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The task of the Chairman and Secretary of Commission 29, in preparing their report, would be complicated and thankless if they made it a strict point to avoid any reference to topics which fall within the province of other commissions or of sub-committees. Indeed, the field of spectroscopic parallaxes which belongs to Commission 24 would be excluded altogether. Yet, how can work on spectral classification be properly reviewed without reference to absolute magnitudes? The spectra of novae and variable stars (sub-committees of 29) would be prohibited, as well as those of the nuclei of planetary nebulae (Commission 34) or of photometric binaries (Commission 42). So would the molecular bands (sub-committee of 29). Of course, spectral intensities belong to Commission 36 and to a sub-committee of 14. To be sure, radial velocities (Commission 30) and observations in the range of radio frequencies (Commission 40) should be excluded. References to instruments belong to Commission 9, and the bearing of the spectroscopic observations upon the theoretical understanding of the stellar atmospheres should go to a sub-committee of 36.

What then remains the province of Commission 29? Numerous observers are still active in the ever-important field of spectral classification. A few descriptive papers, which essentially belong to Commission 29 (i.e. do not belong to any other), have been published. Yet, the President and Secretary of Commission 29 believe that their Report should not be confined within such narrow limits, and that it should endeavour to offer a general picture of the progress in the field of stellar spectroscopy in the course of the past three years, without worrying too much about possible overlapping or duplication.

It is hoped that such an attitude will not be construed as monopolizing, since the point of view of Commission 29 usually differs from that of other commissions.

No attempt at completeness has been made, since a detailed report would take volumes. The fact that certain items are missing may sometimes be due to the absence of an answer to our circular letter.

SPECTRAL CLASSIFICATION

Suggestions

1. The list of standard stars for spectral type, prepared by A. H. Joy and published in Vol. **7** of the *Transactions* (pp. 299–302), has proved most useful. Its extension to southern stars is imperative and it would be helpful to designate a sub-committee for this purpose. While the material available at present (for example, at the Lick Observatory) may be of great help, it is highly desirable that spectrograms be gathered at the Cordoba, Radcliffe and other observatories of the Southern Hemisphere in preparation for a list of southern standard stars.

2. J. A. Hynek suggests that a clearing house be established for composite spectra in the same sense that Princeton Observatory has served this purpose for eclipsing pairs and Yale for parallaxes. The Perkins Observatory might become this clearing house, and reprints of papers dealing with such objects should be sent to Dr Hynek. He submits the following definition of a 'composite spectrum' for consideration by the Commission:

The term 'composite spectrum' should be limited to those spectra that show the total characteristic elements and features of two or more distinct spectral subdivisions, and only to these cases. This excludes the so-called peculiar stars, the metallic-line A stars and stars with symbiotic spectra. That is, only spectra that can be demonstrated to occur by the actual superposition (as in the case of artificial composite spectra) of two standard spectral classes, or the superposition of a peculiar and a standard spectrum, or the superposition of two peculiar spectra, should be included in the definition. The ultimate test of a composite spectrum is, then, whether the observed composite spectrum can be reproduced by the actual combination at the telescope of two (or more) single stars of any given characteristics. It is understood for the most part that we shall be dealing with the superposition of two normal spectra.

As a part of this programme, Hynek intends to continue the production of artificial composite spectra of various differences in magnitude with appropriate microphotometer traces. One application will be the examination of spectral classes of close visual pairs, as well as of spectroscopic binaries. He is also interested in that large statistical group of stars that must exist between the recognized spectroscopic binaries on the one hand and the visual pairs on the other.

Recent Observational Work

The Yerkes system of classification has become more and more widely used. Nothing of real importance may be added to Morgan's statement published in Vol. **7**, p. 289. Most of the recent work has consisted of refinements and applications of the established principles.

1. *Observations with Slitless Spectrographs*

A considerable amount of observational data has been accumulated, especially at Harvard, Cleveland, Tonanzintla, Palomar, Leander McCormick, Arcetri, Uppsala, Stockholm, Abastumani, and Crimea.

Harvard College Observatory. Miss D. Hoffleit has published the spectra and absolute magnitudes of 500 A3–G2 stars. She has also reclassified approximately 2000 spectra of 1000 B8–A3 stars, most of them brighter than 6^m (visual), and obtained estimates of relative line-intensities of the lines characterizing peculiarities or absolute magnitude

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effects on 1000 of the plates. The objective prism plates had been obtained with the 11-inch Draper telescope in the north and the 13-inch Boyden in the south. The dispersions are about 50 A./mm. Some 200 of the stars are not 'normal' main sequence stars and a few are spectrum variables. When the spectrograph for the southern 60-inch is in operation it is proposed to investigate the spectrum variables in detail. In the reductions of spectroscopic absolute magnitudes Miss Hoffleit found the I.B.M. punch-card techniques valuable, at least for normal stars. She calls attention to the dually classified metallic line stars: from the strength of K relative to the Balmer lines, such stars would be classified as A, while F would be obtained from lines near the G-band. Fifty such objects are found among the 500 A–G stars.

On objective prism plates with a dispersion of 95 A./mm. at H_γ Miss M. E. Walther found forty-one peculiar A stars and eight metallic line stars; the total number of A stars having spectra characterized by abnormal intensities of the lines of chromium, silicon, europium or strontium is 13% of the A stars between magnitudes 5·5 and 9·5, at low galactic latitudes.

Case School Observatory (J. J. Nassau and collaborators). The Schmidt telescope of the Warner and Swasey Observatory is used with a 4° objective prism. The dispersion at H_γ is 283 A./mm.

Stars of spectral classes O5–B0, B1 *Ia*–B1 III, B2 *Ia*–B2 II, B3 *Ia*–B3 II, B5 *Ia*, B5 *Ib*, B8 *Ia*, B8 *Ib*, B9 *Ia*, A0 I and A2 I, show marked similarities on objective prism spectra. Such stars are classed as OB. The appearance of weak hydrogen and helium lines furnishes the primary criterion for inclusion in this class.

A survey for OB stars to visual magnitude of about 10·0 in the Milky Way has been completed. The belt extends from longitude 333° through zero to 201° and is 12° wide. The work was undertaken jointly by J. J. Nassau and W W Morgan. The survey is now being extended to include supergiants from F2 to M. During the progress of this work a number of peculiar stars have been noted, among them there is a group showing an abnormally strong line at λ4150 which is observed mainly in giant K0–K5 stars.

A new band in the photographic infra-red (from λ6800 to λ8800) has been observed at λ7900. This band has not been identified and appears mostly in long period variable M stars. In the same spectral region criteria for the classification of carbon stars have been established.

An effort to derive luminosity criteria for M stars in the same spectral region produced negative results. However, in the spectral region λλ5300–6800 a recent study indicates that it is possible to separate dwarfs from giants and supergiants. The appearance of the TiO bands when compared with giants, the great strength of the D lines and the presence of the CaH-band at λ6385 are the principal characteristics of the dwarf M spectra of the region.

Tonanzintla Observatory (Erro, Haro, L. Münch, Terrazas). Among numerous results obtained with the 24–30-inch Schmidt and a 4° objective prism the following ones may be singled out:

By G. HARO. The discovery of fifty-eight objects with H_α emission in M31 and of ninety-seven similar ones in M33; of a concentration of emission line stars in the region of the Orion nebula, 113 stars showing bright H_α in an area of 2·5 square degrees centred on the Trapezium; the observation of faint spectra showing H_α in emission in the obscuring clouds of Ophiuchus and Scorpius and in a region in Sagittarius.

By L. MÜNCH. The classification of numerous spectra on the Yerkes system. A spectral survey of B and other high-luminosity stars down to $m = 11{\cdot}5$ in regions of galactic longitudes 180–235°, and 305–360° (limiting magnitude 13·3 on 103*a*O), for a 90-minute exposure, width of spectra 0·3 mm.; interstellar λ4430 is easily detected in distant objects).

Leander McCormick Observatory (Vyssotsky). Since the last report, Vyssotsky has assigned spectral classes to some 1800 stars which had remained unclassified in the Yale AG zones −2° to −10°; these will be published by Yale together with newly derived proper motions. Of the 37,068 faint stars previously classified at McCormick for the Yale zones, 7460 have been published in Vols. **19–22** of the Yale *Transactions*. The remaining 29,608 classifications are for stars in the zones +15° to +20° and +30° to +50°; these are to be published by Rutherfurd Observatory together with their magnitude observations.

At the request of Bergedorf Observatory spectral types were determined for 1490 faint stars of the new fundamental catalogue in preparation by Dr Larink.

The spectrophotometric search for dwarf M stars has been continued at irregular intervals. To date 356 of these stars have been found, of which more than a half are new.

Arcetri Astrophysical Observatory (A. Colacevich, M. G. Fracastoro, M. Hack). Fracastoro has measured the equivalent widths of H_γ on slitless spectra of various A and B stars, and obtained spectroscopic parallaxes (following the work of Gunther and Petrie and Maunsell) which are in good agreement with the trigonometric values. Miss M. Hack is studying cepheids with slitless spectra, and has begun a search for luminosity criteria in B stars.

Astronomical Observatory, Uppsala (C. Schalén, T. Adolfsson, B. Westerlund). C. Schalén has published spectral types for 1430 stars (to about 11th mag.) in a region at +20° gal. lat. between $19^h\ 30^m$ and 0^h, and for 1175 stars in a region at +40° gal. lat. between 10^h and 16^h. T. Adolfsson has determined the spectral types for 1500 stars to the 12th *pg* mag. in bright and dark areas in Taurus; colours have been measured on the spectrograms; the catalogue gives the line-depths for H_γ, H_δ, and K, and the drop in intensity at the G band and at the CN band. B. Westerlund has studied early-type stars in the visual and in the ultra-violet regions, including the continuous hydrogen absorption.

Stockholm Observatory. At the Stockholm Observatory spectral classes and absolute magnitudes are determined by spectrophotometric analysis of objective prism spectra of low dispersion. J. Ramberg is investigating selected regions, each covering about 10 square degrees, in and around the Milky Way. The regions are situated in two bands at right angles to the galactic circle, one about the gal. long. 69° (in Lacerta and Cepheus), the other about the gal. long. 147° (in Auriga). Spherical co-ordinates, photographic and photovisual magnitudes, spectral types and spectrophotometric data for estimating the absolute magnitudes are determined to phot. mag. 13·5. It is planned to extend the investigation in the future to the southern sky with a band about the gal. long. 250° (in Vela). T. Elvius is doing similar work in Kapteyn's Selected Areas. Results have been published for twelve Northern Areas. G. Larsson-Leander is carrying out similar work for selected open clusters, employing a slitless spectrograph in the prime focus of the 40-inch reflector. The open clusters on the programme are NGC 659, 957, 1528, 1605, 1647, 1664, 2192, 6802, 6940, and IC 1434.

Abastumani and Crimean Observatories. The luminosity determinations of early and late type stars to $9^m{\cdot}0$ in Kapteyn Areas is in progress at the Abastumani Astrophysical Observatory. One list containing several hundred stars was published recently by Mrs N. Kalandadze. The second list of A-type stars by Miss R. Bartaja is now in the Press.

The spectral classification of faint stars (limiting magnitude $12^m{\cdot}0$–$12^m{\cdot}5$) was started at the Crimean Astrophysical Observatory in the autumn of 1950. The instrument used is the 400 mm. astrograph with a 410 mm. prism (250 A./mm.).

2. *Observations with Slit Spectrographs*

A large amount of classification work has been done at Yerkes, Lick, Victoria, Perkins, and various other observatories.

Yerkes Observatory. Morgan has reported to Commission 33 on his application of the spectroscopic parallax method to problems in stellar astronomy. Morgan and Keenan have completed a calibration in temperature and luminosity for the two-dimensional Yerkes classification system; spectrograms having a large range in dispersion may be used. Morgan and Miss N. Roman have published revised standards for supergiants

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on the system of the Yerkes spectral *Atlas*. With his collaborators, Morgan has taken many spectrograms for the determination of the spectroscopic parallaxes of all stars brighter than 6·5, north of $-20°$; all B stars brighter than 10, north of $-20°$ (including objects discovered in the Case survey), and supergiants from A to M. The Yerkes system of spectral classification is being extended to all northern stars brighter than 5·5 visual magnitude.

A re-examination of the problem of spectral classification with varying dispersion was made by Morgan (paper presented at the University of Michigan symposium, June 1950). Data were given for the classification of 'natural groups' for five different dispersions ranging from 100 A./mm. to 1200 A./mm. at H_δ.

Over this range in dispersion, the kinds of stars identifiable change considerably; for example, near the higher limit of dispersion all spectral types and luminosity classes for the O–B5 stars can be recognized. On passing to lower dispersion, however, a point is reached where stars in the above spectral range can be classified only by the intensity of the hydrogen lines and by the presence of the lines of helium, which are observable only near the position of maximum intensity. Similar effects are noted in other parts of the HR diagram. Examples of the results of changes in dispersion are present in the Henry Draper Catalogue, where stars of class O are commonly classified as of class B among the fainter stars.

W P Bidelman has obtained the spectral types and luminosity classes for the accessible stars of types A3 and later contained in Miss Payne's c-star Catalogue of 1930. He is at present working on the spectral classification of: the brighter members of the Hyades, Coma, and Praesepe clusters; the early A-type stars in the regions of both galactic poles; the Be stars near the Perseus double cluster; the long-period variables of periods less than 250 days and those of unknown spectral type (in the visual region, brighter than 10th visual magnitude at maximum); the carbon and S-type stars.

Miss N. Roman has studied some characteristics of the spectra of F-, G-, and K-type stars. She concludes that a large percentage of the stars which have been classed as early G-type giants are probably binaries with composite spectra. Slettebak has discovered a number of new bright metallic-line stars satisfying the criteria stated by Morgan, Roman and Eggen (K line considerably weaker than in average A star; no possibility of explaining the spectrum in terms of one or two normal stars; no similarity to the 'shell' type, not of the 'Si', 'Sr' or 'Eu' groups). There are now nineteen such stars brighter than the 5th magnitude, for δ greater than $-20°$ About 10% of all stars classified as A0–A5 on objective prism plates will turn out to be metallic-line stars.

L. Rosino (of Bologna) discovered and studied variables of the RV Tauri and yellow semi-regular types. This led to the detection of the CH star, AC Her, in which the G band is very strong at spectral phases from G2 to K0.

Kuiper's observations of sixty stars with his infra-red spectrometer and lead sulphide cell (resolving power 80) revealed many strong infra-red features, some of them identified (Paschen and Brackett series in A stars), others unexplained (especially in M and N stars).

Because of the great importance of the Yerkes *Atlas*, this Commission expresses the hope that more copies of the old edition will be made available, until a new series is completed. If the new edition should become too voluminous, an abridged version containing only the more usual types may be desirable.

Lick Observatory. In the Catalogue of radial velocities by Moore and Paddock (edited by N. U. Mayall), spectra and luminosity classes are given for 820 stars of types F–M.

Weaver has examined the spectra of several standard stars of the Yerkes *Atlas* with both moderate and high dispersion in order to determine whether or not these stars show any anomalies not detectable on the low-dispersion spectra used for the Yerkes *Atlas*. He reports on some apparent spectral anomalies found in a few of the *Atlas* standard stars of types FV and GV Differences of two kinds are found: in the general appearance of the spectra as a whole, and in the relative intensities of specific spectral lines. He remarks that all type-V stars do not form a homogeneous group, as was pointed out independently by Eggen on the basis of colours and absolute magnitudes.

Weaver has gathered the necessary observational material for (1) an accurate spectral classification of the stars in five of the nearest galactic clusters (75 A./mm.), and (2) for a detailed examination (75 A./mm. and 38 A./mm.) of the spectral classes and spectral peculiarities of stars having trigonometric parallaxes larger than 0"·05. Both high and low velocity objects have been included among these near-by stars. An important secondary part of the programme on the clusters has involved an examination of the spectral peculiarities (in the sense of line intensity anomalies) of the cluster stars.

The observational material for the spectral classification of the clusters is now about 95% complete. Tests show that an extremely consistent system of spectral classification can be achieved.

The programme on the spectral peculiarities of cluster stars has gone forward with the classification programme. It is apparent that the clusters offer a unique opportunity for a systematic study of line intensity anomalies among the average stars. Among the earlier type stars these peculiarities are very numerous. Fully one-third of the cluster stars in the appropriate absolute magnitude ranges are, for example, metallic-line stars. Some of these are, of course, only incipient cases; others are very advanced cases. The range in degree of metallicism is very great; some hints on the nature of the 'metallic-line mechanism' are given by the cluster stars. However, even a preliminary report on these metallic-line stars would be premature.

Dominion Astrophysical Observatory. R. M. Petrie and C. D. Maunsell have determined the absolute magnitudes for 169 early A stars (B8–A3) on the basis of the intensity of the H_γ absorption. Petrie plans to study the relation of hydrogen-line absorption to absolute magnitude in the B stars. An extensive programme, containing members of moving clusters and visual binaries, is being followed. The observing is about half completed, the measurement of the spectra is making good progress. It is planned, furthermore, to define the Victoria classification of B-type spectra so that it rests upon measured line intensities.

In view of the increasingly wide use of the Yerkes system of classification Petrie has raised the question whether such a fundamental matter should be based entirely upon eyepiece examination of low-dispersion spectra. Weaver's work serves to emphasize the expected result that some loss of accuracy is to be expected with the use of low dispersion. There can be no objection to proposing classification criteria for low dispersion work, indeed that is a necessity, but it may be fairly claimed that the defining stars and line ratios should be adopted from studies of spectrograms made with a dispersion of the order of 20 A./mm. In this way high accuracy may be obtained in the primary classification and the extension to low dispersion would reveal which features have been lost and which preserved.

Perkins Observatory. Most of the work by P C. Keenan is concerned with late-type stars, and is described in the report of the sub-committee on molecular bands. At our request, Dr Keenan has prepared a summary of the bands most useful for the marginal detection of molecules in stellar spectra photographed with small dispersion. This summary is annexed.

Leander McCormick Observatory. The luminosities and spectral subclasses of 681 K stars were determined by Miss Edith M. Janssen. The material consisted of short dispersion slit spectrograms obtained for Dr F K. Edmondson's work at the McDonald Observatory.

Other investigations. It is well known that the number of visible lines in the Balmer series is related to the absolute magnitude of the early-type stars. Linear formulae for this criterion have been given by G. R. Miczaika (Heidelberg) for four spectral intervals between B0 and A8, and for the F0–F5 stars by Udo Becker. The standardization of these formulae may be made fairly accurate using early-type stars in moving and open clusters. Miczaika used the Pleiades for the late B stars (B6–B8) in which the last Balmer line varies between H16 and H20. However, the possibility that

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the Balmer series may behave in a different way in different clusters should not be overlooked.

For his most recent calibration Miczaika divides the B range in three parts: O9·5–B1, B2–B3, B5–B8, and uses Yerkes spectral types and luminosities. Applying this calibration to 115 bright B stars he finds that his luminosity criterion (number of visible Balmer lines) is equivalent to Morgan's criteria.

S. Günther has measured the hydrogen absorption at the Balmer limit of the twelve brightest Pleiades. It is possible to obtain spectral classifications of high accuracy on this basis; the corresponding H.R. diagram has a remarkably clear appearance.

In La Plata, Gratton plans to determine spectral types of physical members of southern clusters (Magellanic clouds).

A. D. Thackeray (Radcliffe Observatory, Pretoria) has made an appeal for renewed interest in the problem of the mean variations of line intensities with spectral type and absolute magnitude, a problem which is apt to be forgotten in the modern method of studying curves of growth in a few selected stars. He has also discussed the inconsistencies of the various criteria for spectral type and absolute magnitude from G5 to K5. A single criterion (e.g. intensity of a particular line) may fix a spectral type with an accuracy of a twentieth part of a spectral class, but inconsistencies of the order of a few tenths may occur when different criteria are used.

Two theoretical papers related to classification have been published by S. Ueno and by Y. Fujita. Ueno computes the number of atoms effective in producing stellar absorption lines by taking into account the continuous absorption of negative hydrogen ions; he compares his results with those of Russell. The calculations show that H_γ and λ4481 Mg II reach their maximum in class A1, in agreement with the observations, whereas previous calculations had placed the intensity maximum at A7 (main sequence) and F0 (giants). Y. Fujita suggests a new classification of late-type stars: three sequences would start near G4; the oxygen series (Ox0, Ox1, Ox2, ...), the carbon series (C0, C1, C2, ...) and the nitrogen series (N0, N1, N2, ...). Such considerations may be helpful in discussions on peculiar late-type stars.

DESCRIPTIVE DATA ON THE DIFFERENT SPECTRAL TYPES

WR and O Stars; Novae

In the course of their spectrophotometric work on O stars at Edinburgh, Greaves, E. A. Baker, and R. Wilson have disclosed the presence of faint diffuse lines, by combining large numbers of spectra, hence reducing the errors from photographic grain. For example, the He II lines starting from the fifth quantum level are shown by combining the results for thirty-nine spectra of stars of type Oe5.

Many papers on Wolf-Rayet stars have been published in the course of the last three years. The region $\lambda\lambda$6600–8900 has been described by Swings and Jose; difficulties and uncertainties in the identifications are due to the incompleteness of the laboratory data on the spectra of C II–IV, N II–V and O II–VI in the infra-red. J. Sahade (Cordoba) is observing numerous southern WR stars; γ2 Velorum, HD 151932, HD 153919, HD 164270, HD 113904, HD 136488, HD 92740, BS 4908. Neubauer and Aller have studied HD 45166, and state that the emission spectrum appears to be what would be observed if an atmosphere having the same abundances of H and He and the same relative abundances of He, C, N and O as in 10 Lacertae or τ Scorpii were excited to a sufficiently high temperature. Chalonge and collaborators are studying HD 184738, HD 211853 and HD 214419.

There is as yet no explanation for the subdivision into WN and WC sequences. Greenstein has found that the ratio N/C in stellar interiors should be high, say, near 30, on the basis of the present nuclear cross-sections of the carbon cycle. This ratio is in apparent disagreement with observation, except in the WN stars. Of course, the atmosphere and the energy-producing core of the stars may not be mixed at all. Swings

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has found additional cases of Wolf-Rayet nuclei of planetary nebulae containing carbon and nitrogen. Temperatures of W-nuclei of nebulae have been determined by Wurm and Page using a new type of application of the Zanstra method, developed by Wurm, based on the ratio of the nebular emission in the Balmer continuum to the nuclear spectrum at the same wave-length, extremely high temperatures are found (for NGC 6720, the temperature of the nucleus is higher than 120,000°).

Important papers on the physical processes in W stars have been published by H. Zanstra and J. Weenen. They have discussed the stratification into successive shells, in each of which the recombination luminosity has been assumed. The most outstanding result is an abundance ratio of carbon to helium $N_C/N_{He}=0{\cdot}37$ on the average for three WC stars, which is more than fifty times the abundance ratio occurring in other celestial objects. Similarly, the abundance ratio of nitrogen to helium in the WN stars would be abnormally high. As stated by Zanstra and Weenen, it may be objected that mechanisms other than recombinations may be operative. Indeed, recent observations of HD 193576 by G. Münch show that this is the case. Selectivities such as were found in the *Of* stars by Swings and Struve appear in the N III and N IV lines at certain phases of HD 193576, hence invalidating the methods of derivation of excitation temperatures based on a pure recombination mechanism.

S. B. Pikelner has developed a theory for the resistance to the motion of atoms in the atmospheres of Wolf-Rayet stars, and applied it to the motions of ions of C, O and N under the action of selective radiation pressure.

Numerous WR stars are binaries, some of them of the eclipsing type. As was shown by O. C. Wilson, it is the photometric and spectroscopic investigation of such binaries that has given us the most valuable information on WR stars, although the picture is still very vague. The two most thoroughly discussed cases are HD 193576 (V 444 Cygni) and CQ Cephei. Only the most recent papers on these stars will be considered here.

The photo-electric observations have such an importance for the interpretation of the spectroscopic data that we shall summarize them briefly here. Observations by Hiltner and by Kron and Gordon have shown that the shape of the primary minimum is practically the same over the wave-length interval $\lambda\lambda$ 3300–7200, an observational fact which confirmed the hypothesis of a large, semi-transparent electron envelope surrounding the WR object, as suggested by Kopal and Mrs Shapley. The photo-electric observations by Kron and Gordon of V 444 Cygni lead to the following picture of this binary. The W component consists of a small opaque core, of effective temperature 80,000°, surrounded by a contiguous, thick envelope that is luminous and semi-transparent, and whose luminosity is a function of wave-length. This structure is enclosed in a second, much larger envelope, which is composed effectively of free electrons. The evidence indicates that the electron envelope must be a relatively thin, hollow shell, probably detached from the inner structure. The optical properties of the electron envelope are independent of λ.

However, the photo-electric observations of CQ Cephei by Hiltner seem to contradict Kron and Gordon's explanation for the site of the emission bands. Hiltner's measures were made on He II λ 4686. This monochromatic photometry technique gave a curve showing two maxima and two minima. The emission is strongest at either conjunction and weaker at either elongation. This intensity increase of λ 4686 during both eclipses observed in CQ Cephei does not necessarily apply to V 444, since the ordinary light curves for the two stars indicate that their geometry must differ considerably.

Münch's extensive spectroscopic observations of V 444 reveal that the WR features experience two kinds of intensity variations through the orbital period: non-periodic changes, best shown by the displaced absorption of He I λ 3889, and also periodic changes in the absorption and emission lines. Especially remarkable are: (1) the appearance at primary minimum of an absorption component to the ^3S–^3P multiplet of N IV, not present outside eclipses; (2) the strengthening of the absorption components of the NV lines at $\lambda\lambda$ 4603 and 4619 at primary minimum and their complete disappearance at secondary; (3) the selectivities shown by the intensity changes of the different multiplets of N III.

The absorption lines of the brighter component (O star) of the system during primary minimum undergo a noticeable change in structure, which has been accounted for in terms of the scattering of its radiation by free electrons in the WR envelopes. By combining the information provided by the photometric study of the light curve with the spectroscopic data, Münch has attempted to construct a working model for a WR envelope, the main characteristics of which are that the state of ionization increases outwards and that the motions are radially decelerated. The observations provide new evidence confirming the plausibility of explaining the shifts of emission lines as a result of self-absorption processes in the WR envelope. In his investigation of the WR binary HD 190918, O. C. Wilson had also reached the conclusion that the red shift of He II λ4686 is to be sought in a process occurring within the WN atmosphere. Decelerated motions are realized if matter leaves the nucleus by the action of an impulsive force: part of the kinetic energy supplied is used for support of the matter against the gravity of the nucleus, and the rest is dissipated into heat of atomic motion by turbulence. A model for a WR envelope based on a similar fundamental idea has been recently constructed by R. N. Thomas.

The absence of an 'occultation effect' which has long been recognized as a serious difficulty of the expanding-envelope hypothesis disappears if, as suggested by Münch, the broadening of the lines is due to electron scattering, turbulence and collisional broadening.

The main conclusions—decelerated motions, ionization increasing outward, broadening not due to ejection velocities—are revolutionary. They would require a complete revision of our views on WR stars. However, serious difficulties are also encountered in this hypothesis, and the question is by no means settled.

A sub-commission being in charge of the spectra of novae, we shall mention only the main results of McLaughlin's investigation, viz. the permanence of absorption-line systems and components. Supposed cases of splitting and merging of absorption have, for the most part, failed to stand up under critical examination. Wide diffuse lines appear to change to multiple sharp components, but most of the components were probably present as separate but diffuse blended lines, which later became resolved through sharpening of the lines. Stratton has taken the first steps in the matter of organizing an atlas of nova spectra.

Normal B and A Stars, including Supergiants

G. and P. Shajn have measured differential displacements of lines in the spectra of white supergiants (β Orionis, 67 Ophiuchi, α Cygni) and suggested an explanation for such differential motions, more or less along the line of McCrea's work.

The lines of different ions bring out very slight but probably real deviations from the laboratory wave-lengths; these deviations are probably due to the very small systematic errors in the laboratory wave-lengths.

The problem of central intensities of the strongest absorption lines in stellar spectra is discussed in a paper which is in the Press. It is found from the observational data that the central intensity: (*a*) increases with the increasing temperature, at least within B0–F5, (*b*) increases with the increasing wave-length in the spectrum; (*c*) does not depend on the kind of element or the oscillator strength of the line in question, (*d*) increases slightly with the increasing luminosity of the early type stars. There is only some qualitative but not in the least quantitative agreement between the observed behaviour of central intensities of strong absorption lines and the computations based on the hypothesis of origin of the lines by the mechanism of true absorption. An analogy was emphasized between the problem of emission lines and the problem of central intensity of absorption lines.

Unsöld has shown that for main-sequence stars agreement between theory and observations is obtained if departures from 'greyness' are taken into account. But in supergiants 'the H_α emission is certainly beyond the range of a theory of static planeparallel atmospheres' Unsöld believes that the difference between the Rosseland and the Chandrasekhar averages of the absorption coefficient has not been correctly handled by all theoretical workers.

The influence of the dispersion used on the equivalent width and on the curve of growth is discussed by Miss T. Fofanov; with the dispersion 10 A./mm. the continuous solar spectrum may be drawn without sensible systematic error to get fair total absorptions of lines and an accurate curve of growth.

Swings has described the spectrum of the A supergiant 3 Puppis (known also as *l* Puppis). Hynek has examined the O I lines and the Paschen series in the spectra of supergiants, and has found that all these lines present a wide variety of aspects.

Struve has suggested that the enormously extended atmospheres of supergiants, like α Cygni, may be caused by a vast field of prominences; similar views have been expressed by Menzel.

The collisional theory of the Stark effect in B stars elaborated by Mrs Krogdahl has been discussed in various papers. The small displacements of He I found by Miss A. Underhill in γ Pegasi favour the collisional theory; however, the observed displacements appear smaller than the theory predicts, this being possibly due to stratification or blending effects. Miss E. van Dien has examined the Stark effect of the higher Balmer lines. Struve and H. Chun have studied the higher members of the 2^3P^0–n^3D series of He I in the B3 supergiant 55 Cygni. They measured members to $n=21$, and found that the broadening is noticeable for the higher members, even in such a supergiant. Miss Underhill doubts the applicability of Mrs Krogdahl's computations because 'the adiabatic hypothesis will not be a good approximation' The anomalous strength of λ4470 and the weakness of $\lambda\lambda$5876, 6678 in main-sequence stars may be due 'to abnormal interactions of an He I atom with a charged particle' She has also prepared for publication a new discussion of the Stark effect of hydrogen. Unsöld is also somewhat critical. He believes that some 'recent papers on the Stark effect. . .do not lead beyond the range of the Holtsmark theory as supplemented by Spitzer' His own treatment, in 1943, of the He lines and their forbidden components has remained little known outside Germany because of war-time conditions.

Merrill has made precise measurements of the displacements of certain He I lines. D_3 frequently exhibits a longward displacement with respect to the lines of other elements; such displacements are particularly pronounced in *c* stars. The dependence of the series classification is not obvious. The triplet lines, as well as the ^1P–^1D lines, have fairly large positive residuals, whereas the ^1S–^1P lines have small residuals. The observed displacements correspond to some extent to those caused by electric fields. But the Stark effect seems not to offer a complete explanation; for example, theory does not predict a longward shift for D_3.

A. Slettebak has determined the rotational velocity for 123 stars comprising the brighter O, B2–B5 and B2*e* stars. His method was similar to that used by Struve and Elvey, and an attempt was made to take into account the effects of limb darkening, gravity darkening, and differential rotation on the computed line contours. Values of $v \sin i$ in excess of 400 km./sec. were found for several stars in each of the three groups studied. The Be stars have the most rapid axial rotation observed for any class of stars, averaging nearly 400 km./sec. at the equator; their mean rotational velocity was found to be at least 150 km./sec. larger than the mean rotational velocity for the corresponding group of B stars.

Observers should make an effort towards a description of the visual, and especially the photographic infra-red region of the B and A stars.

In this paragraph we combine the Be, P Cygni and combination (symbiotic) spectra.

Slettebak's work on axial rotation confirmed the previous result that among the Be stars the shell stars have the largest rotational velocities and the pole-on stars the smallest, which is interpreted as an inclination effect. The observed rotation in the Be stars is somewhat lower than would be expected under the assumption that these stars may be represented by Roche models at the point of rotational instability. It is suggested that radiation pressure and turbulence may be responsible for the discrepancy. Rapid rotation appears to be principally confined to stars on or slightly above the main sequence.

The Mount Wilson Catalogue of Be stars by Merrill and Miss Burwell is a goldmine for spectroscopists, especially those interested in peculiar objects. The lists of 1933, 1943, 1949 and 1950 contain a total of over 1600 objects. The H_α survey of the southern sky is now continued by Henize at the Lamont-Hussey Observatory, Bloemfontein, with the $10\frac{1}{2}$-inch refractor and objective prism which were previously used on Mount Wilson.

Merrill has played the leading role in this field of astronomy. Papers were published on the spectra of HD 187399, 190073, 218393, and of the symbiotic objects R Aqr, BF Cyg, CI Cyg, RW Hya and AG Peg. Among stars now under investigation are Pleione, β Mon A, 48 Lib, XX Oph, MWC 374, HD 31648, 33232, 45910, 183656. Many of these investigations are based on coudé spectrograms of high dispersion, providing excellent wave-lengths, identifications and velocities. HD 187399 resembles β Lyrae in certain respects: the binary orbit is enveloped by a cloud of incandescent hydrogen whose outer absorbing layers are rapidly expanding. In the shell star HD 218393 the profiles and displacements of various hydrogen lines present complex and changing patterns. Various members of the Balmer series frequently yield quite different displacements on the same plate. The term 'Balmer progression' is suggested to indicate the trend of measured radial velocity from successive lines of the series. Lines of ionized metals vary in intensity; their displacements usually correspond to those of the hydrogen lines toward the limit of the series. In the peculiar Be star HD 45910 the Balmer lines have been studied in more detail than was possible in previous observations, thanks to excellent Coudé spectrograms. The changes in structure and displacement from plate to plate are very striking. On most plates the lines are clearly double with interesting changes in the displacements and relative intensities of the components from line to line along the series. It is possible that the lines toward the limit of the series represent a higher atmospheric level than do the lines of longer wave-length. On this hypothesis there is an acceleration of the atoms toward the centre of the star, although the motion is outward.

At the present time the term 'shell spectrum' is reserved to a small group of stars, chiefly of types B and A, having narrow absorption lines. Merrill has described a typical shell spectrum and given a list of the shell stars.

Miss Underhill has published an investigation of Pleione, and nearly completed similar studies for ζ Tauri, 48 Librae, 14 Comae, and 9 Sagittae. She finds that the shells are quite dense, being confined to an equatorial ring. Excitation and ionization may be described by $T = 8000°$ and $\log p_e = 3{\cdot}0$.

McLaughlin has continued his studies of correlated changes of emission-line structure and displacements of absorption and emission lines in Be spectrum variables. A study of β^1 Monocerotis has been completed. This star has strong 'V/R' variation and also has a well-developed shell absorption spectrum. Except for the binary ϕ Persei, the union of these two characteristics is unique among the brighter members of the class. The displacements of absorption and emission in β^1 Monocerotis are correlated with the V/R variations in the same manner as in other V/R variables (e.g. 25 Orionis, δ Aquarii).

Changes of bright lines of hydrogen, Fe II and [Fe II] have been followed by McLaughlin in the spectra of Boss 1985 and VV Cephei. The latter especially shows complicated changes, involving V/R variation of the hydrogen emission, appearance of positively displaced 'satellite' absorption lines of hydrogen, appearance and disappearance of Ti II 'shell' absorption lines, and variations of relative intensities of permitted and forbidden Fe II emission.

The spectrum of Boss 1985 at its 1947 outburst has been described by P. Swings; the [Ni II] lines are particularly strong, forbidden lines of singly ionized metals other than [Fe II] and [Ni II] have been found in B 1985 and similar objects, especially [Cr II].

Slettebak has studied the correlation of the O I emissions at $\lambda 8446$ with the emission strength of H_α and H_β. His results support Bowen's suggestion of resonance excitation by Lyβ as the reason why O I $\lambda 8446$ goes into emission more readily than O I $\lambda 7774$. In the famous Ae star 17 Leporis, Slettebak discovered an absorption band due to TiO at $\lambda 7054$. This shows that 17 Leporis has a composite spectrum, the companion being approximately of type M2. Eggen has already found that the colour of 17 Leporis is very red. Struve has recently described his Mount Wilson Coudé spectrograms of this star.

Various shell stars have been described by Bidelman (HR 7415 and the brighter component of 1 Del), Gregory (γ Cas), V F Haase (γ Cas), Gascoigne (λ Pav), Sahade (λ Pav) or are under investigation (Chalonge and collaborators). Various southern emission-line stars are on the observing programmes of Sahade and Platzeck in Cordoba and of Gratton in La Plata. Gaviola is working on the spectrum of η Carinae. Detailed information on this object, especially in the ultra-violet, visual and infra-red regions not covered by the Lick spectrograms, are eagerly awaited by all astronomers interested in bright-line stars.

C. S. Beals has continued his investigations of P Cygni stars. He has studied in detail HD 190073, and compiled the essential data on all known P Cygni stars (wave-lengths, line intensities and profiles, displacements). Some material on the interpretation of line profiles in terms of atmospheric motions is included, and the relationship of the early-type emission-line stars to the rest of the stellar sequences is discussed. Chalonge and his collaborators have measured the Balmer discontinuity in HD 190073 and found it to be large, but not so large as found earlier by Struve. Since everything else in this star is variable, perhaps this feature too is not always the same.

A. D. Thackeray (Pretoria) has discovered nebulous envelopes around three stars whose spectra have been classified as of P Cygni type at Harvard. The available dispersion at the Radcliffe Observatory is at present inadequate to study the fine structure of the hydrogen emission lines in these stars; the new Cassegrain spectrograph will remedy this situation.

The essential need at the present time, as far as observations go, is for work in the visual and especially the photographic infra-red region. Swings has shown that numerous strong forbidden lines of metals may be expected in the region $\lambda\lambda 6500$–9000, especially lines of [Fe II], [Ni II] and [Fe I]. One of the first stars whose infra-red spectrum should be taken is the [Fe II] star HD 45677, which does not seem to have a late-type companion.

The combination (symbiotic) spectra have continued to be the object of numerous investigations, the most important being those by Merrill. Using high dispersion spectrograms of Z Andromedae and other high excitation objects, Merrill was able to obtain more accurate wave-lengths than the calculated values for a few lines of [Fe V] and [Fe VII]. Tcheng Mao-Lin at St Michel has also obtained good spectrograms of Z Andromedae and AG Pegasi.

R. E. Wilson found that the non-variable star HD 4174 has a spectrum combining the features of the spectrum of a normal M2 giant and bright lines of H (to H_{18}), [O III] and [Ne III] (but not $\lambda 4686$ He II). The only other apparently non-variable star with a combination spectrum of high excitation is BD $+67°$ 922. H. W Babcock has found that HD 4174 has a varying magnetic field (probably irregular), and that H_β also varies in intensity and character. It would be interesting to observe the ultra-violet brightness of these stars, in order to find whether or not their ultra-violet high-excitation 'component' is really non-variable.

Sanford has continued his high-dispersion investigation of TC Br. The absorption-line spectrum of type *g*M 3 indicates a variable radial velocity, semi-amplitude 21 km./sec., period 230·5*d*, systemic velocity −29 km./sec. The bright lines reveal also a systematic velocity of −29 km./sec., but do not show any certain velocity variation. Neither orbital motion nor pulsation seems adequate to explain a velocity variation for the *g*M 3 source and a lack of variation for the emission-line source. The same object has been studied by Brahde in Stockholm (observations of the coronal lines, probable presence of Mg II in absorption), by Gratton and Kruger in Arcetri (who state that the 'classical' model of a binary and a nebula is sufficient to interpret the main spectral features), and by the French observers (Mlle Bloch, Dufay, Fehrenbach and Tcheng Mao-Lin) at St Michel.

Sahade has several southern symbiotic stars on his observing programme. From numerous notes published at Harvard, it is evident that many southern objects are of the symbiotic type: their observation should be fruitful.

Several theoretical investigations on emission-line objects have been published recently. In his thesis, Weenen tries to explain the observations of a typical star like 48 Librae. His work consists essentially in refining Kosirev's treatment of the extended atmospheres by taking into account the absorption of hydrogen and the electron scattering. The spectrum of Weenen's theoretical model is strongly distorted, giving rise to a large colour index in the visual region, but not to Kosirev's excess of radiation in the ultra-violet which, on the contrary, is very weak. The model does not compare well with 48 Librae, but may be useful in other cases.

Important theoretical papers have been published by V V Sobolev on the contours of spectral lines produced by the moving atmospheres of stars, and on the radiation of stellar envelopes in the absence of radiative equilibrium. A research monograph by the same author on the moving shells of stars, concerns itself with all types of bright line objects (Be's, nebulae, novae, stars of late classes). Other valuable theoretical investigations on Be stars are due to S. Miyamoto and to W Unno. The former treats in detail the three-level and the four-level problems for Be atmospheres, while Unno discusses the equation of transfer for the Lyman continuum radiation in circumstellar atmospheres.

Martin Johnson has studied theoretically the adjustments within the shells and asymmetric ejecta from Z And, ζ Aur, β Lyr, ρ Cas, and γ Cas. He applies McCrea's equations, and Grotrian's formula for the time required by an envelope to adjust itself to a change in the exciting radiation.

Stars of the β Cephei Type

Heard has removed most of the evidence supporting the inclusion of eight stars in the β Cephei group. Struve has found that the properties of the β Cephei stars can be interpreted in terms of a model involving a normal B-type star possessing a quiescent atmosphere and a diametrically opposite region of fairly large turbulence. He suggests that the origin of this phenomenon may be the existence of a very small and dense companion revolving around the primary not far from the latter's surface. This working hypothesis is of necessity crude and it violates certain previous conclusions that had been regarded as fairly well established. Nevertheless, there are many reasons to believe that these earlier conclusions are partly in error. Hence, the new hypothesis, though not as yet fully tested, provides an interesting subject for further research. M. Walker found photo-electrically that 16 Lacertae and 48ν Eridani are genuine members of this group, and Struve has embarked upon a high-dispersion study of several of them (β CMa, 12 Lac, ν Eri) with the Mount Wilson Coudé.

Eclipsing Binaries

These stars have been the object of a large number of investigations by Struve, Hiltner, Sahade, Gratton, Münch, Joy, Herbig, Thackeray, Chalonge and others. Since a special commission is devoted to this question, only the principal outcome of Struve's work is mentioned here: it is the recognition that all close binaries are associated with gaseous streams of a nature resembling whirlpools. These streams produce emission and absorption lines which are superposed over the normal stellar spectra of the two components. Especially interesting are the distortions of the line profiles found by Struve and Hardie in U Cephei and by McNamara in U Sagittae. The evidence suggests that there is really no such thing as a 'normal' binary. Presumably the interaction of the components is always large when the separation is small. This may have far-reaching consequences in other fields. For example, can we rely upon the mass ratios, and hence the individual masses, of eclipsing and spectroscopic variables? The question arises whether nebulous masses exist in wider pairs. They would escape recognition by ordinary visual or photographic methods. An attempt by Struve to place the slit of the spectrograph between the companions of Castor gave no emission lines, but this test should be repeated not only when the seeing is good enough, but when the optical parts have been especially freed of scattered light. In the case of Antares, the emission of [Fe II] is concentrated in a small disk surrounding the faint B-type companion.

ζ Aurigae and the somewhat analogous star 32 Cygni have been studied extensively. The thorough investigations by O. C. Wilson had indicated that turbulence probably increases with height in the atmosphere. Qualitative comparison of spectrograms of the eclipses in 1934, 1937, 1939–40, 1942 and 1947–48 made by McLaughlin shows approximate uniformity of extent of the atmospheres, except in 1937 when it was more extensive than normal. A permanent asymmetry exists: absorption is stronger during ingress than during egress. M. G. Fracastoro has also commented on the early appearance of atmospheric lines in the ultra-violet spectrum of ζ Aurigae. lines due mostly to Fe I, Ti II and Ca II appeared sixty days before the beginning of the 1947–48 eclipse.

H. L. Welsh has measured the intensities of the chromospheric H and K lines of Ca II in the spectrum of ζ Aurigae for the 1947–48 eclipse. He has also evaluated and studied earlier data, showing that of the seven cases where information is available, three showed an abnormally large extent of Ca II atmosphere.

While the spectral changes due to atmospheric eclipse in 32 Cygni are similar to those of ζ Aurigae, McLaughlin showed that the extent of the atmosphere of 32 Cygni is considerably greater than that of ζ Aurigae. Colacevich is at present studying McDonald spectrograms of the same star.

Peculiar A Stars

Three topics may be singled out for their special interest: the hydrogen-poor stars, the stars with magnetic fields, and the metallic-line stars. Two of the former have been investigated with some detail: υ Sagittarii and HD 30353.

Recent contributions to our knowledge of the peculiar helium star υ Sgr are due to Greenstein, Merrill, Greenstein and Merrill, Greenstein and Adams, McLaughlin and Bidelman. Wave-lengths and intensities were measured by Greenstein, Adams and Merrill at high dispersion. Difficulties arose in the identification work, especially in the region from H_α to λ8800, on account of the lack of laboratory data. A curve of growth for ionized metals was constructed by Greenstein; it permitted the determination of empirical relative f-values for lines of metals and ionized gases. These prove useful in analysis of late B and A stars. The variability and P Cygni features of the spectrum have also been studied. Bidelman has examined also the displaced absorption lines whereas McLaughlin has studied the hydrogen-absorption satellites on a series of plates taken over an interval of twenty-eight years, but especially during 1949 and 1950. Periods of great activity (strong satellites) last for a few years, and alternate with periods of quiescence (weak satellites).

The hydrogen-poor A5 star HD 30353 studied by Bidelman is somewhat similar to υ Sgr, but has a slightly lower temperature.

Far-reaching results have been obtained by H. W Babcock on the magnetic fields of stars. At the present time, general magnetic fields have been observed in more than twenty-five of the peculiar stars and spectrum variables of types A and early F, including

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HD 125248, α^2 CVn, HD 10783, HD 153882, HD 188041, HR 710, 78 Vir, β CrB, and γ Equ. In nearly all, the field is found to vary; in the first four stars listed the polarity is reversed periodically. The pronounced variations in intensity of certain lines in some of these stars, not explicable by ionization theory, are only partially accounted for by Zeeman broadening of saturated absorption lines; zonal concentration of elements in the atmosphere as a result of electromagnetic processes must be important.

From three years' work on the magnetically oscillating star HD 125248, Babcock concludes that HD 125248 is in fact an oscillator, observed pole-on, in which the varying magnetic field is coupled with material pulsations of a special type (perhaps according to the theory of M. Schwarzschild), the observations could not be interpreted according to the 'oblique rotator' theory, in which the dipole axis makes an angle i' with the axis of rotation, while the latter, fixed in direction, has an obliquity i to the line of sight. In the atmosphere of a magnetic oscillator, two effects are of particular interest: (1) velocity of drift of ions in the crossed magnetic and electric fields, and (2) possible acceleration of charged particles to very high energies in the extreme outer atmosphere. The theory of these effects is still rudimentary.

Babcock is observing several other magnetically variable stars for determination of period, amplitude, and associated effects, considerable diversity is found.

Now that HD 125248 has been identified as a *bona fide* magnetic oscillator, it becomes plausible to envisage that stars of this type are the sources of cosmic rays. The stellar magnetic effects observed by Babcock give also substance to electromagnetic theories of cosmogony, such as those of K. Birkeland and H. Alfvén, that were formerly speculative.

The continuous spectra of three A stars of the metallic-line group (τ UMa, 15 UMa, ζ UMa ft) have been compared by D. Chalonge and co-workers at St Michel with several normal stars of Morgan's luminosity class V (ζ UMa br, 78 UMa, 38 Lyr, ϵ Cep). Of special interest is the difference of the Balmer discontinuity in these two groups.

Miczaika (Heidelberg) has investigated the metallic line star 15f UMa. The line intensities in the spectrum variable ι Cas have also been measured at Heidelberg: the intensities of the H lines remain constant; the intensities of the characteristic variable lines mentioned by Deutsch were measured over the whole period.

F, G, K, and M Stars

Adams has worked on high-dispersion spectra of α Orionis. Variations in the character of the lines certainly occur but are not conspicuous. The ground-level lines of Mn, Cr, Ti, etc., show some interesting features. They are complex with a sharp violet component which indicates no variation in radial velocity. The velocity agrees with that from the potassium lines near λ7800. The great majority of the lines are diffuse and unsymmetrical with indications of maxima on the violet side. These lines indicate a variable radial velocity such as Spencer Jones and Sanford have noted. Their period of 5·8 years fits the observations roughly, but with large occasional discrepancies far beyond the errors of measurement. The light curve of the star shows a similar erratic behaviour.

Adams suggests the desirability of investigating supergiant red stars, such as α Orionis, and Cepheids, with high dispersion, since low dispersion is quite inadequate to show most of the details. Adams wonders whether sufficient attention has been given to the possibility of the existence of very large 'sunspots' on a star like α Orionis.

Miczaika is also studying the behaviour of the spectrum of α Orionis on average dispersion spectrograms covering the last three-year interval.

P. F. Shajn has reported on a systematic study of the shift of certain spectral lines in the spectrum of Mira Ceti. The lines with excitation potential less than 0·20 are systematically shifted to the violet relative to the lines with higher excitation potentials. The effect is similar to that found by Adams, but almost twice as large as his. Possibly there is a general increase of this shift with the decrease in excitation potential, rather than an abrupt change. G. A. Shajn has shown that the exciting radiation which

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produced the H emission in the long-period variables has no relation to the usual photospheric radiation. In 1949–50 G. Shajn and V Hase continued their work on the isotopes and presented evidence in favour of the presence of numerous bands of heavy molecules $C^{13}N^{14}$ in the spectra of N-type stars.

At present the measurements of the intensities of the bands $C^{12}C^{12}$, $C^{13}C^{12}$, $C^{12}N^{14}$, $C^{13}N^{14}$ are in progress. The purpose is to determine the ratio $C^{13}:C^{12}$. In the spectral region of N and M stars that is more or less free from molecular bands the intensities of atomic lines are nearly the same, excepting hydrogen and sodium. The greatest difference is the absence of hydrogen absorption lines in the spectra of N stars. Attention is paid to the problem of sodium in M and N stars.

J. G. Phillips has examined the rotational intensity distribution in M2, M3 and M6 stars and found unexpectedly low rotational temperatures of the order of 1000° K., from a comparison with laboratory furnace spectra he concluded that the rotational temperatures must be lower than 1900° C. Further work in this direction is desirable. O. J. Lee points out the following facts based on the Dearborn Observatory survey of red stars: the relative scarceness of distant M5–M9 giants; the astounding nest of N stars just east of Orion; the large proportion of M5–M9 stars which have relatively much light in the violet. J. Landi Dessy (Cordoba) is engaged in a spectroscopic programme including several long-period variables (L2 Puppis, T Centauri, W Hydrae, R Centauri, etc.) and red stars such as CD $-74°$ 1067 and CD $-62°$ 466. Thackeray has reported hydrogen emission in the three long-period variables in 47 Tucanae.

In a study of Coudé spectrograms of K stars, Gratton finds a line at λ4339·27 whose intensity is very different in different stars of the same spectral class and luminosity; this wave-length is very near λ4339·287 Dγ. This coincidence may be accidental and should be discussed carefully. If the identification is confirmed, it would provide the first evidence for deuterium in stars.

Joy and R. E. Wilson have published a catalogue of 445 stars whose spectra have bright H and K lines of Ca II. In general, the supergiants and giants show the H3 and K3 reversals, whereas the subgiants and main-sequence stars have fairly sharp, single emission lines. Variations in intensity are suspected in many stars. The Ca II emission seldom occurs in stars hotter than G5.

Joy has stressed the fact that the strongest emissions of Ca II and H appear mainly in the late-type stars of lowest luminosity. especially those with spectra M4 or later. More than seventy bright-line dwarfs are now known. A thoroughly convincing explanation for the appearance of emission lines in such small stars with low temperatures and high densities is yet lacking. In addition, many dwarfs with similar spectra have been found among the T Tauri variables and the stars involved within the Taurus dark clouds.

A characteristic common to both the *d*Me stars and the Taurus bright-line stars is a tendency to sudden flares (Luyten's flare star!) which produce in a few minutes of time a manifold increase in brightness, and at the same time a most remarkable veiling of the spectrum by an overlying continuous spectrum corresponding to a hot star (Joy). Similar flares in brightness and spectrum have actually been observed among the Me dwarfs with large proper motion as well as the Taurus stars.

From his photometric observations, Kron concluded that the non-uniformity of illumination of certain late-type dwarf stars is in the form of small areas that are brighter or dimmer than the average surface brightness. The bright H and K lines probably originate in the small areas. As for the flares observed in stars such as BD $+20°$ 2465 and L 726–8, they probably originate in the small areas. Comparison with the solar activity associated with sunspots is attractive.

Thackeray observed variations in the intensity of the emission lines of the spectrum of Proxima (*d*Me) (now recognized as a flare star), and tentatively attributed these variations to short-lived flares.

In several colloquia in the U.S.A. during the autumn of 1950, Unsöld 'suggested that patches with line emission (bright faculae approaching the character of flares) or late-type dwarfs might allow the observational detection of rotation. The emission lines would exhibit variations whose quasi-periods might be found using Chree's method of superposed days.

Wildt found that the region $\lambda < 3300$ of the flare-star $+20°$ 2465 and of the other *d*Me star YY Gem reveals outstanding Fe II emission lines belonging to low-excitation multiplets, such as were also found by Herzberg in α Herculis (M 5) and α Scorpii (M 1), and also by Swings and Struve in B 1985 and WY Gem. Wildt stresses the remarkable parallelism in emission characteristics between dwarfs and supergiants of type M. Acting upon the advice of A. Unsöld, Struve undertook a systematic survey of YY Gem in order to record changes in the intensities of the bright lines. There are conspicuous variations from season to season, and small changes even from one 20-hour cycle to the next. Moreover, H and Ca II sometimes behave differently. We are undoubtedly concerned with a kind of activity that resembles the solar activity. The consequences, in terms of radio-emission, cosmic rays, etc., may still further enhance the significance of these and related studies.

A few peculiar stars of types F, G, K, and M have been studied. Merrill has discovered a rapidly rotating G-type star, HD 117555, showing bright H_α; the equatorial speed is approximately 75 km./sec.

The peculiar object ρ Cas, whose changes in recent years have already been investigated by Thackeray, W S. Tai, Greenstein, Bidelman, and others, is still being studied by Bidelman, Swensson and others.

Bidelman is at present working on the spectra of a group of K-type stars which appear to be cases of intermediate carbon abundance. These stars show the (0, 0) C_2 band and the CH band in unusual strength, though much weaker than in the typical carbon stars. Typical members of this class are HR 774 and HR 5058; ζ Capricorni shows the (0, 0) band of C_2 and thus is a somewhat hotter member of the class. In addition, these stars show extremely strong resonance lines of Ba II. Bidelman hopes to derive relative carbon abundances for a considerable number of late-type stars by means of molecular spectra, in the next few years.

Bidelman plans to publish in the near future a catalogue of all emission-line stars of types F and later, together with a bibliography giving references to all spectroscopic observations of these stars. He wishes to encourage all observers of these objects to send to him any unpublished material which they would care to have incorporated in this catalogue and bibliography.

S, R and N Stars

According to Bidelman, the star GP Orionis, long considered as a carbon star is actually an S star. The absorption and emission spectra of the long-period variable χ Cygni (Me + Se) have been studied by Merrill on high dispersion spectra and by Tcheng Mao-Lin and Fujita on medium dispersion spectra. On the basis of the TiO bands, Fujita found a rotational temperature of 2200° at light maximum. This value is attained by assuming that the Hutchinson formulae for the probabilities of the vibrational transitions is valid in the case of TiO. While the Hutchinson formulae which have been established for a symmetric molecule may still give reasonably good results in the case of TiO, this matter should be further discussed.

Since 1948 McKellar has been carrying out a series of spectrographic observations of the N-type long-period variable RS Cygni. The purpose of the investigation is primarily to study the emission-line spectrum. Among the results so far obtained is the establishment of the presence of the pair of Fe I lines at $\lambda\lambda$ 4202 and 4307 and the conclusion that, as regards variation in intensity with phase, they behave much as in spectra of M-type long-period variables.

Theoretical (Wurm, Miss W Lehman, Fujita) as well as observational (Keenan, Morgan, Bidelman) work has been devoted to the relative abundances of H, C, N and O in late-type stars. The observations of Keenan and Morgan seem to indicate variations in the carbon content of the atmospheres of carbon stars, although the matter is still

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somewhat obscure. Fujita treated the molecular equilibrium problem in various cases of abundances intermediate between those adopted by Rosenfeld, Cambresier and by Russell to explain the oxygen and carbon branches. Wurm thinks that the abundances of H, N, and C are of the same order in the R stars. Accordingly, Miss W Lehmann (Hamburg) has calculated the dissociation equilibrium of a mixture of H_2, C_2, N_2, CH, NH, CN, H, C, N in conditions of similar abundances of H, C and N; she has solved the corresponding system of quadratic equations by approximations.

Determinations of rotational temperatures based on CN (especially the red system), CH, C_2, ZrO and TiO would help greatly in elucidating the problems of the unusual, and even the normal, carbon and S stars. Such determinations are now possible with the use of Coudé spectrograms of high resolution.

Work by Swings, McKellar and K. N. Rao on the late-carbon stars is in progress. New intense ultra-violet bands have been observed in late N stars, and clues as to the identification of the unidentified bands in the blue-green, λ4050 and ultra-violet regions have been found.

Variable Stars

Other commissions and a special sub-committee being concerned primarily with variable stars, only a few results which are of importance in general stellar spectroscopy are given here.

Merrill has made a survey of the recurrent changes in stellar spectra, the periods varying from about 0·2*d* (β Cephei stars) to decades (recurring novae); for the combination spectra and the shell stars, the periods are of the order of 800 and 4000 days respectively.

Several important investigations have been based on high-dispersion spectrograms of bright cepheids. Adams finds that η Aql and ζ Gem show marked changes in spectrum with phase, the lines at minimum of light becoming broad, diffuse and unsymmetrical (especially in η Aql). The results of a high-dispersion investigation of η Aquilae have been published by M. Schwarzschild, B. Schwarzschild and Adams. Forty-three lines of Fe I and II were examined on twenty Coudé spectrograms (dispersion 2·9 A./mm.) covering the entire pulsation cycle. The radial velocity variations of these lines were found to indicate that the selected lines of Fe I and II arise essentially from the same atmospheric layers. From the depth measurements of these lines the variations of the excitation temperature and electron pressure were determined.

The equivalent widths determined for a few Fe lines at mid-descending branch, showed that the H/metal ratio in η Aql can differ from that in the Sun by only a small factor. The curve of growth at the same phase gave turbulent velocities much smaller than the velocities determined from line profiles, which may possibly indicate the existence of a fast turbulence with very large elements.

From the above data, the density variation was computed. The comparison of this variation with that of the velocity suggests that possibly in the atmosphere of η Aql the kinetic temperature increases greatly with height and that in the highest layers the pulsation has the character of a simple progressive wave.

Another investigation of Coudé spectrograms of η Aql and ζ Gem by J. Grandjean (Liége) is nearing completion. Radial velocity measurements of hundreds of lines reveal slight, but progressive, variations with intensity; the relations with excitation potential and height in the chromosphere are also discussed.

A. Van Hoof and R. Deurinck (Louvain) investigated microphotometer tracings of high dispersion spectrograms of η Aquilae obtained by Adams, and found that the asymmetry of the line profiles varies in agreement with the predictions of the pulsation theory for a coefficient of limb darkening $u = 0{\cdot}6$. They followed the variation of the turbulence with the phase, and pointed out that the ratio of the velocity dr/dt along the radius of the star to the observed radial velocity depends on the intensity of the line concerned.

Special attention is directed to the work of Sanford on W Virginis, and of Sanford and of Struve and Blaauw on RR Lyrae. The splitting of the absorption lines on the ascending

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branch of the light curve and the appearance of H in emission in RR Lyrae show that the phenomena in the atmospheres of some Cepheids are more complicated than was thought previously.

Herbig has made an extensive series of spectroscopic observations of the irregular variable RW Aurigae with the aim of studying in as much detail as possible a typical T Tauri star. Supplementary observations of colour and of energy distribution in the continuous spectrum have been made as well. The variations in light, energy distribution, radial velocity, and line character make it evident that we are dealing with an object of considerable complexity.

In the winter of 1948–49, the earlier work of Struve and Greenstein and of Herbig on the spectra of the variables in the Orion nebula was extended to fainter stars. Emission lines of the type found in T Tauri stars appeared in eleven objects, although no stars with strong bright lines of the ionized metals, as are frequently found in dark nebulae, were discovered. Haro's objective-prism work on bright-line stars in the Orion nebula has been reported in the section on classification problems.

The spectrum of the nebulosity, discovered by Burnham and by Baade, closely surrounding T Tauri has been observed by Herbig. The spectrum of the nebulosity consists entirely of emission lines of H, [O II], and [S II], no reflected light from T Tauri being seen although the nebulosity all lies within 8″ of the star. The excitation of this spectrum can hardly be due to the same primary mechanism operating in gaseous nebulae since the spectral type of T Tauri is *d*G5.

The outer nebulosity at T Tauri (Hind's Variable Nebula = NGC 1555) is now (1950–51) a fairly easy visual object again, almost a century after its discovery. Its spectrum is a duplicate of that of T Tauri, both as regards energy distribution and bright and dark lines. There seems, accordingly, to be a significant difference in physical constitution between the inner and outer nebulosities.

Two additional objects have been observed with spectra very similar to that of the close nebulosity at T Tauri. They are faint (16–17 mag.) semi-stellar nebulous objects located in a dark nebula in Orion. The associated stars are relatively much fainter than in the case of T Tauri since the emission line spectrum can be observed without serious interference from the weak continua which are present. As at T Tauri, the lines of *H*, [*S* II], [O I], and [O II] are very strong but many weaker lines can be seen as well; these have been identified with *Ca* II, [*Fe* II], [O III], and [*Ne* III]. The large range in excitation energy is remarkable. Since the stars involved in these objects have $M_v \sim +8$ to $+9$, corresponding to a late-type main sequence star, the source of energy for the production of the emission spectra cannot be an ordinary blue star. In fact, the continuous spectra are not those of high-temperature stars, so that, as at T Tauri, the source of the excitation is a subject for speculation.

Other spectroscopic studies by Herbig include an investigation of the ultra-violet spectra of the T Tauri stars, a study of the spectrum of the T Tauri-like object BD −6° 1253 and the associated nebulosity, and a survey of the spectra of twenty faint variables in five bright diffuse nebulae. The spectra of the so-called RW Aurigae stars are also under investigation.

The spectrum of R Coronae Borealis was extensively observed by Herbig during the deep minimum of 1948–49, in which the visual magnitude fell from mag. 6·0 to 14·0. No change was noted in the spectrum or radial velocity until the star reached mag. 10·0, when weak emission began to appear in the Ca II lines. As the star continued to fade, this emission strengthened and many more lines appeared. The D lines of Na I, H and K of Ca II, and low-level lines of Ti II and Sc II were present in great strength, but no H emission was found. This agrees with the apparent low abundance of H in R CrB, a fact which had previously been inferred from the weakness of the Balmer lines in the absorption spectrum near maximum. Many other problems arose from the study of this fascinating spectrum. Observations during the rise to maximum indicate that the same general changes took place, in reverse order, as the star brightened.

These observations indicate the importance of further observations of the spectra of

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the R CrB stars both at maximum and minimum light. To this end, a systematic survey of the spectra of all accessible stars of this type has been started at Lick with slit spectrographs giving dispersions of 75 and 130 A./mm. Plates have thus far been secured for ten certain members of the group and of two doubtful members. In addition, systematic observations of R CrB itself at maximum light are being made at Lick with the Mills three-prism spectrograph (dispersion 10 A./mm.). The radial velocities obtained during the 1949–50 season confirm the velocity variation found by McLaughlin and by Berman, and show that it is not entirely periodic, although there is a tendency for the velocity curve to exhibit waves of length 50–80 days with an amplitude of about 8 km./sec. Correlation of this variation with the small light fluctuations known to take place near maximum light would be desirable.

General Problems

Models of Stellar Atmospheres; Curves of Growth, Abundances, Turbulence

Purely theoretical investigations such as those by Chandrasekhar, Huang, Wrubel, and others on turbulence or curves of growth will not be reviewed here since they belong to the Commission on spectrophotometry Only a few applications will be listed, they are mostly due to J L. Greenstein, L. H. Aller, Miss A. Underhill, K. O. Wright, O. Struve, A. Unsöld and W Buscombe.

Greenstein has made a survey of the detailed changes in the line spectra of the F stars of various luminosities using curves of growth. This survey has served as a basis for the study of a metallic-line A star. Deviations from the elementary theory of ionization have been applied to the metallic-line stars. Greenstein is at present engaged in a similar but larger survey of luminosity effects in the G5 stars using 3 A./mm. Mount Wilson plates. Eight stars, high and low velocity objects, ranging from bright giant to subdwarf, are being studied. Abundance effects, and in particular pressure effects, will be studied.

Aller has investigated many early-type stars. These objects, in which the stellar absorption coefficient is predictable in detail from theory, provide abundances for the light elements H, He, C, N, O, Ne, etc., which are of interest in connection with the stellar energy generation problem. Aller has computed models for several atmospheres (10 Lacertae, γ Pegasi). He has studied supergiants and main sequence B stars, normal, subdwarf, metallic and peculiar A stars. In the case of γ Peg, Aller proceeded by the curve of growth technique, and by the calculation of theoretical intensities of selected lines of H, C, N, O with the aid of a model atmosphere. In general, the relative abundances which he obtains agree with those in planetary nebulae or in the Earth's crust. In collaboration with Sanford and Chamberlin, Aller studied two A-type subdwarfs, HD 19445 (A4sp) and HD 140283 (A5sp), the comparison star being 95 Leo (A4s). Using the curve of growth they found that the subdwarfs had a lower ionization temperature (6500°) and electron pressure (60) than the normal A star ($T=8400°$, Pe = 100). However, this question is being re-examined on the basis of a study of the narrow Balmer lines following the method of the stellar atmospheres, which takes into account the rapid variation of excitation with depth in the atmosphere.

Wellman is investigating the curves of growth of ξ Lyra A, 17 Com, ρ Cas, and ξ Aur (K-comp.).

Miss A. Underhill has made thorough calculations of models for high temperature atmospheres, including O5. From the intensities and profiles of lines in some B-type stars, and using her model atmospheres, she has derived the relative abundances of various elements and the shape of the line absorption coefficient. She also proved that the observed spectral variation of the continuous spectrum of α Lyrae from λ4040 to λ9870 can be predicted satisfactorily from a model atmosphere in which the effective temperature is 10,080°, the electron pressure p_e is 10^4, and the opacity is given by neutral H atoms and H^- ions.

Keenan and Hynek have studied the behaviour of the infra-red lines of O I in fifty-six

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stars. The relative abundance H/O has been estimated for five stars for which curves of growth are available. They found approximately one oxygen atom for 1000 hydrogen atoms.

The relative theoretical strengths of the $^1D_2$–$^3P_2$ and $^1D_2$–$^3P_1$ transitions in O III and Ne V have recently been calculated by S. Obi to be 2·90 and 2·79 respectively.

Miss McDonald (Michigan) has undertaken a theoretical study of the structure of the atmospheres of B-type stars. The problem is complicated by extreme departures of the stellar material from greyness. Preliminary results indicate that the Chandrasekhar mean gives results much closer to the correct mean absorption coefficient than does the Rosseland mean, in agreement with the findings of Miss Underhill and in contradiction with the conclusion of Unsöld.

Extending the work of Struve and Wurm on the theory of the excitation of He I absorption lines in a field of diluted radiation, Wellmann has calculated the transition probabilities b_n for He I levels up to quantum number $n=4$. In this way better b_n-values for the lower He I levels are obtained, which in turn lead to a relation between the emission intensity and the number of atoms producing a line. Using this relation, the properties of the shell surrounding γ Cass have been determined, a similar study of the spectrum of P Cygni is under way.

Cook (Princeton) has begun a detailed integration of the structure of an A-star atmosphere. For a star of high luminosity, only absorption by hydrogen atoms need be considered, since H^- absorption and electron scattering are both negligible.

O. Struve has started an investigation of the chemical abundances of the elements in several stars. He is especially concerned with the properties of the two components of Capella, with α Cygni and with ϵ Aurigae. These three stars present interesting problems related to the study of their curves of growth. Clearly, we have reached some sort of impasse in our study of curves of growth by conventional methods. What is needed now is not so much a refinement of the existing theory, as the introduction of some fundamentally new idea—just as the concept of turbulence was in 1934. It is difficult to predict what form this suggested extension will take: it may come through the recognition of changes in turbulence with height, or it may involve new types of motion—under the influence of magnetic fields, for example. It is encouraging to learn that Unsöld is planning to extend his classical work on τ Sco to other 'normal' dwarfs and giants, and that even now a study of 55 Cyg is in progress at Kiel.

Y Fujita has used the curve of growth method to determine the relative abundances of various elements in Z And, α Boo, R CBr, δ Cep, and α Sco. In Z And and α Sco the abundance of oxygen was estimated high. In R CBr carbon was found to be more abundant than hydrogen, while δ Cep showed a comparatively high abundance of nitrogen.

G. Shajn has re-examined the question of the cores of the hydrogen lines in the spectra of early-type stars. The conception that the central part of the broad hydrogen lines in spectra of the ordinary early-type stars is due to atoms in the highest atmospheric layers, and the wings to atoms in the reversing layer, leads to a peculiar shape of the profile of H lines characterized by the presence of a central core. This hypothesis finds support in spectrophotometric and spectroscopic observations. Perhaps one may consider as an extreme case the analogous phenomenon in the cores of H lines in stars with shells. Stellar rotation explains to a great extent the large difference in the observed profile of H lines in spectra of stars of the same absolute magnitude.

The observational results on turbulence phenomena are of considerable importance. In the case of η Aql, M. Schwarzschild found that the turbulent velocity obtained from the curve of growth is 4 km./sec., while the line profiles give 12 km./sec. Since the larger velocity is also required to support the atmosphere, it follows that the turbulent elements are large compared with the thickness of the atmosphere. From their investigation of the spectrum of η Aurigae 1946–48, K. O. Wright and Miss van Dien conclude that the turbulent velocity decreases with increasing potential. In ζ Aurigae, O. C. Wilson found that the turbulence seems to increase with height in the atmosphere. W Buscombe

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has investigated the main sequence A star, γ Gem, and the A supergiant, α Cyg. He finds for the turbulent velocity:

From curve of growth:

	In γ Gem	4 ± 1 km./sec.
	In α Cyg	13 ± 2 km./sec.

From profiles:

	In γ Gem	14 ± 2 km./sec.
	In α Cyg	29 ± 2 km./sec.

These results may be compared with those of Struve and Unsöld in their interpretation of the peculiar phenomenon of macro-turbulence in δ CMa.

The recent theoretical developments, especially by Huang, have a direct bearing on all these observations.

Spectroscopic Comparison of the High-Velocity and Low-Velocity Stars

Many attempts have been made to discover spectroscopic differences between Baade's populations I and II in the various spectral classes. Most investigators have been concerned with the discrete atomic or molecular spectra, although W Becker has envisaged rather the intensity distributions in the continuous spectra. High dispersion appears favourable to a detection of differences, but it is imperative to follow precise photometric techniques, and especially to draw the continuous background with accuracy. The comparisons should always be made between stars having rigorously the same spectral type. Actually, one may wonder whether a sharp separation between the two velocity groups may be made; it would seem probable that high- and low-velocity stars may actually be found in either population type, only their relative numbers being different.

Most observers have examined individual stars selected in the two groups on the basis of their velocities. Miss N. Roman proceeded differently. She examined ninety-four stars, giants and dwarfs, of the late F and early G types brighter than 5·5 mag. No star earlier than F5 was considered, since broadening of the star lines by rotation makes it difficult or impossible to detect small differences between the two groups. Some stars were observed to have systematically weaker lines than others of the same spectral type and luminosity class. On this basis, two groups of stars can be distinguished. An examination of the velocity distribution of the two groups shows definite differences. The velocities of the stars with weaker lines have a larger dispersion than those of the stars with stronger lines; the conventional 'high velocity' stars occur only in the weak-line group. The two types of stars are about equally numerous among the bright northern stars. Stars with velocities less than 70 km./sec. are found in both groups.

M. and B. Schwarzschild have studied high-dispersion spectrograms of nine F dwarfs, three of which have high velocities, and three others low velocities. Depths, equivalent widths and profiles were measured. No difference was found between the two velocity groups, with the following exceptions:

(1) The intensity ratio CH/Fe I is greater in high-velocity dwarfs, leading to an abundance ratio C/Fe, 2·5 times higher in high-velocity dwarfs than in low-velocity dwarfs.

(2) A difference seems to appear (although this is not certain) in the equivalent widths of the Fe I lines, indicating that possibly the abundance ratio H/Fe I is slightly larger (say, by a factor of 2) in the high-velocity dwarfs, as compared with the low-velocity dwarfs.

G. R. Miczaika (Heidelberg) found no difference between the O, B and A stars in the two velocity groups. He also compared seven normal and six high-velocity KO giants. No appreciable difference was found for the atomic lines; however, the intensity of CH was greater and that of CN lower in the high-velocity stars, in agreement with Morgan's previous results. This weakening of CN in high-velocity giants is being measured at present by Keenan and Keller as part of a programme of spectral classification of the high-velocity stars. As mentioned earlier, Greenstein is studying high- and low-velocity G5 stars. Gratton is investigating a few selected K giants in which he measured about 3000 lines: so far the main differences discovered refer to molecular lines.

Laboratory and Instrumental Matters

While great progress has been made in the measurement and analysis of atomic and molecular spectra of astronomical interest, and in the theoretical and experimental determinations of intensities, a tremendous amount of spectroscopic work remains to be done. It is gratifying to notice a revival in spectroscopic interest on the part of many physicists. The Joint Commission for Spectroscopy established by the I.A.U. and the I.U.P.A.P convened in Cambridge, England, in September 1950. Plans were made toward a closer co-operation between astrophysicists and laboratory spectroscopists. A general report by P Swings surveyed the wide field of still unexplained astronomical topics requiring laboratory data.

The astronomical equipment which is now at the disposal of the stellar spectroscopists has increased greatly in the course of the last three years, and additional progress is imminent. Among new instruments we may mention: the new Coudé grating spectrograph at McDonald (dispersions: 4·8, 8·7, 18·2 and 36·3 A./mm.), the prime focus and cassegrain instruments at Radcliffe (Pretoria), a three-prism slit spectrograph on the Mount Stromlo (Canberra) reflector, quartz and glass spectrographs on the 32-inch reflector in Eva Peron, etc. New reflectors at present under construction (120-inch of Lick, 74-inch of Mount Stromlo, etc.) will, within a few years, add to their efficient spectrographic equipment. Other auxiliary instruments such as the integrating exposure meters, automatic guiding devices, Hiltner's monochromatic photo-electric photometer at the camera of the McDonald cassegrain spectrograph, and his ingenious technique for scanning stellar spectra directly in the focal plane of the Coudé spectrograph, etc., have added new possibilities.

A project of major significance is reported upon by Th. Dunham, Jr., on behalf of the Fund for Astrophysical Research (Room 1001, 71 Broadway, New York 6, N.Y.) of which he is a member·

We are still planning to mount the 70-inch disk as a short-focus spherical mirror telescope to feed a Coudé spectrograph on an uninterrupted programme of work on southern stars, either in South Africa or Australia. It is expected that the mirror can be figured at Mount Wilson in the near future on the same equipment that was used to figure the 72-inch mirror for the Palomar Schmidt. Concave mirrors for reflecting cameras ranging in focal length from 14 to 114 inches are already available. A 48-inch mirror is to be figured at Mount Wilson for the longest camera of 180 inches focal length. The general design of the spectrograph and of the telescope mounting has been worked out. It will be necessary to find additional funds to cover the cost of constructing the mounting and the mechanical parts of the spectrograph, but the total cost will be moderate in comparison with other astronomical installations because the short focal length of the telescope (about 14 feet) will permit the use of a very small dome, and because there will be no provision for work at any focus other than that of the Coudé. It is hoped that the cost can be covered on some co-operative basis involving several observatories where there is interest in spectra of the southern stars. The project might well be considered in connection with plans for an international observatory.

It seems clear that the usefulness of a Coudé spectrograph with a large aperture grating, and with a 70-inch telescope serving more as an accessory to the spectrograph than as an independent instrument, would not be limited to recording the spectra of bright stars. It would be equally efficient for photographing with moderate dispersion relatively faint stars, for example, those in the Magellanic clouds. If the spectra were photographed in accordance with a general programme planned jointly by several observatories, and if they were distributed for study in accordance with the advice of Commission 29, it seems likely that results of value might result.

It is impossible to conclude this report without making special mention of the two most perfect stellar spectrographs now in existence: the great Coudé at the 100-inch on Mount Wilson, and the even greater Coudé at the 200-inch on Mount Palomar. While there is plenty of important work to be done with any good instrument—even one attached to a small telescope—yet, the greatest advances have been scored, and are likely to be scored, with these two remarkable technical achievements. Both were made possible through the pooling of experience and ideas of many individual workers: Anderson's early recognition of the advantages of Schmidt cameras, and Dunham's pioneering work in using them for stellar spectrographs; the two Babcocks and R. W Wood's success in ruling better and better gratings; and especially Adams's genius in combining all individual advances to produce an instrument which now provides material for dozens of workers all over the world. And, finally, Bowen's equally concentrated attack upon the construction of a spectrograph, having a beam aperture of 12 inches and utilizing four individual gratings, has already yielded excellent spectra by himself, O. Wilson, and others.

P SWINGS, *Chairman*
O. STRUVE, *Secretary*

APPENDIX A

SUMMARY OF THE BANDS MOST USEFUL FOR THE MARGINAL DETECTION OF MOLECULES IN STELLAR SPECTRA PHOTOGRAPHED WITH SMALL DISPERSION

A requirement for consistent spectral statistics is that those types which are defined in terms of the presence of absorption bands of particular molecules should be distinguishable on the small-scale spectrograms which must be used for the classification of the fainter stars. Weak bands usually become more difficult to detect as the dispersion is reduced, and if we are to avoid confusing or throwing away some of the important spectral subdivisions (e.g. type MO) we need to know the spectral regions in which each molecule has its bands which are most persistent and least obscured by other absorption features.

The following list of useful bands of the most prevalent molecules is provisional and should be closely criticized and extended by other workers in this field. The bands are arranged in order of usefulness in classification, and the Eastman spectroscopic sensitizing most efficient for their photography is given. Term notation and other details of all the systems included can be found in *The Identification of Molecular Spectra*, Second Edition, by Pearse and Gaydon.

Molecule	Spectral types	Sensitive bands	Remarks
TiO	M	**7054, 7088, 7126** γ System I-U or I-N emulsions	These bands of the red system are as strong as the corresponding blue-green bands and are less blended with atomic features. λ7126, the R_c head of the **0, 0** band, is in the most favourable position, but the whole triplet can be seen in giants as early as K4 even with low prismatic dispersion, and permits good distinction between types K5 and MO.
—	—	**5167, 4954, 5448, 4761** α System 103-D emulsion 103*a*-O emulsion for λ**4761**	The 0, 0 band, λ5167, is strongest, but blending with atomic lines of the *b*-triplet of Mg is troublesome. On blue-sensitive plates λ4761 (2, 0) must be used, but is often difficult to see at MO. Other bands in the orange and red are fairly strong but show peculiar luminosity effects and may be blended with bands of other molecules.

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Molecule	Spectral types	Sensitive bands	Remarks
ZrO	S	5552, 5629, 5718 β System 103-D emulsion	Of these triple heads of the 0–0 bands, λ 5552 is the most sensitive feature for detection of ZrO even in stars with strong TiO. A dispersion of about 150 A./mm. is sufficient to separate it from the weak neighbouring bands of TiO. Type S can be defined by the presence of this band on such spectrograms. The other two heads are valuable in assigning subdivisions of type S.
—	—	6474, etc. γ System 103-F emulsion	The 0, 0 band, λ 6474, is as strong as λ 5718 but is badly blended with $\lambda\lambda$ 6479 and 6483 of TiO. The other bands of the red system are also obscured by overlapping TiO bands.
		4620, 4638, 4641 α System 103*a*-O emulsion	The blue system is fairly strong and λ 4620 can rather easily be separated from λ 4626 of TiO, but the band does not correlate well in intensity with the other ZrO bands in S-type stars and may not be a safe criterion for the recognition of this type. $\lambda\lambda$ 4638 and 4641 can be used only when TiO is weak compared to ZrO.
LaO	S	7403, 7910 Red System I-N emulsion	This doubleti s the strongest characteristic feature of the infra-red spectrum of the cooler S-type stars, and is a valuable criterion of classification in stars too red to be easily photographed in other spectral regions. The bands are very sensitive to temperature and disappear in the hotter S-type stars. The bands of the yellow system of LaO are badly blended with TiO bands and atomic lines.
C_2	C (R, N)	5165, 4737 Swan System 103-D, 103*a*-O emulsions	The 0, 0 band, λ 5165, is strongest, but the head is blended with lines of the Mg *b*-triplet. The band is degraded shortward and the break in the continuous spectrum can be used to detect it on small-scale plates in spite of the blending. The 1, 0 band, λ 4737, is next in intensity, and has the advantage of being accessible on blue-sensitive plates. The presence of these two band heads defines the red carbon stars.
CN	G, K, C	4216, 4197, etc. Violet System $\Delta v = -1$ Sequence 103*a*-O emulsion	This is the most generally useful system for estimating CN intensities, as in luminosity classification, on blue-sensitive plates. A dispersion at least as high as 30 A./mm. is necessary to separate the individual bands, such as λ 4197, from neighbouring atomic lines. The strongest head, λ 4216, however, is not separable from the intense Sr II line at λ 4215. On plates with scales in the range 50–150 A./mm. the break in the continuum at λ 4216 serves as a measure of the band strength. On smaller slitless spectrograms depression in the continuum between λ 4216 and λ 4150 can still be used effectively.
—	—	3883, etc. Violet System $\Delta v = 0$ Sequence 103*a*-O emulsion	Although this is the strongest sequence of the violet system, it is not so accessible as the λ 4215 bands, requiring considerably longer exposures. Also, the individual bands are seriously blended with strong Fe lines. The depression in the continuum between λ 3883 and λ 3850, however, is of great value for luminosity classification on slitless spectrograms.

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Molecule	Spectral types	Sensitive bands	Remarks
CN	—	7874, 8067, etc. Red System $\Delta v = 2$ Sequence I-N emulsion	The red system is more open than the bands in the blue and the heads degrade longward. Although the stronger sequences lie farther to the infra-red, near $\lambda 9200$ and $\lambda 11{,}000$, the bands in the $\lambda 8000$ region are quite strong in the more luminous K-type stars and persist to M3 in the giants. They can be used to detect red carbon stars even on small-scale prismatic spectrograms, for they dominate the whole infra-red end of the spectrum and break it up into a characteristic pattern.
CH	G, K, CH stars	4315–4295 $\lambda 4300$ System $\Delta v = 0$ Sequence 103*a*-O emulsion	The compact Q-branch of the 0, 0 band forms the familiar G-band which is recognizable in the G-type stars even with low dispersion. A scale of about 10 A./mm. is required to separate the individual band-lines from strong atomic lines near by, except in the CH stars, where the bands dominate the blue end of the spectrum.

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Perkins Observatory

December 1950

REPORT OF THE SUB-COMMISSION ON MOLECULAR BANDS IN STELLAR SPECTRA

I. ACTION ON RESOLUTIONS

At the meeting of the I.A.U. in Zürich in 1948, two resolutions were passed requiring action by this Sub-Commission. The resolutions called for (1) the compilation of a table of molecular constants for molecules of astrophysical importance, and (2) the preparation of a photographic atlas of band spectra of astrophysical interest. Definite progress has been made on both projects.

(a) *Compilation of Molecular Constants*

The progress has occurred in two ways. First, in the new edition of his book *Spectra of Diatomic Molecules* (D. van Nostrand Co., 1950), G. Herzberg has incorporated an excellent table of the most important constants for all the known states of the diatomic molecules studied up to 1950. This table, being prepared and checked by one person, using a consistent set of physical constants, has the advantage of homogeneity. Secondly, as suggested at the meeting in Zürich, collaboration has been maintained, through B. Rosen, with the *Tables of Constants* project of the International Union of Chemistry. The collaboration has taken the form of some members of this Sub-Commission assuming responsibility for assembling the data on certain classes of molecules. The molecular data to be listed in the *Tables of Constants* will be more extensive than those given by Herzberg. According to the latest advice from Mme Allard, secretary of the *Tables of Constants* project, and Dr Rosen, editor of the section covering diatomic molecules, the final date for receipt of material was December 10, 1950. Therefore, its publication may be expected within the next year.

(b) *Photographic Atlas of Band Spectra*

At the meeting in Zürich and shortly thereafter, P Swings and B. Rosen had consultations with A. Gatterer and J Junkes of the Vatican Observatory As a result, Dr Gatterer, on condition that both technical and financial help should be provided by the I.A.U.,

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undertook to produce the Atlas. This undertaking by the Spectroscopic Laboratory of the Vatican Observatory was most gratifying to the members of the Sub-Commission. The capacity and ability of Drs Gatterer and Junkes for the work has been amply demonstrated by their excellent atlases of *restlinien* (1937) and *Spectra of the Rare Earths* (1945). It is also well illustrated by the considerable progress made on the present project. The able and active co-operation of Dr Rosen should also be recognized. The progress, the present situation and future plans, are best shown by quoting a report written by Dr Gatterer dated November 4, 1950:

Work on the *Atlas of Band Spectra of Astrophysical Interest* is still in a preliminary state; however, we hope that we can start taking the definitive band spectrograms early in 1951.

Our programme of preliminary work includes:

1. The selection and arrangement of band spectra in the Atlas.
2. The test charts and their submission to members of the Sub-Commission for examination.
3. The creation of auxiliary means to facilitate the use of the spectrograms.
4. Obtaining the instruments needed for excitation and reproduction of the spectra.
5. Procuring the necessary chemical and photographic materials.
6. The search for an expert assistant in the difficult experimental work.

This programme is in great part completed, although several important things are still to be done. The following remarks may be made in regard to each individual item of the agenda.

1. The author forwarded a detailed questionnaire and a test chart to nearly all members of the Sub-Commission. Using the remarks and corrections suggested by the members, he was able to decide how many molecules should be included in the Atlas. The original questionnaire showed about 110 diatomic molecules (56 oxides, 33 hydrides, 4 nitrides, 5 sulfides, 7 fluorides, several C-molecules and an appendix of four polyatomic molecules). The corrected questionnaires returned to the author would add to the list 50 other molecules. Naturally, we will try to satisfy these demands, but we cannot guarantee success in every case.

Concerning the extension and disposition of the work, we are now resolved to follow the suggestion to publish the work in two stages. The first volume will contain only the spectra of strictly astrophysical interest, and a second volume will deal with molecules of general chemical and physical interest, thus satisfying also the requirements of Dr Meggers and others who are especially interested in physical and chemical problems. The spectral range to be represented was chosen as from 9000 to 2300 A.

2. A test chart representing the six band spectra was approved by all members of the Sub-Commission. The linear dispersion of these spectra is 2 A./mm. Short and long exposure spectra are given with an adjacent iron comparison spectrum.

3. A new auxiliary Atlas representing a combined arc and spark grating spectrum of iron is now in the Press. It should greatly facilitate the orientation and evaluation of the band spectra.

4. The principal instrument is a grating spectrograph in Wadsworth mounting with an original concave grating ($6'' \times 4''$, $F=21'$, 15,000 lines/inch). For the work on the Band Spectra Atlas, the Laboratory has acquired a current transformer continuously yielding 10 kW., to feed an electric furnace and to produce the 'Carbon-Flame'. A suitable hydrogen tube has been obtained for the absorption spectra in the ultra-violet. There are, however, still lacking two expensive excitation instruments: a King vacuum furnace and a high-frequency generator of about 2 kW. energy.

5. The Astrophysical Laboratory has at its disposal a remarkable quantity of chemicals and photographic material for the purpose of the Atlas. Several samples of pure metals were kindly furnished by Dr McKellar from Canada. Funds for another collection of very pure substances were granted by the I.A.U., and Dr Rosen purchased the collection from Hilger. Nevertheless we still need several other expensive chemicals and photographic material.

6. With a grant of the I.A.U. and the kind permission of Prof. Swings, Dr B. Rosen will come to Rome for three months and will aid the author with the difficult experimental work.

The problem of the Band Spectra Atlas was also submitted to the first meeting of the 'Joint Commission for Spectroscopy' held in September 1950 at Cambridge (England). In the discussions, the members of the Commission encouraged the author to undertake the task and promised whole-hearted and effective support. A similar recommendation came during the subsequent meeting of the 'Journées Spectroscopiques' at Liége arranged by Prof. Swings. In private conversation with Prof. Swings and Dr Rosen, the author pointed out needs concerning the electric furnace and the high-frequency generator. Prof. Swings kindly promised to have the vacuum furnace built in his workshop and to apply for grants to cover the costs of the instruments (about 3000 dollars) to both the Joint Commission for Spectroscopy and the International Astronomical Union.

It is hoped that the work will go ahead rapidly if all the necessary apparatus and materials can soon be placed at our disposal.

Reference should be made in this section to the second edition of the book *The Identification of Molecular Spectra*, by R. W B. Pearse and A. G. Gaydon (London: Chapman and Hall, 1950). This book, containing lists of wave-lengths of the main bands of all known systems, numerous reproductions of band spectra, data on excitation conditions, etc., is related to the two projects outlined above, and is a welcome addition to the literature.

II. Progress in Problems Outlined in Previous Report

In the Report prepared in 1947 (*Trans. I.A.U* **7**, 295, 1950) problems judged important to progress in molecular astrophysics were listed. A resumé of progress on these problems reported since 1948 is given below. The subjects are designated and numbered as in the previous report.

(a) *Observational Problems*

1. The classification of the S-type stars has been studied by P C. Keenan who has published an abstract outlining his criteria and some preliminary results (*Astr. J* **55**, 172, 1950).

4. A study of the violet region of the spectra of the N-type stars has shown for Y CVn some strong absorption bands that have been very tentatively identified as the λ4050 group that occurs in cometary spectra (A. McKellar, *Ap. J* **108**, 453, 1948. P Swings and A. McKellar, *Ap. J* **108**, 458, 1948).

6. The unidentified band at λ3682 reported by P W Merrill in the Me and Se spectra has been identified by G. H. Herbig as arising from ZrO (*Ap. J* **109**, 109, 1949).

7. Publications on isotopic bands in stellar spectra since 1948 include those of G. H. Herbig on the titanium isotopes from the TiO bands (*Publ. A.S.P* **60**, 378, 1948), of A. McKellar, mainly on the carbon isotopes (*Publ. Dom. Ap. O.* **7**, 295, 1948; *Publ. A.S.P* **61**, 34, 1949, and ibid. p. 199) and of G. A. Shajn and V F Haze on the isotopic $C^{13}N^{14}$ bands of the CN systems in the spectra of the carbon stars (*Publ. Crimean Astrophys. Obs.* **2**, 131, 1948 and **5**, 24, 1950).

(b) *Experimental Work in the Laboratory*

1. The experimentally determined relative transition probabilities for bands of the Swan System of C_2 have been published by R. B. King (*Ap. J* **108**, 429, 1948).

2. While CH_4 is not known to exist in stellar atmospheres, it may be of future value to refer to recent work at the McMath-Hulbert Observatory that has led to an experimental evaluation of the absolute f-values of the lines of the λ16660 bands.

4. A series of important papers on CN, C_2 and TiO bands has appeared, mainly from the spectroscopy laboratory of the Yerkes Observatory. G. Herzberg and J. G. Phillips have given a new vibrational analysis of the red CN system (*Ap. J* **108**, 163, 1949). They showed that a revision of the numbering of the upper state was necessary and that

the great intensity of the new infra-red bands indicated a large total intensity for the system. J. G. Phillips has published four extensive papers on C_2 band systems (*Ap. J* **107**, 389, 1948; **108**, 434, 1948; **110**, 73, 1949, and **112**, 131, 1950) which have added a new band system and both extended and improved the data on known systems. He has also published analyses of two singlet systems of TiO (*Ap. J* **111**, 314, 1950) and is at present working on the rotational analysis of the γ system of this molecule.

A useful laboratory study of the band systems of ZrO has been reported by M. Afaf (*Proc. Phys. Soc., London*, A, **63**, 1156, 1950).

(c) *Calculation from Theory*

1. The relative intensities of bands in the Swan System of C_2 have been the subject of two short notes. In the first, N. R. Tawde and J. M. Patel (*Ap. J* **112**, 210, 1950) have given calculated values for $\Delta r_e = 0{\cdot}046$ A. and have pointed out apparent discrepancies with previous calculations and with experimental values. In the second note A. McKellar and N. R. Tawde (*Ap. J* **113**, 440, 1951) have clarified and accounted for the apparent differences in the two sets of computed values. Also, C. Fehrenbach has reported that he and R. Bouigue have carried out calculations of the relative transition probabilities for the C_2 bands and for the red system of CN.

2. The oscillator strengths for the $^3\Pi_g$–$^3\Pi_u$ (Swan system) and $^1\Pi_g$–$^1\Pi_u$ transitions of C_2 and for the $^2\Sigma_u^+$–$^2\Sigma_g^+$ system of N_2^+ have been calculated by H. Shull (*Ap. J* **112**, 360, 1950). For these three transitions he obtained the f-values 0·13, 0·17, and 0·12, respectively. G. Stephenson has made similar calculations for the first two systems and obtained the lower f values 0·029 and 0·039 (*Proc. Phys. Soc., London*, **64**, 99, 1951). This type of calculation is of much interest in molecular astrophysics for it allows the evaluation of the concentration of the molecules concerned and the determination of selective radiation pressures. It is hoped that similar computations will be carried out for other band systems that occur in stellar spectra.

III. Additional Contributions to Molecular Astrophysics

In addition to the researches noted in Section II, a number of other investigations of interest have been reported. They are briefly noted below, first those dealing with astrophysical observations, and secondly, laboratory work. While no claim to completeness is made either in Section II or III, it is hoped that not many major contributions have been overlooked.

An extensive study of the spectra of several of the cool carbon stars has been published by V F Haze and G. A. Shajn (*Publ. Crimean Astrophys. Obs.* **2**, 51, 1948). They have discussed in detail the problems of identification of atomic and molecular features in their spectra which were of moderately low dispersion.

An interesting and valuable atlas of the spectra of a number of R- and N-type stars has been presented by R. F Sanford (*Ap. J* **111**, 262, 1950). The photographic reproductions, of high dispersion considering the spectral type, and the accompanying discussion, make up a significant contribution to the literature on the cool carbon stars.

P C. Keenan identified the LaO bands in S-type spectra in 1948 (*Ap. J* **107**, 420, 1948). Subsequently, collaborating with J. J. Nassau and G. B. van Albada (*Ap. J* **109**, 333, 1949), he found two sets of as yet unidentified bands. In the spectra of long-period variables of type M7 and later, the strongest heads occur at $\lambda\lambda$7372·6, 7404·7, 7433·4, 7865·1, 7939·3 and 7974·3 and are degraded to the red. In the cooler S-type spectra red-degraded heads appear at $\lambda\lambda$7561, 8464, 5610 and 8820. In order to make a laboratory survey of possible emitters of these bands, a low-dispersion spectrograph is under construction at the Perkins Observatory.

Researches reported by C. Fehrenbach include a study by Mme and M. Pecker and M. Peytureaux of the intensity of the CN, CH and C_2 bands in the solar spectrum as a function of sin θ (intensity a maximum near sin $\theta = 0{\cdot}9$), and an investigation under way

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by R. Bouigue of the spectral classification of the cool carbon stars using simple criteria between λ5500 and λ6800. It is reported too, that R. Bouigue has derived 'vibration' temperatures for these stars ranging from 4000° to 1800° K., using the transition probabilities for the C_2 and the red CN bands referred to previously.

G. Herbig has reported on plans to try to detect CO in stellar atmospheres. The large amount of CO which must exist has been recognized for many years, but observational detection has been hampered by the resonance electronic bands being in the inaccessible ultra-violet region. With photo-conductive cells one may hope that direct evidence of the presence of CO could be found through observation of the first overtone vibration-rotation band at 2·4μ. Herbig is making calculations of the expected strength of this band in stellar atmospheres using the latest dissociation energies of relevant compounds, curve of growth techniques and an *f*-value obtained from laboratory data.

G. Herbig also reports that he has shown the 'channelled' appearance of the Hβ emission in the spectrum of *o* Ceti to be due to the superposition of identifiable rotational lines of the 2,0 and 3,1 TiO bands. Despite the resulting excitation of some molecules to higher states, actual search showed no sign of fluorescent emission in other rotational lines.

J. Hunnaerts (*Ann. d'Ap.* **10**, 237, 1947; *Comm. Roy. Belgique*, No. 1, 1948) has studied carefully the intensities of molecular lines of CN, C_2 and CH in the solar spectrum using the *Utrecht Photometric Atlas*. The study was extended to the OH and NH bands using Rowland's Table. He evaluated the excitation temperature from the band lines (4500° K.), derived a curve of growth for molecular lines, and made estimates of the abundances of the molecules in the solar atmosphere.

P. Dobronravin has investigated the effect of absorption bands of TiO in the region λ4000 to λ8000, on the distribution of energy in the continuous spectrum of the M-type stars. He concluded that this effect was much larger than hitherto assumed (*Publ. Crimean Astrophys. Obs.* **5**, 59, 1950). In this connection G. Shajn indicates that a study in the laboratory of the relative intensities of the TiO bands is in progress.

G. Shajn has reported that he and V. Haze are continuing work on measuring intensities of isotopic bands of CN and C_2, involving the C^{12} and C^{13} isotopes. He has also reported that V. Haze is making a spectrophotometric study of the depressions in the spectra of N-type stars. It is hoped to explain these depressions in terms of molecular bands.

Estimates have been and are being made by W. W. Morgan and Miss Roman at the Yerkes Observatory, by R. P. Plassart at Haute Provence and by P. C. Keenan at the Perkins Observatory, of the intensities of the CN bands (both violet and red systems) in the spectra of stars of types G, K, and M. The variations of intensity among stars of a given luminosity, temperature and velocity-class are being studied. Also Keenan and Kellar are measuring the weakening of the CN bands in the spectra of high-velocity giants.

With P. Swings, Miss D. Jehoulet is studying the behaviour of C_2, CN and CH bands in the spectrum of the carbon cepheid-variable RU Cam.

Turning to laboratory investigations, very interesting further studies have been made of the λ4050 group of bands, originally found in cometary spectra and recently tentatively identified in the spectrum of YCVn. These bands were first produced in the laboratory in 1942 by G. Herzberg and ascribed, on apparently good evidence, to CH_2. They have recently been shown by A. Monfils and B. Rosen (*Nature*, **164**, 713, 1949) to appear with identically the same structure when deuterium instead of hydrogen is used in the excitation process. This result, showing that the spectrum is due to a molecule not containing hydrogen, has been verified by A. E. Douglas at Ottawa, who has proceeded further and produced the same spectrum with C^{13} replacing C^{12}. In this case slight shifts do occur, indicating that at least carbon atoms are present in the emitter of the bands. But, the emitter is still not known. The bands are under further investigation.

The fine structure of the atmospheric oxygen bands has been analysed in much detail by L. Herzberg on the basis of new precise measurements by H. D. Babcock of the Mount Wilson Observatory (*Ap. J.* **108**, 229, 1948).

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An investigation of the spectra of NO^+ and NH^+ is being made by M. W Feast at the National Research Laboratory, Ottawa, Canada. He has found that the green bands, ascribed in the literature to NO^+, actually are due to NO (*Canadian J Res.* **28**, 488, 1950).

In the Utrecht Physical Laboratory, J. A. Smit is carrying on studies of spectral intensity, including investigations into determinations of temperatures from band structures.

A large King-type furnace has been built at the National Research Laboratories, Ottawa. There it will be used, under the direction of G. Herzberg, to study the absorption spectra of C_2, CN and SiO in the near and far ultra-violet. It is hoped that this investigation will lead to a better understanding of these molecules and particularly to reliable values of their dissociation energies. In the case of SiO, it is hoped to find an intercombination system which may be of importance for spectra of late-type stars.

Mention should be made of plans well under way at the spectroscopic laboratory of the Institut d'Astrophysique, Université de Liége, to pursue researches in band spectra of importance in astrophysics. Included are programmes involving new work on oxides and other molecules using a King-type furnace, new hollow cathode tubes, etc.

IV Subjects for Possible Discussion

1. P C. Keenan points out the great need for detailed laboratory investigation of the many diatomic molecules involving cosmically abundant atoms, that have not been thoroughly analysed. He notes that most molecular physicists have deserted the field of diatomic molecules and urges that astrophysicists do their share to make sure that work on diatomic molecules is not completely neglected. He emphasizes that some of the unidentified bands in stellar spectra are quite strong and represent molecular species playing important roles in the dissociation equilibrium of the atmospheres of the cooler stars. He suggests strong encouragement of the work of those laboratory spectroscopists in studies of diatomic molecules.

2. P C. Keenan also points to the volume of observations being made by the growing number of Schmidt telescopes equipped with objective prisms. This suggests the importance of calling the attention of the astronomers concerned to every criterion that will help them refine their classifications of the banded spectra and lead to the discovery of new members of small, but possibly important, groups of peculiar stars such as the CH stars. He suggests that perhaps the I.A.U. could circulate a table of the bands in each spectral region which are most suitable for the marginal detection of astrophysically important compounds. He notes that on several occasions the Perkins Observatory has co-operated with the Warner and Seasey Observatory in testing the effectiveness of given criteria at different dispersions and that he would be willing to prepare a summary of their results. This has been done and the summary is given as an appendix to the present Report.

3. John G. Phillips urges the prosecution of investigations leading to good values of transition probabilities and dissociation energies for molecules showing bands in stellar spectra, these quantities being of special importance in researches into the physical conditions in the late-type stellar atmospheres.

4. R. F. Sanford suggests that there might be some discussion of the limitations to studies of bands in stellar spectra, so that fruitless effort may be avoided. He cites, for example, the limitations imposed by the practical limits to usable dispersion. Any discussion might encompass the limits of dispersion required for investigations of various sorts.

5. G. Herzberg suggests that a point that might be discussed at the I.A.U. meeting is the relation of the Joint Commission for Spectroscopy to this Sub-Commission of Commission 29.

6. G. Shajn suggests the possibility of discussing the problem of isotopes in stellar atmospheres.

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7. The Sub-Commission in general strongly supports continued active participation in the two projects in which it has a part, and which are described in Section I of this Report. It urges, in particular, that any reasonable requests of financial assistance to the treasury of the I.A.U. to expedite the work at the Vatican Observatory on the Atlas of Band Spectra of Astrophysical Importance, be given favourable consideration.

ANDREW MCKELLAR
December 15, 1950 *President of Sub-Commission*

REPORT OF THE SUB-COMMISSION ON SPECTRA OF VARIABLE STARS

The Committee recommends intensive investigations of selected variables, especially concurrent spectroscopic and photometric studies, as timely and strategic. To this end the Report lists variables in special need of accurate observations. We suggest that observers considering further observation of any of these variables correspond directly with the astronomer under whose name the star is mentioned.

Mrs GAPOSCHKIN (*Harvard Observatory*):

1. Cepheid-like variables at considerable distances from galactic plane: TW Cap, ST Pup.
2. Variables in Carina:
   A. Eclipsing. Spectroscopic observations needed.
   B. Cepheids. Photo-electric observations needed.
   C. Peculiar. Both spectroscopic and photo-electric observations needed.
   AD, CG Car.
3. Miscellaneous:
   A. Symbiotic variables (photometry in several colours).
   B. υ Sgr, AX Mon = HD 45910.

G. E. KRON (*Lick Observatory*)

1. Dwarfs that show evidences of spottedness.
2. Eclipsing variables.
3. Subgiants.
4. Low-luminosity stars with emission lines.

The following variables are under photo-electric and/or spectroscopic observation by Kron and Herbig:

RT And	AR Lac, 16 Lac (CMa type)
RT, RW, ψ Aur	T, BF Ori
UV Boo	Y, RY, Sgr
SV Cam	S Sge
R, α CrB	SV, 28 Tau
DT Cyg	α UMi
YY Gem	WW Vul
89 Her	Ross 248

B. V KUKARKIN (*Sternberg Astronomical Institute*):

1. Variables similar to Algol, non-periodic: DG Aur, CH Cep, CO Cep.
2. RR Lyrae type with pronounced secondary variations: AC And, RW Dra, AR Her.
3. Long-period cepheids with large Z co-ordinate: W Vir, AL Vir, Y Com.
4. Variables in Orion nebula.
5. CE Cas (A and B).
6. Photo-electric observations especially desirable: W Ser, RY Sct, AC And, AI Vel.

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P Th. Oosterhoff (*Sterrewacht, Leiden*):

1. In the southern sky spectroscopic observations of many eclipsing binaries ar needed (e.g. GL Car, GV Car, AI Cru).
2. Radial velocities of cepheids and long-period variables, especially in the souther sky.
3. Accurate radial-velocity curves, combined with multicolour photometry of cepheid with characteristic light-curves (e.g. RZ Vel, VY Cyg, S Sge).
4. Photometric control of spectrum variables.

G. A. Shajn (*Simeis Astrophysical Observatory*):

1. Long-period variables. Simultaneous observations of spectra and accurate observa tions of brightness.
2. Variable stars connected with diffuse nebulae, e.g. Orion.
3. Observe variable nebulae in light of $H\alpha$: NGC 1555, 2261, 6729, γ Cas.

Otto Struve (*Students' Observatory, University of California*) recommends detaile photometric studies of the following variables of the β Canis Majoris type (in order o importance) 12 Lac, β Cep, β CMa, σ Sco, γ Eri, δ Sct.

P Swings (*Liége, Belgium*) recommends a new photometric study of the carbo cepheid RU Cam, whose spectrum is being investigated by Miss D. Jehoulet in Liége.

The following variables are under investigation at the Yerkes Observatory:

W P. Bidelman ρ Cas (peculiar supergiant), FU Ori (super slow nova), υ Sgr; abou 225 long-period variables for spectral classification (SX Peg, mag. 8·4 at max. is of typ Se; R. Capricorni, $m_v = 8{\cdot}7$ at max., type Ne).

G. Münch: AC And (peculiar RR Lyr type).

G. Van Biesbroeck: magnitudes of the components of o Cet, X Oph.

A. H. Joy (*Mount Wilson and Palomar Observatories*) is preparing a report on hi spectroscopic observations (low-dispersion) of the following RV Tauri variables:

BD + 20° 2337	TW Cam	AC Her	R Sge
WY And	RX Cap	W LMi	AR Sgr
BL Aqr	RU Cep	UW Lib	AX Sgr
TW Aql	TZ Cep	U Lup	AI Sco
AD Aql	AV Cyg	U Mon	R Sct
DY Aql	DF Cyg	TT Oph	RV Tau
EZ Aql	V 360 Cyg	TX Oph	WW Tau
KK Aql	SS Gem	UZ Oph	S Vul
Z Aur	SU Gem	TX Per	V Vul
AG Aur	UU Her		

Other variables needing simultaneous photometric and spectroscopic observations are:

1. Taurus stars with bright lines most of which are probably variable in light an spectra.
2. R Coronae Borealis variables at minimum.
3. Eclipsing stars with emission rings or streamers.
4. W Virginis variables (period 14–20 days) to get bright lines and shape of light curve.
5. AE Aqr. Probably a SS Cyg variable.

H. W Babcock (*Mount Wilson and Palomar Observatories*). Two magnetically variabl stars known to show light variations are α^2 CVn (Nilonov and Brodskaja, *Bull. Acad. Sci Georgian, S.S.R.* **3**, no. 7, 657, 1942) and HD 125248 (D. W N. Stibbs, *Nature*, **165**, 195 1950). They have long been known as spectrum variables; these and other spectrum variables on Armin Deutsch's list (*Ap. J* **105**, 283, 1947) might likewise repay observa tions for changes in luminosity. Two additional magnetically variable stars with reversing polarity, not recognized as spectrum variables, are HD 10783 and HD 153882 (H. W Babcock, *P.A.S.P.* **61**, 226, 1949); the periods are a few days. HD 188041 and HD 133029 likewise show large variations in magnetic field intensity, but without change of polarity. The magnetic period of HD 188041 is probably several weeks, while that of HD 133029 is much shorter, perhaps of the order of 1 day.

R. F. SANFORD (*Mount Wilson and Palomar Observatories*) has high-dispersion spectrograms of the following cepheids: TU Cas, DT Cyg, FF Aql, U Vul, W Vir, T Mon, SV Vul, AC Her (RV Tau type).

P. W MERRILL (*Mount Wilson and Palomar Observatories*). Systematic photometric observations of the following stars would be valuable:

1. Symbiotic variables: Z And, R Aqr, BF Cyg, CI Cyg, RW Hya, AX Per, AG Peg = BD + 11° 4673.
2. Shell stars: 48 Lib, HD 33232, AX Mon = HD 45910, Pleione, β Mon A, HD 50138, HD 172694, HD 183656, MWC 374, XX Oph.

G. C. MICZAIKA (*Heidelberg*). Photometric observations of symbiotic stars.

P. W. MERRILL
President of Sub-Commission

REPORT OF THE SUB-COMMISSION ON SPECTRA OF NOVAE

This report is a review of researches published after the 1948 Congress, as well as of the more extended papers not mentioned in the previous report. It must be noted that the present report has been written on the basis of the published material, since, of the investigators from abroad, only Ch. Bertaud has sent his report.

A number of novae have recently been discovered by Solovyev, Bertaud, Bartaya, Haro and Zwicky. However, since 1948 there have been no bright nova that would draw the attention of spectroscopists, and the more detailed experimental investigations were chiefly devoted to novae, which had formerly been bright. In this respect, mention should first be made of the investigation of the spectrum of N Per 1901 carried out by McLaughlin (*Publ. Obs. Michigan*, **9**, no. 3, 1949). This investigation is of a monographic character and, aside from the up-to-date analysis of the observed details of the spectrum, it gives valuable curves of the variation of radial velocities and of the structure of the emission spectrum.

B. Vorontsov-Velyaminov's paper (*A.J U.S.S.R.* **23**, 269, 1946) contains a spectrophotometric examination of fifty of A. A. Belopolsky's spectrograms and gives curves of the variation of the full intensity of the bright bands in the spectrum N Per 1901, as well as the data on temperature variations and the radius of the star.

During the elapsed period investigations have appeared on the theory of novae, which are represented in a number of papers by E. R. Mustel (*A.J U.S.S.R.* **25**, 156, 1948). Mustel showed that the origin of the emission bands in the spectra of novae immediately following the maximum of brightness is connected not only with fluorescence in the main shell but also with the processes of the ejection of matter from novae. The energy of ejected atoms is transformed in various ways into the energy of the emission bands. In another paper (*A.J U.S.S.R.* **24**, 97. 155, 1947) he discussed the problems of the continuous ejection of matter from novae. It has been shown that for the atoms producing the diffused spectrum, an important role is played by radiation pressure. The matter of the Orion spectrum is ejected from the deeper parts of the nova, under the action of forces similar to those which produce eruptive prominences (*Crimean Publ.* **4**, 152, 1949).

Two papers (*Crimean Publ.* **1**, p. 2, 91, 1948; **4**, 23, 1949) consider the problem of t
transformation of the premaximum spectrum into the principal. These phenomena m
easily be explained if we assume that at the moment of maximum brightness only t
outer parts of the nova's extremely extended reversing layer are separated from t
nova, while the photosphere of the star, having reached its greatest dimensions, beg
to contract. This leads to the rise of a large gradient of velocities in the inner parts of t
reversing layer of the nova, which leads to an increase of the selective radiation pressu
on the separating parts of the reversing layer. In this connection, the author expla
the most important phenomena of the ejection of matter from novae. In addition,
Crimean Publ. **4**, p. 23, 1949, he showed that all the other mechanisms advanced as
explanation of the substitution by the principal of the premaximum spectrum a
attended by very great difficulties.

In four papers (*A.J U.S.S.R.* **22**, 65 and 185, 1945, **23**, 289, 1946; *Crimean Publ.*
2, 91, 1948; **4**, 152, 1949) the problem of the expansion of novae preceding maximu
brightness was considered. It was pointed out that the interpretation of these phenome
leads to extremely large values of the masses of the novae, of the order of several hundr
times the Sun's mass and for N Aql 1918 approximately 1500 M☉ This conclusion
arrived at from the following considerations: (*a*) the above-mentioned interpretati
of the phenomena of the transformation of the premaximum spectrum into the princip
spectrum; (*b*) the absence of a large jump (of the recombination type) at the limit of t
Balmer series in the spectra of novae immediately following the maximum brightne
This also indicates that the non-transparent photosphere remains with the nova an
therefore, the velocity of the photosphere preceding the maximum brightness is less th
the velocity of escape. In another work (*A.J U.S.S.R.* **24**, 280, 1947 and **25**, 11, 194
the author confirms the large masses of novae from a different point of view. He is l
to this conclusion by the most probable interpretation of the decrease of the shift
certain absorption systems in the spectra of novae near the maximum brightness. T
conclusion concerning such large masses of novae is apparently not shared by certa
other specialists in this field.

In the last work (*Sternberg Inst. Reports*, No. 41, 1950) the masses of the shells thro
off by the novae have been computed; an interpretation has also been given of the bas
phenomena observed in spectrum N Her 1934 during its large April minimum.

On the other hand, the processes in novae were likewise studied by D. McLaughlin
the basis of an analysis of the observational data (*Publ. A.S.P.* **59**, 244, 1947 and **62**, 18
1950). In general, his interpretation of the origin of various bright bands and absorpti
lines in the spectra of novae is similar to Mustel's interpretation. However, he does n
consider it possible to conclude from a decrease of the shift of certain systems
absorption lines that the masses of these stars are large. He considers this shift to
caused by the change of the radius of the effective layer determining the given spectru
and not by the gravitational slowing down of the ejected shell. The important proble
of the masses of novae cannot be considered as solved. The author of the review expec
the novae to have masses close to those which, according to the mass-luminosity relatio
correspond to their luminosity at minimum.

A note by S. Rosseland (*Ap. J* **104**, 325, 1946) and two large papers by L. E. Gurevi
and A. I. Lebedinsky are devoted to the cause and the still obscure mechanism of t
outbursts of novae. Rosseland assumed an analogy between the central explosion in t
star and the underwater explosion. Gurevich and Lebedinsky (*C.R. Acad. Sci. U.R.S.*
56, nos. 1 and 2, 1947; *A.J U.S.S.R.* **23**, 15, 1946) investigated mathematically t
theory of the thermal explosion provoked by nuclear reactions. This theory is simil
to the theory of chemical explosions. An explosion in the peripheral layer may be caus
by the transformation of deuterium or of light metals in a nova and would bring abo
the observed asymmetry in the ejections of gas from the surface. No such asymmet
is produced by a central explosion, the theory of which is connected with the proble
of the internal structure of the star. If the central explosions are degenerated they m
be repeated when the fuel reserves are so small that they burn out while still in t

process of heating. The induction time of such an explosion is several years. It was possible to develop more extensively the theory of a single peripheral explosion producing asymmetrical ejections, on the condition of the absence of convection reaching to the centre of the star. Fifteen of the concrete nuclear reactions considered lead to a temperature of explosion from 1 to 15 million degrees and require a reasonably small concentration of the corresponding elements. Repeated peripheral explosions might produce the absorption of a neutrino by a proton with the formation of a neutron, and then of a deuteron. Unfortunately it is difficult to check this theory.

In 1948 a large monograph appeared in Moscow written by the author of the review who considers the mutual relations of the gaseous nebulae and stars with non-stationary atmospheres, chiefly the novae. A critical examination and list of all the existing data and observations in systematic form is accompanied by a catalogue of supernovae and novae, in which a new detailed classification of their light curves is given and, apart from it, a classification of spectral stages, slightly modifying that given by D. McLaughlin. In this monograph, the author sums up the results of his own researches and gives certain data and considerations hitherto unpublished. Thus, arguments are given in favour of the idea that stars of the P Cygni type, familiar to the Be stars, are giants with non-stationary atmospheres of the Gamma Cassiopeiae type, and must not be confused even with such slow novae as η Car. Statistics of computed losses of energy delivered in different ways by a number of novae during outbursts is also given. It becomes apparent that in the case when the shell separates at maximum brightness, the main part of energy is lost by radiation. If the shell is torn off at the beginning of the outburst, the energy of radiation is slightly less than the energy necessary for the separation of the shell. Since this energy depends upon the amplitude of light variation, that is, from the luminosity previous to the outburst, the separation of the shell at the beginning of the outburst is more probable. The energy lost during the outburst is comparable to the energy expended between the outbursts, and the relation of these energies, but not the absolute quantity of energy, characterizes the extent of the shock of the star.

Earlier the author has found that novae, before and after their outbursts, belonging in both cases to hot stars, do not represent a homogeneous group of stars, but rather form on the Russell diagram a long sequence, connecting the Wolf-Rayet stars with the white dwarfs. This white-blue sequence might be interpreted as an evolution, because the decrease of mass during outbursts is observed in the sequence directly. The spectra of the recurrent novae of the type of N Sagittae 1913 and 1946 do not differ from the spectra of other novae, and therefore their physical nature does not show any difference. It is now absolutely unquestionable that the outbursts of all novae are repeated. Since the luminosity between the outbursts of recurrent novae diminishes with the increase of the interval of time between the outbursts, and the mass diminishes rapidly and must inevitably lead to a decrease in the luminosity, it is almost certain that the outbursts of a certain nova must gradually become rarer but stronger, and the star must pass into the condition of a stable dwarf, or of a star but slightly different. It is possible that the recurrent novae originate from Wolf-Rayet stars experiencing the intermediate stage of a star of Z And type. These and other cosmogonic conclusions of the author do not, however, interfere with the basic purpose of the monograph which was intended to give a detailed analysis of the present state of the problem of the nature of hot giants and their connections with the nebulae both as regards genetics and methods of investigation. Literature given is exhaustive, the only exceptions being abbreviated reports of the observations of trivial novae and theories, that are of no interest at the present time.

It is believed extremely desirable that the members of the Commission assist in the realization of the following suggestions:

1. In order to establish the amplitude of the light variations of a number of novae to obtain some photographs in their vicinity by large telescopes capable of reaching stars up to the 20th magnitude.

2. To publish lists of spectrograms of novae, being at the disposal of observatories, that have not yet been used.

3. To organize regular spectrography and photometry of novae, at least from time to time, for the whole accessible period of their light variations.

4. Complete the series of objective-prism spectrograms of all the stars in the zone of the Milky Way with minimum dispersion, at least up to the 13th magnitude, for the purpose of establishing the spectra of typical novae prior to their outbursts.

5. Check the duplicity of T CrB, which would justify the suggestion that the red giants are hot stars with cold shells, and would bring us closer to the determination of the masses of novae.

6. Resume systematic observations of novae in the spiral nebula in Andromeda.

B. VORONTSOV-VELYAMINOV
President of Sub-Commission

The following comments are offered on the above suggestions:

1. Most of the brighter novae, whose brightness at maximum is known, are still being followed by visual observers such as Dr Steavenson. Many of the fainter ones were not caught till after maximum. A list of the remainder might be prepared and observatories with suitable telescopes asked whether they could secure occasional photographs from time to time. Care should be taken to avoid duplication of work on any one star.

2. This would be a very big task. The spectrograms obtained for one nova, Nova Herculis 1934, are several thousand in number. Probably the most effective way of securing the information required by a student of the history of a particular nova would be for him to send a note to the *Astrophysical Journal* asking that directors of observatories who had material on the nova should send details of spectrograms available for study to the student concerned.

4. This is most desirable as so little is known of the pre-outburst spectral types of novae.

5. This study is important and should be extended to such stars as Z Andromedae or R Aquarii.

F. J. M. STRATTON

29. SUPPLEMENT AU RAPPORT DE LA COMMISSION DES SPECTRES STELLAIRES

1. V. G. GORBATSKY. 'Interprétation des changements du spectre de γ Cas' (*Journ Astr.* **26**, no. 5, pp. 307–19, 1949; **28**, no. 6, pp. 450–65, 1951). Les deux publications ont un caractère théorique. Dans la première, on étudie surtout comment l'expulsion des couches superficielles pendant la période 1936–41 devait influencer la température de couleur et la brillance de l'étoile. En se basant sur les formules déduites, l'auteur constate un accord entre la théorie et l'observation. Dans son travail le plus récent, V. G. Gorbatsky démontre que le changement du spectre de γ Cas en 1936–38 était dû à l'éjection non-stationnaire de matière par l'étoile en rotation. En comparant la théorie et les observations, l'auteur détermine la dimension des couches superficielles et la vitesse de leur mouvement.

2. P. P. DOBRONRAVIN. 'Sur la répartition de l'énergie dans les spectres de quelques étoiles froides' (*Isvestiya de l'Observatoire de Crimée*, **5**, 59–85, 1950). La répartition de l'énergie dans les spectres de β Peg, ρ Per et α Her a été étudiée entre 4000 et 8000 A. La différence des logarithmes de l'intensité de l'étoile observée et de l'intensité dans α Ari, en fonction de $1/\lambda$ est loin d'être une fonction linéaire, qui correspondrait au rayonnement de Planck. La courbe de déviation par rapport à la droite montre un bon accord avec la courbe déduite de l'intensité des bandes de TiO. La prise en considération de la diminution de la luminosité de ce spectre continu 'conventionnel', montre que la

variation de température de 3000 à 2500° ne diminue la luminosité visuelle que de $0{\cdot}^{m}8$. En se basant sur les données publiées par d'autres auteurs, il est possible d'étudier l'augmentation régulière de la déviation non linéaire de la dépendance de $\Delta \log I_\lambda$ par rapport à $1/\lambda$ lorsqu'on passe des étoiles K aux étoiles M.

3. T. M. FOFANOVA. 'Spectrophotométrie des supergéantes' (*Isvestiya de l'Observatoire Astronomique principal de Poulkovo*, III, no. 144, pp. 68–117, 1950). Ce travail considérable consacré à l'étude des supergéantes, d'après la méthode des courbes de croissance, se base, d'une part, sur le matériel obtenu à Poulkovo, d'autre part sur l'atlas publié de microphotogrammes des intensités de spectres stellaires obtenus au foyer coudé avec une très grande dispersion. Signalons les résultats suivants: Pour déterminer la température d'excitation de l'étoile, l'auteur a suivi la méthode d'Adams-Russell ainsi que la nouvelle méthode utilisant la comparaison des courbes de croissance d'étoiles possédant des atmosphères de structure analogue. Afin d'établir une comparaison des observations avec la théorie, des courbes de croissance théoriques ont été construites pour différents modèles de structure des atmosphères, et il a été démontré qu'il est possible d'utiliser le modèle le plus simple de Schuster-Schwarzschild. On a étudié en détail le rôle du coefficient d'absorption continue pour l'examen des courbes de croissance et on a démontré que la variation du coefficient d'absorption continue en fonction de la longueur d'onde, ainsi que de l'absorption due aux ions negatifs de l'hydrogène, ne modifie pas le résultat d'une façon appréciable.

4. P A. BARTAYA. *Détermination des magnitudes absolues de 233 étoiles chaudes*. Dans ce travail l'auteur donne les résultats de la détermination des magnitudes absolues de 233 étoiles chaudes en se basant sur les mesures des largeurs équivalentes des raies de H. Les spectres ont été obtenus à l'aide d'une chambre à prismes en utilisant une dispersion d'environ 130 A/mm.

5. L. S. GALKIN. 'Double classification des spectres stellaires obtenus avec une dispersion très faible' (*Isvestiya de l'Observatoire astrophysique de Crimée*, Vol. **1**, 1952). Le travail contient la classification des spectres d'après deux paramètres, pour plusieurs centaines d'étoiles dans trois sections de la Voie Lactée.

6. E. S. BRODSKAYA, J. M. KOPILOV, L. S. GALKIN et V V SIDORENKO. A l'Observatoire astrophysique de Crimée, on continue les travaux importants commencés en 1950 en se rapportant à la détermination de spectres d'étoiles faibles jusqu'à $12^{m}.0$–$12^{m}.5$. La dispersion est d'environ 250 A/mm. On détermine les indices de couleur en même temps que les spectres. Jusqu'à présent, on a déterminé les spectres de plus de 20.000 étoiles. La publication de la classification spectrale commencera en 1952.

G. A. SHAJN
Académicien

Additions to the Draft Report

I. *Notes received from U.S.S.R.*

1. G. A. Shajn (*Crimean Publications*, **1**, part 1, p. 5, 1947) has studied the hydrogen and iron (ionized and neutral) emission lines in the spectra of long-period variables.

The width of the hydrogen lines appears to be larger than the Doppler width for the temperature of these stars. The hypothesis of the blanketing by bands and lines explains the anomalies of the relative intensities of $H\gamma$ to H_{16}.

In the behaviour of the iron lines intensity anomalies caused by blanketing have also been discovered.

2. In the spectrum of α Cyg, G. A. Shajn (ibid. **1**, part 1, 1947) has discovered a negative displacement of the order 3–4 km./sec. for the lines of excitation potential less than 0·2 volts.

3. G. A. Shajn and V F. Gaze have investigated (ibid. **1**, part 1, 1947) the limit of convergence and the so-called tail bands in the spectra of carbon stars. The faintness in the

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continuum in the spectra of the N- and R-type stars in the regions of the +1- and 0-sequences of the swan bands is explained by the existence of the usual bands of C_2. The influence of the tail bands in this region has not been observed. The identification of a number of bands carried out by various authors has been critically considered and appears to be incorrect, in certain cases.

4. V F. Gaze and G. A. Shajn (ibid. **2**, 51, 1947) have carried out an extensive investigation of the spectra of the carbon stars. The question of the intensity of the atomic lines in the regions free from molecular absorption has been investigated.

The question of the atomic abundance of sodium in cold stars of the carbon and oxygen branches has been discussed.

A great number of bands (some unidentified), mainly in the visual region, has been discovered. Bands of MgH and other molecules, in particular $C^{13}N^{14}$, have been observed for the first time.

5. G. A. Shajn and V F. Gaze (ibid. **2**, 131, 1948) have discovered bands due to the heavy cyanogen molecules $C^{13}N^{14}$ (violet system $^2\Sigma - {}^2\Sigma$) in the spectrum of Y Can Ven. The relative abundance of C^{13} with respect to C^{12} exceeds many times the value given by the nuclear reaction theory. This work is a further development of G. A. Shajn's work (*Vestnik of the Academy of Sciences of the U.S.S.R.* No. 10, p. 52, 1940; *Bulletin Abastumani Observatory*, No. 6, p. 1, 1942) in which it was found that in the atmospheres of the *N*-type stars the abundance of C^{13} relative to C^{12} ranges from 0·05 to 0·50.

6. G. A. Shajn and V F. Gaze (*Crimean Publications*, **5**, 24, 1950) have discovered bands due to the heavy cyanogen molecule $C^{13}N^{14}$ (red system $^2\Pi - {}^2\Sigma$) in the spectra of carbon stars. This work confirms the results of the above investigation.

7. G. A. Shajn and V F Gaze have obtained new data concerning the systematic displacement of lines in the spectra of the white supergiants α Cyg, β Ori, 67 Oph (ibid. **4**, 49, 1949).

8. From spectra obtained with a prismatic camera, N. B. Kalandadze has given new data for the determination of the absolute magnitudes of G- and K-type stars (*Abastumani Bulletin*, No. 10, p. 63, 1944).

9. O. A. Melnikov has carried out an extensive spectrophotometric study of δ Cep and η Aql (*Publications of Pulkovo Observatory*, **64**, 1950). The spectral variations with phase have been studied, the hydrogen lines along with other features exhibit marked changes. The line contours are asymmetrical for both stars. From the curves of growth the variation of the atmospheric turbulence with phase (maximum near the minimum brightness) has been discovered. The colour and excitation temperatures as well as the relative atmospheric abundances of the elements were determined. From a study of the line contours and radial velocities it has been shown, that there is an outflow of matter from the atmospheres of these stars in particular and of long-period cepheid variables in general.

10. R. A. Bartaya has reported on a spectrophotometric investigation of N Ser 1948, discovered by the author at the Abastumani Observatory (U.S.S.R.). During the period of the observations nebular characteristics have been observed in the spectrum. A study of the total line intensities as well as the light-curve has shown that the star is a typical nova. The velocity of expansion of the envelope is 1600 km./sec., an electron temperature of 8000° is indicated.

11. G. A. Shajn and V F. Gaze have discovered some very interesting features of interaction for the 'light signals' illuminating the diffuse nebulae near Nova Aur 1891, FU Ori (nova-like), AE Aur (variable). On one plate a newly discovered parabolic nebula is seen at a distance of about 10 minutes of arc from the star FU Ori. On another plate a filamentary nebula is seen at a distance of 3·8 degrees from N Aur.

12. The spectral types for 25,000 stars (to magnitude 12·5) have been determined at the Crimean Observatory.

13. An investigation by B. V Kukarkin (1) is devoted to the study of the general characteristics of novae. He has found that the sub-system of novae in our galaxy has contradictory characteristics. The distribution of the novae by *z*-co-ordinates shows

a large concentration towards the galactic equator for the flat sub-systems; the appreciable concentration of novae towards the galactic centre is peculiar to the spherical sub-systems.

14. P. P Parenago(2) has deduced final light-curves for the four novae of 1936, N Oph 1948, T Aur 1891, the two supernovae of 1937 and the supernova S And 1885. The curves were obtained from published data as well as from observations carried out in Moscow.

15. The expansion of novae before maximum brightness has been studied by E. R. Mustel(3), who showed that during expansion, a nova has a very extended reversing-layer. He has also calculated the velocity of expansion of the photosphere before the maximum for six bright novae(4). Theoretical contours for the absorption lines in the spectra of the novae, WR-, P Cygni- and Be-stars have been calculated by V V Sobolev(5). Estimates of the masses of the envelopes ejected by the novae have also been calculated by V V Sobolev(6). He has studied the theory of the luminosity of stellar envelopes in which there is a deviation from the radiative equilibrium. This theory is applied to explain the increase in brightness of N Her 1934 after the very deep minimum of 1935 (April). Calculations of the mass of the envelopes give $2 \cdot 3 \times 10^{28}$ gr. The condition of the outer parts of the novae itself after the maximum brightness has been discussed by Mustel(7). He has shown that in the spectrum of a nova (immediately after the maximum brightness) the absence of a discontinuity at the limit of the Balmer series may be explained by assuming that the outer part of the nova (where gas masses move with supersonic velocities) is in nearly isothermal equilibrium.

16. The origin of nova outbursts has been discussed by Mustel(8); after a consideration of all novae characteristics he arrived at the conclusion that only for large masses can a plausible answer be given. In this case the outburst could be considered as a mechanism, by means of which the nova frees itself of a mass excess. A. I. Lebedinsky(9) has theoretically considered the question of the velocities of the envelopes ejected by the novae.

17. The most important step in future investigations of novae is a study of their spectra under normal conditions, that is between outbursts. The study of physical conditions prevailing in novae between outbursts will help to solve the question of the origin of the nova outbursts.

Of special importance are investigations in which the problems of the masses of the novae are studied. The following investigations are suggested:

1. In view of the high masses of the novae attempts should be made to discover faint emission bands and absorption lines in the spectra of the old novae displaced towards the red.

It is possible that the undisplaced emission bands found in the spectra of old novae (in the spectra of the novae themselves and not of their ejected envelopes) originate in the extended envelopes, where the gravitation potential is exceedingly small. In this connexion the problem of the process of ejection of matter from the old novae (with an estimation of the dimensions of the envelopes) must be solved. For this work it is necessary to use filters covering the respective emission bands.

2. A search for a possible shift towards the red of the absorption lines in the spectrum of Nova Aql 1918 (Harvard Observatory has spectrograms obtained before the outburst).

3. A further spectroscopic investigation of a double system such as T CrB, especially the study of the variations of the radial velocities from the absorption lines in the spectrum of the satellite (class gM). The emission bands in the spectrum of a recurrent nova should also be studied. An investigation by Sanford (*Ap. J* **109**, 81, 1949) demonstrates the probable presence of large masses in recurrent novae.

REFERENCES

(1) B. V. Kukarkin: *Investigation of the structure and development of stellar systems, based on the study of variable stars* (Moscow, 1949).
(2) P. P. Parenago: *Variable Stars*, **7**, no. 3, 109, 1950.
(3) E. R. Mustel: *A.J. U.S.S.R.* **22**, 65, 185, 1945.
(4) E. R. Mustel: *A.J. U.S.S.R.* **23**, 289, 1946.
(5) V. V. Sobolev: *A.J. U.S.S.R.* **25**, 3, 1948.
(6) V. V. Sobolev: *A.J. U.S.S.R.* **27**, 81, 1950.
(7) E. R. Mustel: *Bull. Crimean Obs.* **7**, 118, 1951.
(8) E. R. Mustel: *Bull. Crimean Obs.* **6**, 144, 1951.
(9) A. I. Lebedinsky: *A.J. U.S.S.R.* **29**, 135, 1952.

II. *Notes received from Japan*

S. Ueno, On the Spectral Sequence of the Stellar Atmospheres. I. *Contributions*, No. 3, *Publ. A.S. Japan*, **1**, 59, 1949.

S. Ueno, On the Spectral Sequence of the Stellar Atmospheres. II. *Contributions*, No. 4, *Publ. A.S. Japan*, **1**, 138, 1950.

Following Russell, assuming the isothermal atmosphere above the photosphere and the opacity due to the continuous absorption of neutral hydrogen atoms and of its negative ion derived by Chandrasekhar and Breen, we have determined the electron pressure and the number of the effective atoms of various elements for each spectral type; and, further, discussed the intensity distributions of absorption lines and the condition for the maximum along the spectral sequence, as well as the hydrogen-metal ratio.

Allowing for Russell's mixture of elements, modified recently by Menzel and Strömgren, we have shown that the theoretical maxima of Hγ and Mg II 4481 are found in spectral type A1, in agreement with observations, these shifts of maxima to the earlier spectral type compared with the current theory can be interpreted in terms of the continuous absorption of H^- and neutral hydrogen atoms.

S. Obi, 'Multiplet Intensities for the Lines $^1D-{}^3P$ of O III and Ne V' *Publ. A.S. Japan*, **2**, 150, 1951.

The relative strengths of the transitions $1s^2 2s^2 2p^2\,{}^1D_2-{}^3P_2$ and $1s^2 2s^2 2p^2\,{}^1D_2-{}^3P_1$ in O III and Ne V are computed including mutual magnetic interactions. The radial integrals which determine the influence of various couplings on the transition probability were calculated with wave functions of the analytic type determined by the present author. The theoretical values of the ratios of the intensities in O III and Ne V for $^1D_2-{}^3P_2$ and $^1D_2-{}^3P_1$ are 2·90 and 2·79 respectively. As is known from simple considerations, the influence of mutual magnetic interactions on the transition probability is very small, but their effects on multiplet splittings are considerable.

Yoshio Fujita, 'Absorption Lines and Bands in the Spectrum of Chi Cygni' *Ap. J* **113**, 626, 1951.

This paper gives results from five spectrograms of χ Cygni obtained with spectrographs attached to the 36-in. refractor of the Lick Observatory. The mean radial velocity of this star near its light-maximum was found to be 2·4 km./sec. from atomic absorption lines, from heads of absorption bands of TiO and ZrO, and from rotational lines of TiO. The existence of AlO, MgH, AlH, CH, etc., molecules in the star's atmosphere appears to be probable from the identification of corresponding lines. The intensity distribution of vibrational bands of TiO was calculated and compared with observation. The vibrational-band temperature of this star was found to be 2200° K.

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Y Fujita, 'A Note on the Chemical Composition and the Classification of Late-Type Stars' *Publ. A.S. Japan*, **1**, 171, 1950 (*T.A.O.R.* No. 57).

From the chemical composition of some late-type stars, it is intended to make an extended new attempt in the general classification of late-type stars. The main point is to classify them into carbon sequence, oxygen sequence and nitrogen sequence.

REPORT OF MEETINGS

Meeting of the Sub-committee on the Spectra of Variable Stars. 10 September 1952

PRESIDENTS: Prof. P SWINGS (afternoon session).

Prof. B. KUKARKIN (evening session).

SECRETARY: Dr J. W. SWENSSON.

This meeting was held jointly with Commissions 27 and 42, and was devoted to an unofficial symposium on the spectra of variable stars, originally suggested by Dr P W Merrill, Chairman of the sub-committee on the spectra of variable stars. At this meeting twenty-seven communications were presented. (See p. 801.)

Meeting of the main commission. 12 September 1952

PRESIDENT: Prof. P SWINGS.

SECRETARY: Dr J. W SWENSSON.

1. List of standard stars for the Southern hemisphere. An informal sub-committee consisting of: *Chairman*: Thackeray; *Members*: Nassau, Gratton, Gascoigne, van Albada will report at the next General Assembly.
2. Clearing house for composite spectra, at Perkins Observatory. Dr Hynek's suggestion was unanimously approved.
3. Additional documents submitted by the Japanese and Russian astronomers after completion of the Draft Report will be added in the *Transactions*. A list of recent publications by Argentine astronomers has been received from Dr Sahade; the corresponding papers will be considered as belonging to the next three-year period.
4. The report of Commission 29 was adopted.
5. The following papers were then read, they were the object of lively discussions:
   (1) K. Wurm, 'Remarks on the Zanstra method'
   (2) D. Chalonge, 'Classification des étoiles des premiers types spectraux, d'après la discontinuité de Balmer'
   (3) G. Thiessen, 'A Magnetic Polarization Effect in Resonance Lines of Stellar Spectra'
   (4) R. Garstang (presented by H. Weaver), 'The Spectrum of Zeta Capricorni'
6. Statements and suggestions were made by various members on the present spectroscopic work at the Bergedorf, Case School, Victoria and Radcliffe Observatories.

Meeting of the Sub-Committee on the Spectra of Novae. 12 September 1952

ACTING CHAIRMAN: Prof. F J. M. STRATTON.

SECRETARY: Prof. L. GRATTON.

Of the different points on which the acting President of the Sub-commission on novae called for discussion the following decisions have been adopted.

Point 2. That a list should be published of all observatories possessing spectra of novae, containing the names of the stars, the number of spectrograms, a general indication of the dispersions, and whether the spectra were taken with a slit spectrograph or with an objective prism.

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Point 4. The Commission is in favour of the project of covering the whole sky with objective prism plates, but is of the opinion that no special programme is needed for this. It is suggested that small instruments might co-operate in this scheme of observations.

Suggestions (1), (3), (5) and (6) are already considered in the programmes of several observatories.

Meeting of the Sub-committee on molecular bands in stellar spectra. 12 September 1952

ACTING CHAIRMAN: Prof. P SWINGS.

SECRETARY: Dr J. W SWENSSON.

The Acting Chairman reported on recently published tables, including the compilation in the new Landolt-Bornstein, *Zahlenwerte und Funktionen*, 3ter Teil, Molekeln II, Springen, 1951.

Father Gatterer reported on the present status of the preparation of the *Atlas of Molecular Bands*. The Acting Chairman stressed the importance of this *Atlas*; he mentioned that Drs Rosen and Swensson analysed several of the spectra of the rare-earth oxides obtained by Dr Gatterer. Dr Pearse expressed his view that Dr Gatterer's *Atlas* will be a very fine piece of work.

It was unanimously agreed that the work of Father Gatterer should be supported.