant d'une raie de $^{13}C\,^{14}N$, λ 3874·358; il trouve la valeur assez curieuse $^{12}C:^{13}C = 10^4$. L'effet centre-bord des bandes moléculaires a été discuté par J. C. Pecker [12].

Etoiles M, S et C. Le comportement des diverses bandes a fait l'objet d'intéressantes études de R. Bouigue, Y. Fujita et collaborateurs, M. W. Feast, J. G. Phillips, J. Humblet et G. Mannino, etc.... Bouigue a discuté la classe S [13]; il a aussi effectué un essai de classification rationnelle des étoiles M, en partant des températures de vibration (à paraître prochainement). Fujita a étudié le comportement de TiO dans le spectre de χ Cygni près du maximum [14].

Dans cinq étoiles carbonées (WZ Cas, U Cyg, U Hya, V Aql et RY Dra) il a comparé les intensités de bandes de C_2 et CN de la région rouge-infra rouge [15]. Il a étudié les bandes moléculaires de la région rouge-infra-rouge de UV Aql [16]. En collaboration avec Y. Yamashita et S. Nishimura, il a discuté les bandes de TiO, ZrO, C_2, CN et SiC_2 dans plusieurs étoiles avancées M, S et C [17]. J. G. Phillips a appliqué ses nouvelles déterminations de probabilités de transition dans les séquences de C_2, à l'étude de l'étoile de type R, HD 182040 [18]. M. W. Feast a effectué la spectrophotométrie de la région violette de AM Cen, une étoile à très grande opacité violette, mais sans bande de C_2 [19]. La distribution d'intensité du continuum d'absorption diffère de façon appréciable de celle qu'on trouve dans les étoiles carbonées avancées; on répond ainsi à une objection à l'attribution à C_3 de l'opacité continue violette des étoiles C. Au cours de la période 1953–57, G. Mannino a obtenu un grand nombre de spectres de 14 étoiles C avec une dispersion de 40 Å/mm à Hγ. En collaboration avec J. Humblet [20], Mannino a porté son attention sur le comportement des bandes de Merrill-Sanford; l'intensité de celles-ci n'est pas en relation directe avec celle des bandes de C_2. On est tenté de penser que les bandes de Merrill-Sanford sont particulièrement sensibles à la luminosité absolue. Mannino a aussi estimé le rapport d'abondance $^{12}C:^{13}C$ dans de nombreuses étoiles N en suivant la méthode appliquée par McKellar; il obtient des valeurs comprises entre 1·7 et 4·1 [21]. W. Iwanowska [22] a utilisé les bandes de VO comme critère de population I ou II dans les variables à longue période.

Les déterminations les plus récentes de températures stellaires basées sur les bandes moléculaires sont celles de A. A. Wyller [23] et de J. G. Phillips [18]. Les résultats discordants obtenus pour les températures vibrationnelles lorsqu'on emploie des bandes de C_2 assez distantes sont en relation directe avec le fait que l'opacité augmente considérablement lorsque l'on passe du rouge au bleu.

Il reste encore quelques bandes inexpliquées dans les étoiles S, notamment $\lambda\lambda$ 5849·1; 8263; 8463·9; 8610·2 et 8820·5; il s'agit vraisemblablement de bandes d'oxydes.

QUELQUES TRAVAUX THÉORIQUES SUR LES MOLÉCULES STELLAIRES

Les calculs des abondances des diverses molécules stellaires caractéristiques (TiO, ZrO, VO, LaO, C_2, CN, CH, C_3, SiC_2,...) et l'application de tels calculs à la différentiation spectrale des étoiles froides ont fait l'objet de travaux de R. Bouigue [13], J. C. Pecker et M. Peuchot [24], C. de Jager et L. Neven [25] et J. Humblet et G. Mannino [20].

La question controversée de l'opacité continue due aux molécules dans les étoiles froides a, enfin, été discutée soigneusement par R. Wildt [26]. L'absorption continue par les ions H_2^+ se révèle importante [27], de même que la diffusion Rayleigh par H_2 [26]:

Selon Wildt, l'absorption continue due à l'ion H_2^- joue, peut-être, un rôle. Il faut, d'ailleurs, remarquer [26] que la formation de H_2 cause une extension marquée de la zone de convection vers le haut, dans les étoiles plus avancées que K5 environ.

QUELQUES TRAVAUX DE LABORATOIRE SUR DES MOLÉCULES D'INTÉRÊT ASTRONOMIQUE

Nous avons déjà signalé plus haut que B. Kleman a reproduit les bandes de Merrill-Sanford en laboratoire. D'autres travaux descriptifs, effectués à Ottawa (G. Herzberg) concernent des molécules d'intérêt astronomique. Deux systèmes de Si_2 apparaissant dans la région astronomiquement accessible ont été trouvés par A. E. Douglas [28]. Le spectre de SiH a été considérablement étendu [29]. L'analyse du spectre de NH_2 a été presque complétée par D. A. Ramsay [30]; il n'est pas exclu qu'on puisse trouver ce radical dans les étoiles les plus froides. Pour la première fois, on a obtenu le spectre de CH_3 qui est situé près de 2160 Å; une autre bande faible existe, peut-être, à de plus grandes longueurs d'onde [31]. L'analyse des spectres de HCO et HNO a été effectuée [32]. Il faut remarquer que si les molécules polyatomiques stables abondantes dans les étoiles froides (H_2O, CO_2,...) ne sont pas décelables dans le domaine astronomiquement accessible, en revanche les radicaux polyatomiques (NH_2, CH_2, C_2H,...) présentent des bandes électroniques dans ce domaine. Les spectres ultra-violets lointains de CN [33], NO [34] et NO^+ [35] ont été étudiés et de nouveaux états électroniques ont été établis.

Au laboratoire de Dublin (T. E. Nevin) [36], P. Daly a étudié les spectres de ZrCl et FeF. P. K. Carroll a examiné, à haute dispersion, les bandes de Goldstein-Kaplan de N_2 et certaines bandes de Schumann-Runge de O_2; il a analysé le système $C^2\Sigma \rightarrow X^2\Sigma$ de N_2^+. P. K. Carroll et P. Daly ont montré que certaines bandes attribuées à ZrF étaient, en fait, dues à CuF. J. Byrne a approfondi l'analyse du deuxième système négatif de O_2^+.

Nous avons signalé plus haut l'étude du spectre infra-rouge de VO par A. Lagerqvist; celui-ci a aussi étudié le spectre de AlO [4]. N. H. Kiess et H. P. Broida ont étendu le spectre de C_3 de λ3600 à λ4200 [37]. Les spectres des hydroxydes et oxydes des alcalino-terreux ont fait l'objet de nombreuses études [38]; cependant leur interprétation est encore très discutée à l'heure actuelle. B. Rosen et C. Lemaître [39] ont réinterprété les bandes de Dunér de TiO; ils ont trouvé une nouvelle transition électronique dans TiO et deux dans ZrO. Le Père Junkes s'occupe de l'analyse du spectre de HfO.

Des progrès sérieux ont été faits dans nos connaissances des chaleurs de dissociation des molécules stellaires, soit par voie spectroscopique [40], soit par spectrométrie de masse [41].

Comme travaux sur les probabilités de transition, nous citons ceux de J. G. Phillips sur C_2 et ZrO [42] et de R. Bouigue sur TiO (étude théorique et expérimentale) [43], ainsi que les recherches théoriques effectuées par le groupe de l'Université de Western Ontario couvrant la plupart des molécules d'intérêt astronomique [44].

P. SWINGS

Président de la Sous-Commission

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Report of Meetings

First Meeting: 14 August 1958.

Present: Members of Commissions 10, 11, 12, 13, 29 and 36 and their Sub-Commissions.

Subject: The resolution concerning commission reorganization submitted to the Executive Committee of the Union by J. L. Greenstein, President of Commission 29 (resolution (*e*), page 22 of these *Transactions*).

PRESIDENT: J. L. Greenstein.

SECRETARY: W. P. Bidelman.

The President opened the meeting by stating that it had been called to allow discussion of the resolution submitted by him to the Executive Committee which proposes a reorganization of the several commissions represented. In brief, this resolution proposes that the work of Commissions 10, 11, 12, and 13 should be taken over by new Commissions 10, 12 and 13 (Commission 11 being abolished), and that Commissions 29 and 36 should be combined into a new Commission 29. Greenstein informed those present that this resolution had grown out of an exchange of letters between himself and A. Unsöld, and others, and that a memorandum relating to the proposed commission changes had been previously circulated to all members of the Commissions involved. Some seventy replies had been received in answer to this memorandum, and after consideration of these replies, the resolution had been submitted to the Executive Committee of the Union. Since, however, not all replies were favourable to the proposals, the present meeting had been called for further discussion.

Unsöld then outlined the proposed reorganization, stating that Commission 10 would be composed of those who are mainly concerned with various aspects of the active Sun, while Commission 12 would comprise those concerned with the spectral and radiation properties of the normal Sun as well as with their theoretical interpretation. Work done with and without eclipse, and also work in solar radio astronomy, should be co-ordinated in this Commission with other aspects of the normal Sun. The new Commission 13 on Solar Eclipses would deal with the technical and geodetic aspects of eclipse observing and the planning of future eclipse expeditions. Sub-Commission 11*a* on Cinematography of Chromospheric Phenomena would continue as Sub-Commission 10*a*, Sub-Commission 36*a* would be eliminated, and Sub-Commission 36*b* on the Theory of Stellar Atmospheres would continue as a Sub-Commission of Commission 29.

Considerable discussion of these proposals ensued. Kienle expressed concern about the continued activity of Sub-Commission 36*a* if it ceased to exist as a Sub-Commission, but Unsöld stated that it would continue its work as a working group of Commission 29. It was proposed to abolish Commission 13 (Solar Eclipses) and to transfer its activities to a Sub-Commission of Commission 12, in order to relate its activities more closely to those of that Commission. Miss Bugoslavskaya objected to such a transfer, on the grounds that Commission 13 was charged with various astrometric and geodetic matters associated with solar eclipses, in addition to astrophysical matters which might well be transferred to a Sub-Commission of Commission 12. Unsöld then proposed that such astrometric and geodetic considerations should become the responsibility of a group concerned with geodesy (presumably similar to the now discontinued Commission 18 on Geographical Positions) rather than the responsibility of the proposed Sub-Commission 12*a*.

Various persons pointed out the desirability of close co-operation between small working groups in the various commissions, in particular between those working on the theory of the solar atmosphere and those working on the theory of stellar atmospheres.

The only strongly expressed opposition to the proposed reorganization of commission structure was that of Pecker, who felt that such a change would bring about a succession of similar small changes throughout the Union. He felt that while such changes might in individual cases be desirable, it would be better for the Executive Committee of the Union to institute a thorough and detailed examination of the question of the reorganization of the commission and sub-commission structure of the entire Union. Pecker felt that the best solution lay in the creation of many small working groups in the various commissions, a point of view that had considerable support. Schatzman suggested that commission presidents should be permitted to set up such groups without the necessity of formal approval by the Executive Committee, and should be encouraged to do so. (Secretary's note: Commission presidents do in fact have such power.)

After much discussion of possible working groups felt to be desirable, it was moved that the proposal submitted by Greenstein to the Executive Committee, as modified by the meeting, be endorsed. This motion was seconded and passed, and the Secretary was directed to transmit to the Executive Committee the following proposed commission scheme in lieu of that previously submitted (see Resolutions nos. 22 and 58). The name for the new Commission 12 was selected by de Jager, Unsöld and Goldberg.

New commission scheme for the former Commissions 10, 11, 12, 13, 29, *and* 36

Commission 10: Solar Activity.

Sub-Commission 10*a*: Cinematography of Chromospheric Phenomena.

Commission 12: Radiation and Structure of the Solar Atmosphere.

Sub-Commission 12*a*: Solar Eclipses.

Commission 29: Stellar Spectra.

Sub-Commission 29*a*: Theory of Stellar Atmospheres.

A further recommendation, proposed by Pecker and heartily endorsed by the meeting, was that the program of future meetings of the Union contain enough free time—of the order of a day—for various working groups to have time for consultation. This was deemed especially important if, as hoped, the number of working groups and informal sub-commissions increases.

Second Meeting: 16 August 1958.

Present: Members of Commission 29 and Sub-Commissions 29*a* and 29*b*.

PRESIDENT: J. L. Greenstein.

SECRETARY: W. P. Bidelman.

As a first item of business, the *Draft Report* was accepted. Then followed consideration of the several items in the *Draft Report*, listed by the President for discussion (see page 454):

(1) The recommendations (see above) endorsed by the joint meeting of Commissions 10, 11, 12, 13, 29, and 36 were reviewed. The President also noted the recommendations already submitted to the Executive Committee concerning the transfer of the two existing Sub-Commissions of Commission 29 to other Commissions, Sub-Commission 29*a* on the 'Spectra of Variable Stars' to Commission 27 and Sub-Commission 29*b* on 'Molecular Bands in Stellar Spectra' to Commission 14. With regard to Sub-Commission 29*a*, it was felt by the members of this group that the desired co-operation between Commissions 27 and 29 could be more easily achieved by the proposed arrangement. It was made clear by Mrs Payne-Gaposchkin, the President of this Sub-Commission, however, that variable-star spectra studied for their own sake, rather than from the standpoint of variability, would still fall within the province of Commission 29, while discussions of a more general nature dealing with correlation of observing programs and the relation between spectroscopic characteristics and variation of light would be handled by the new Sub-Commission. With regard to Sub-Commission 29*b*, Swings, its President, recalled the origin of this group and the program that it has carried out. The aim of the new Sub-Commission would be limited to bringing together physicists and astronomers interested in molecular spectra of astronomical interest. After these explanations, the Commission endorsed the recommendations for transfer of the two Sub-Commissions.

(2) The desirability of bringing up to date and continuing the Perkins Observatory bibliography of spectroscopic observations of individual stars, with the aim of establishing at that Observatory an international center for the dissemination of such information, was emphasized by several persons. After discussion, a resolution requesting financial assistance from the I.A.U. to aid in this work was approved by the Commission and forwarded to the Finance Committee of the Union. This resolution read as follows (see Resolution no. 56).

Commission 29 requests a subvention from the Union of $2000 per year for a term of three years to assist in the preparation and maintenance of a complete bibliography of all spectroscopic observations of individual stars. The Perkins Observatory, Delaware, Ohio, has already begun such a bibliography, under the direction of Dr P. C. Keenan, but additional funds are needed to bring it up to date and to continue it in the future. The Perkins Observatory has indicated its willingness to act as a general information center for stellar spectroscopic work, and would, if aided by the Union, send desired bibliographical information concerning such work to interested parties. (Secretary's note: The Finance Committee and General Assembly approved a grant of $1500 per year for this project.)

Jaschek stated that a similar catalogue containing observations of southern stars had been begun at La Plata, and Mrs Mayall suggested that the Harvard card catalogue covering variable stars might be incorporated into the Perkins card file.

(3) Miss Roman stated, concerning MK spectral types for faint stars, that she has classified numerous stars in several selected areas which should be of use to those doing classification work using an objective prism. With reference to a new edition of the Yerkes *Spectral Atlas*, Morgan mentioned that, while no work along this line is currently under way, it might be practicable to issue a revision in a few years. It was pointed out that direct photographic copying of the existing *Atlas* prints is not particularly expensive, and could be recommended. A general discussion of various matters concerning spectral classification followed, in the course of which Bidelman emphasized the desirability of

setting up a Sub-Commission of Commission 29 to deal with all problems involving classification. This group could, as part of its duties, establish standard stars for southern hemisphere observers, a matter that has been previously considered by an informal working group of Commission 29; it should, however, also concern itself with bringing together and co-ordinating the activities of the numerous astronomers now working in the field. At the suggestion of Morgan, Bidelman proposed that this Sub-Commission be charged to deal with problems of *Stellar classification*, rather than merely with those of *spectral classification*, since necessarily it would also be concerned with the classification of stars by use of interference filter and other similar techniques. It was hoped that all of the present 'schools' of stellar classification could be represented on such a Sub-Commission. Upon the general agreement of the Commission as to the desirability of setting up such a group, the President recommended that the next President of Commission 29 set up a working group or Sub-Commission to deal with problems of stellar classification.

(4) The publication of a spectral atlas utilizing plates taken with a dispersion of about 40 Å/mm, as suggested by Thackeray, was deemed desirable, and Gratton expressed interest in carrying out this program, since many of the spectrograms needed are already available at Cordoba.

(5) It was suggested that photo-electric scanning could be utilized to provide the 'pseudo-tracings' desired by Miss Hoffleit. According to Aller, however, such photoelectric tracings should be altered, before publication, to resemble more closely those that would have been obtained using photographic techniques.

(6, 7) Nothing further was added on these points; their importance is evident.

(8) The problem of the publication of a spectrophotometric atlas of normal and peculiar stars of the highest accuracy was discussed at length; it is evident that the cost of publication of such an atlas would be prohibitive, if many stars are involved. It would appear more feasible to provide individual astronomers with a few high-accuracy tracings, rather than attempt to reproduce them generally. Bidelman pointed out that high-accuracy tracings are not required for identification purposes and for rough intensity work, and thought that a small number of tracings of somewhat lower accuracy could rather easily be made available by the larger observatories.

(9) The problem of the exchange of spectrograms and microphotometer tracings—often more feasible than the exchange of personnel—was extensively considered. It is evident that many astronomers would like an opportunity to avail themselves of the abundant plate material which, occasionally is not exhaustively utilized by those observatories at which it has been obtained. It was suggested by Miss Iwanowska that the exchange of such material should be arranged through Commission 29. It was further suggested that the Perkins Observatory information center might well serve also as a center for information concerning available spectroscopic material. At the suggestion of Deutsch, the President appointed Miss Iwanowska and A. Slettebak as a committee to investigate means of bringing about a more general exchange of spectrograms and other astronomical plate material.

At the last part of the meeting, four short scientific papers were presented:

E. K. Kharadze: Work on Be, Ae, and T Tauri Stars with the 70-cm Maksutov Telescope.

C. Jaschek: Recent Work on Peculiar and Metallic-Line Stars.

E. R. Mustel: A Spectrophotometric Investigation of Nova Herculis.

W. P. Bidelman: 3 Centauri, a Star Showing Strong Phosphorous Lines.

Third Meeting: 19 August 1958.

Present: Members of Commissions 27 and 29 and their Sub-Commissions.

PRESIDENT: Mrs C. H. Payne-Gaposchkin.

SECRETARY: W. P. Bidelman.

At the opening of the meeting, the President informed the group of the existence of a comprehensive bibliography of the observations of spectroscopic binary stars being prepared by Martynov and Korodnikov, now complete to 1947. The members of the two Commissions expressed their interest in this work. A formal motion was passed encouraging this project, and expressing the wish to see the bibliography published.

A statement was made by Vorontsov-Velyaminov concerning the present status of his extensive compilation listing all existing spectrograms of novae, a work in which he, in collaboration with several co-workers, has been engaged for some years. Some difficulty has been encountered in completing this compilation, but, encouraged by the interest of those present in its completion, Vorontsov-Velyaminov will endeavor to bring it into final form with the assistance of Mrs Payne-Gaposchkin and D. B. McLaughlin. The question of its publication was raised; it was agreed that this was not essential if those astronomers wishing to be informed of the spectroscopic material available on certain novae could be readily supplied with the desired information. It was suggested that after its completion this compilation could be transferred to the Perkins Observatory spectroscopic information center (see report of second meeting of Commission 29, page 471). For the immediate future, however, it will remain in the possession of Vorontsov-Velyaminov.

The President noted the memorandum of G. J. Odgers, who emphasized the desirability of simultaneous photometric and spectroscopic observations of β Canis Majoris stars and also of objects undergoing chromospheric eclipses. Deutsch pointed out that recent image-tube developments may soon make it possible for important spectroscopic work to be carried out on faint variable stars with relatively small telescopes.

Bidelman reiterated the willingness of the Sub-Commission on the Spectra of Variable Stars (now a Sub-Commission of Commission 27) to serve as a center for the dissemination of information on both the photometric and spectroscopic characteristics of variable stars (see *Trans. I.A.U.* **9**, 429, 1957). Spectroscopists wishing information on the photometric properties of various objects and variable-star investigators wishing information on spectra are invited to communicate with the President of the Sub-Commission, Mrs Payne-Gaposchkin, who will assist in the exchange of information between interested parties.

The meeting closed with the presentation of two short scientific papers:

D. H. McNAMARA: Spectroscopic Peculiarities of RZ Scuti.

G. BADALIAN: The Color Variations of T Tauri Stars.

Compte rendu de la Séance de la Sous-Commission 29b. 14 août 1958

PRÉSIDENT: P. Swings.

SECRÉTAIRES: K. Wurm et L. Houziaux.

EXAMEN DU DRAFT REPORT

(*a*) Le Président propose l'envoi d'une lettre au Père Junkes, lui exprimant la sympathie et la gratitude de la Sous-Commission et lui disant combien la préparation et la publication de l'Atlas des Spectres d'Oxydes se révéleront utiles. Adopté à l'unanimité des membres présents.

(*b*) Le Président résume le *Draft Report*. Les communications suivantes sont faites par des personnes assistant à la séance: J. L. Greenstein signale une étude des bandes de

ZrO dans l'étoile S, R Andromedae. W. P. Bidelman pense que les bandes de R Cygni attribuées à ZrF sont plus probablement dues à CuF. G. Mannino signale qu'il a effectué de nouvelles observations d'étoiles N dans la partie violette. Madame R. Herman annonce l'étude des bandes de Schumann-Runge, à haute température, de λ 1900 à λ 6000 Å. J. C. Pecker fait remarquer qu'un terme devrait être supprimé dans les fonctions de partition de C_2 et O_2, lors des calculs des abondances moléculaires théoriques.

(*c*) Le *Draft Report* est adopté.

AVENIR DE LA SOUS-COMMISSION

Le Président rappelle que la Sous-Commission avait initialement été constituée afin d'encourager la préparation de tables et atlas de spectres moléculaires intéressant les spectroscopistes stellaires. Ce travail est, en grande partie, accompli. D'autre part, dans les conditions actuelles, il paraît préférable de ne plus séparer les spectres moléculaires concernant les étoiles de ceux qui intéressent le soleil (disque, chromosphère, taches), les planètes, les comètes et la matière interstellaire. Le Président est donc d'avis que la Sous-Commission 29*b* pourrait être dissoute, quitte, éventuellement, à créer une Sous-Commission 14*b* intitulée 'Spectres moléculaires d'intérêt astronomique'. Cette question a été discutée avec Prof. B. Edlén, Président de la Commission 14.

K. Wurm demande si le Président veut séparer l'observation de bandes moléculaires dans les astres et les études en laboratoire; il se demande quelle commission s'occupera de la théorie des abondances moléculaires dans les atmosphères stellaires. Le Président répond que, selon lui, la Sous-Commission 14*b* établirait surtout la liaison avec les travaux de laboratoire. B. Edlén rappelle que la Commission 14 s'occupe des étalons de longueur d'onde et des tables de longueurs d'onde. Il ne verrait aucune objection à la constitution de 14*b*.

G. Herzberg se demande si la Sous-Commission 29*b* a le droit de se dissoudre de sa propre initiative. Il lui est répondu que les Sous-Commissions ont une vie essentiellement limitée, puisqu'elles s'occupent d'un problème spécifique. P. P. Dobronravin approuve la dissolution de la Sous-Commission. J. L. Greenstein estime que la Sous-Commission 14*b* devrait s'intéresser surtout aux travaux de laboratoire.

A l'unanimité des membres présents, la Sous-Commission 29*b* est dissoute.

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