

45. COMMISSION DES CLASSIFICATIONS SPECTRALES ET INDICES DE COULEUR A PLUSIEURS BANDES

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It is our sad duty to record at the outset of this first report of Commission 45 the loss by death of four of the Commission's most distinguished members: Daniel Barbier, Bertil Lindblad, Jason J. Nassau, and Robert M. Petrie. And, though not Commission members, it is appropriate to add to this list the names of Dean B. McLaughlin and Joel Stebbins. Each of these six men was, in his own way, a real pioneer in the fields of interest to this Commission. Their work will long live in the memory of their successors. Our deepest sympathy goes to their families and colleagues.

INTRODUCTION

The large amount of activity in the fields of spectral classification and multicolor photometry during the past three years certainly attests to the wisdom of the Union in setting up Commission 45. New and most unusual types of objects have been discovered (quasi-stellar sources, X-ray sources, infrared stars) that must be observed and whose spectra must be classified, and new spectral regions have opened up for study in a most dramatic fashion. After all, who would have thought a few years ago that the Lyman- α line would ever be observed from the surface of the Earth, or that one would become accustomed to casually plotting the energy curve of an object using a wavelength scale ranging over a factor of 10^7 ! At the same time previous classification methods have been critically examined and improved and applied to an ever-growing variety of astronomical problems.

THE BIBLIOGRAPHY

It is hoped that the accompanying bibliography, which is a continuation of two previous efforts along the same line (*Trans. int. astr. Un.*, **11A**, p. 335, 1962, and **12A**, p. 479, 1965), will prove useful. Inadequacies are the fault of the compiler and of those who did not bring papers published in obscure journals to his attention. The arrangement and choice of material included are, of course, the responsibility of the compiler alone.

Prospective users are warned, specifically, of the following limitations of the bibliography:

1. Numerous publications reporting colloquia or symposia are noted simply by a single title. Individual contributions in these volumes are *not* noted separately under any heading.

For example, papers given in the recent IAU symposia at Canberra, Utrecht, and Saltsjöbaden are not listed separately. To have done so would have been to increase substantially an already over-long list of references.

2. The bibliography does not contain references to papers giving a classification or photometry for a single object. This policy has no doubt resulted in the omission of a number of significant papers.

3. References are not, in general, given to papers dealing with three-color wide-band photometry. It can be argued that this exclusion is unwise. However, it appears that most of these papers deal with clusters, variable stars, or galactic research, and it is hoped that adequate references to them will be found in other Commission reports. Details concerning all types of photometric systems will, of course, be found in the report of the Commission on Stellar Photometry.

In the construction of the bibliography it has proved useful to attempt to distinguish between papers that actually list classifications and those that provide fundamental spectroscopic data that will, no doubt, be used eventually for the classification of previously unstudied objects. Many of the latter papers contain new and exciting results. The large number of recent papers dealing with the problem of the abundances of lithium and beryllium in stellar spectra, the first steps in the investigation of the ultraviolet spectra of stars, and the spectacular new studies of the astronomical infrared which have led to the discovery of H₂ and H₂O in the spectra of the cool stars all belong to this category.

Section 6, which deals with calibration problems, has been broadened to include the calibration of stellar temperatures and atmospheric chemical compositions as well as of luminosities alone.

UNPUBLISHED WORK

One of the disadvantages of listing the unpublished work known to the President is that of completely leaving out a very large proportion of the work that is, in fact, going on or planned by members of the Commission. The reader is strongly urged, thus, to consult, in addition to the bibliography, the reports of other Commissions, the annual reports of the various observatories, and also J. Sahade's *Information Bulletin for the Southern Hemisphere*, if he wishes to be reasonably well informed of the current state of research in any specific field.

COMMENTS ON THE PAST THREE-YEARS' WORK

It is clearly impossible to summarize adequately the papers published during the past three years that involve work of interest to Commission 45. A few comments may, however, be appropriate:

Though there was much activity in objective-prism work, new techniques (7, 18, 84) were the exception rather than the rule. Stephenson has given (522) an interesting summary of the astrophysical utilization of objective-prism spectra. Spectral data on surprisingly faint stars were shown to be obtainable with a 24-inch (61-cm) telescope (82), and the possibilities of moderate-dispersion objective-prism equipment for accurate spectral classification were emphasized (40). Several investigators (3, 12) pointed out the advantages of fairly high dispersion in surveys for bright-line objects, while the usefulness of the visual region for discovery of S-type stars was noted at the Warner and Swasey Observatory (79).

New phenomena were noted, new classification systems proposed, and substantial improvements in classification accuracy made (118, 148, 149, 171, 172, 173, 178, 188). As is evident from the bibliography, much of the effort of large telescopes was spent on the quasi-stellar sources, and there is now enough material available to justify a rough attempt at spectral classification. A fairly large number of informative papers have dealt with the properties

of the faint blue stars and related objects (106, 125, 136, 137, 139, 146, 147, 161, 185). An interesting development of the problem of the metallic-line stars was the demonstration (119) that the weakness of λ_{4246} of Sc II can conveniently be used to detect marginal cases. And the infrared stars have been shown, at least in some cases (216, 298), to be not quite so unusual as they first appeared to be.

The current situation in narrow- and intermediate-band photoelectric work has been well summarized by Strömgren (261). New techniques have been invented (220, 239, 240, 244, 245, 250, 259, 263, 266), while previous ones have been applied to many normal and peculiar (228, 260, 267) objects. Extensive investigations involving $H\alpha$, the sodium D lines, and other spectral features have continued at Cambridge.

A very large amount of highly accurate multicolor photometry has been carried out in the past three years by Johnson and his collaborators. The infrared photometry of normal stars (290, 310), M dwarfs (292), galaxies (294), carbon stars (311), infrared stars (298, 302, 308), and the truly spectacular results found for several T Tauri objects (309) represent a very substantial increase in our knowledge. Yet the limitations of the multi-color, as compared with the spectroscopic, approach are clearly evident in Figure 3 of Johnson's paper (298), which shows very similar energy curves, as measured through his filters over a large wavelength range, for a highly reddened late B-type supergiant and a much less reddened M2 supergiant!

Spectrophotometric methods have yielded a number of interesting new results, especially involving the equivalent widths of $H\gamma$ in Magellanic Cloud stars (352) and the discovery that the width of $H\alpha$ (355) and of other lines as well (394) can be used as a luminosity indicator in the later-type stars. While much use has been made of the equivalent widths of the various hydrogen lines as an index of luminosity, the surprising results of Lacoarret (359) and of Walker (375) on the variability of the profiles of these lines in the B stars leads one to ask whether this method is really as reliable as it is often claimed to be.

It has become increasingly evident that even among stars that are not noticeably peculiar photometric data are often unfortunately a rather poor substitute for a spectrogram. That this is true in the later spectral types has been recognized for some time. However it has been generally assumed that Strömgren's m_1 value is a good index of the metal/hydrogen ratio in F- and G-type stellar atmospheres. This assumption has recently been called into question by Conti and Deutsch (457), who have pointed out that the value of the turbulent velocity is also of major importance in this connection. Though the situation is not entirely clear at this time, it is evident that the correct interpretation of even quite sophisticated photometric data is a very difficult problem, and one not to be attacked lightly.

A controversy affecting stellar luminosities has recently arisen through Hodge and Wallerstein's claim (461) that the distance of the Hyades is some 18% larger than has been previously believed. The effects of this change on galactic and extragalactic distance scales are, of course, very substantial. It may be hoped that this matter will be settled soon. The effect of stellar rotation on the position of stars in the H-R diagram has also come in for very considerable discussion (404, 456, 462, 464, 467, 470, 474). It will probably prove desirable to set up standards of differing rotational velocity for the most accurate classification of early-type stars.

CATALOGUES OF SPECTROSCOPIC DATA

Several very valuable compilations of spectral classifications and photometric data have been published during the past three years. It is already evident that these are proving of great value to workers in our field.

1. Miss Hoffleit's new edition of the *Yale Catalogue of Bright Stars* (503) now contains either MK spectral types or at least spectroscopic indications of luminosity (*c,g,d*) for a large proportion of its 9110 stars.

2. The exhaustive *Catalogue of Stellar Spectra Classified in the Morgan-Keenan System* (506) compiled by Jaschek, Conde, and de Sierra is an essential aid to the stellar astronomer. A second edition including new data is eventually planned.

3. The large compilation of stellar rotational velocities by Boyarchuk and Kopylov (485), the list of photoelectric $H\beta$ values of 1217 bright stars published by Crawford and his collaborators (232), and Keenan's catalogue giving spectral types from individual spectrograms of 253 Mira variables (156), are all most useful pieces of work.

4. Two extensive and very useful catalogues of photoelectric multicolor data have been published by the Arizona group:

(a) Five-color photometry (*UBVRI*) of the 1325 brightest stars north of $\delta = -50^\circ$ (288). This is largely complete to $m_v = 5.0$.

(b) Multicolor data (five colors or more) for 1567 stars of the *Bright Star Catalogue* (304). Six hundred and fifty-three of these have been measured in J and K (1.25 and 2.2μ), and 268 in L (3.4μ). Also *UBV* data are given for nearly 5000 bright stars over the entire sky on the basis of a new reduction of available Cape reflector *U* values.

Those who have labored long and diligently to prepare these data catalogues merit our heartiest congratulations and thanks.

Two additional catalogues of spectroscopic data are also in the planning stage:

1. (Jaschek): A new catalogue and bibliography of Be stars, continuing the work of Merrill and Burwell, is being prepared. It is hoped that this will be ready in 1967.

2. (Stephenson): A comprehensive catalogue of the carbon stars is being compiled at the Warner and Swasey Observatory. Spectral plates are being used to check ambiguities in published data. While it was originally planned to publish this catalogue in the near future, it has been decided to delay publication until more data for stars of the Southern Hemisphere become available.

Both Dr Jaschek and Dr Stephenson will appreciate receiving unpublished data for inclusion in their catalogues, and will be happy to make information available upon request.

Despite the numerous stellar data catalogues now available or in preparation, it is unfortunately true that there is still much labor involved in obtaining relevant information concerning miscellaneous spectroscopic work, duplicity, variability, proper-motion and radial-velocity data, etc., for specific objects. This situation is made even more complicated than it needs to be by lack of agreement on a common equinox for tabulated positions. The President has a strong preference for the use of 1900 coordinates in data catalogues, and feels that to use any other equinox is to invite chaos; positional catalogues are, of course, a different matter.

The total number of individual stars in the Milky Way system for which spectroscopic information of some sort is now available appears to be of the order of at least 800 000, and if we add in the remaining unclassified stars for which various types of significant data exist we arrive at a figure of the order of approximately one million for the number of objects that should be contained in a master stellar data catalogue. It can be argued that not all of the information that might be contained in such a catalogue is especially useful (!), but certainly data have a surprising way of becoming useful just when we least expect it.

There already exists a fairly comprehensive spectroscopic information card catalogue at Michigan for those normal stars for which two-dimensional spectral classifications exist and for a large variety of spectroscopically peculiar objects. However, this contains a mere 25 000 or so stars, a far cry from a million. And even this has proved troublesome to keep up to date.

Yet the President feels that the time may be ripe for at least investigating the possibility of establishing a general stellar information center that would eventually become a comprehensive storehouse of information—giving data and the sources thereof—on the various inhabitants of the Galaxy. Perhaps the Commission on Galaxies would like to start thinking about a similar data center for galaxies. Presumably by the time either center becomes organized the question of which center should include the quasi-stellar sources will be settled for good!

SPECTRAL ATLASES

At the moment a number of spectral atlases are being prepared:

1. (Fehrenbach): An atlas of stellar spectra obtained with the small objective prism will appear shortly in the *Journal des Observateurs*; prints from this atlas will be available separately at cost.

2. (Landi Dessy and Jaschek): The Córdoba spectral atlas at $42\text{Å}/\text{mm}$ is approaching completion and it is hoped to be able to exhibit it at the Prague meeting. As far as possible the MK criteria have been retained; this has been feasible in general in the earlier spectral classes.

3. (Meinel and Christy): A new atlas containing spectra of about 300 stars, equally divided between normal and peculiar objects, is being prepared. The plate material covers a large spectral range.

4. (Morgan, Keenan, and Hiltner): Work is continuing on the revision of the MK classification system in connection with the preparation of the new edition of the Yerkes Spectral Atlas. New criteria have been introduced that permit a smoother and more precise classification for the O and B stars. A series of standard coeval spectral sequences will be incorporated in the Atlas.

Members of the Commission await the appearance of these atlases with great anticipation. The need for these has been the subject of repeated concern at recent IAU meetings.

W. P. BIDELMAN
President of the Commission

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Unpublished Work

(Bidelman): Numerous new H α -emission stars, many fairly bright, have been noted on 10 $^{\circ}$ Curtis Schmidt plates and are awaiting publication. Three stars in the faint unstudied galactic cluster NGC 2421 were detected as emission objects by D. MacConnell.

(The): Approximately 90 bright-line stars, $m_v = 12$ to 16, have been found by B. Hidajat in a region of about 60 square degrees in Ara.

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Unpublished Work

(Albers): One hundred and nineteen of the Hetzler 'infrared' stars have been classified on plates obtained some years ago at the Warner and Swasey Observatory. In agreement with the results of C. F. Rust (*Astrophys. J.*, **88**, 525, 1938), the majority of these stars are found to be normal late M-type stars; a few are carbon or S-type objects.

(Bartaya): Additional classification work has been carried out at Abastumani and at the Sternberg Institute as follows:

Author	Region	No. of Stars
Kalandadze, N. B.	$\alpha = 4^{\text{h}}26^{\text{m}}, \delta = +19^{\circ}$ $\alpha = 4^{\text{h}}40^{\text{m}}, \delta = +29^{\circ}$	3400
Metreveli, M. D.	$\alpha = 4^{\text{h}}30^{\text{m}}, \delta = +25^{\circ}5'$	3000
Apriamashvili, S. P.	$\alpha = 19^{\text{h}}00^{\text{m}}, \delta = +5^{\circ}$	4000
Apriamashvili, S. P., and Kuznetsov, V. I.	$\alpha = 19^{\text{h}}20^{\text{m}}, \delta = +17^{\circ}$	500
Uranova, T. A.	$\alpha = 19^{\text{h}}15^{\text{m}}, \delta = +11^{\circ}$ $\alpha = 18^{\text{h}}21^{\text{m}}, \delta = +22^{\circ}5'$	1500
Bartaya, R. A., and Kharadze, E. K.	Vul I Cas III, Cas IV, Cas VII	1300 400
Kostiakova, E. B.	Orion	7000
Voroshilov, V. I.	Aquila	—

Also M. A. Shiukashvili has examined criteria for quantitative two-dimensional classification of objective-prism spectra of Fo-G5 stars.

(Bidelman): F- and G-type stars of low metal abundance can be readily detected on high-quality plates taken with the 10°-prism combination of the Curtis Schmidt. A program of discovery and further study of such objects is now being carried out by H. Bond. Another

student, J. Schmitt, is engaged in an extensive investigation of K-type stars possessing abnormally strong CN bands, and is detecting many such stars on available objective-prism plates.

The visual and infrared regions of Curtis Schmidt spectra are the subjects of detailed examination by D. MacConnell and H. Albers. Much profitable work remains to be done in these spectral regions.

(Iwanowska): Observations for the Toruń spectral sky survey are being continued. The Milky Way belt accessible from Toruń within latitudes $\pm 6^\circ$ has been covered with photometrically calibrated exposures. A number of plates have also been taken at higher latitudes.

Spectrophotometric gradients for about 60 F, G, and K stars in the blue-yellow-red region have been determined by R. Głębocki. He is attempting to distinguish stellar population types from these observations.

(Lodén): The pre-classification of stars, by visual inspection of their objective-prism spectra, for the selection of interesting objects involved in the Stockholm Southern Milky Way survey, is being carried out in collaboration with A. Sundman. A special study of the possibility of performing accurate spectral classification by visual inspection of microphotometric records of objective-prism spectra is also under way. Spectral classes have been derived in this manner by K. Lodén for 447 stars in S.A. 193 from plates taken at the Boyden Observatory.

(McCarthy): M. F. McCarthy and P. J. Treanor, in cooperation with A. Upgren of the U.S. Naval Observatory, have begun a study to determine the degree of inclination of layers of equal star density at intermediate galactic latitudes. Plates centered on Selected Areas 28, 54, 106, and 107 have been obtained at the Dyer and Vatican Observatories.

M and emission-line stars are under study in the Cygnus region at $l = 88^\circ$, $b = 0^\circ$, which was searched earlier for carbon stars. Also, the search for concentrations of Population I objects in regions where high-velocity hydrogen gas clouds have been detected is continuing.

(McCuskey): P. Pesch has shown that the infrared Ca II triplet can be detected in emission on widened spectra of bright T Tauri stars taken with the 4° prism of the Burrell Schmidt. Its possible detection in very faint stars is a matter for further study.

As part of a continuing study of dM stars in the Hyades, Pesch has investigated the use of the sodium D lines in low-dispersion spectra as a luminosity discriminant. Due to a nearby TiO band, the D lines cannot be seen in dwarf M stars later than M1 on plates taken with the 4° prism; on dense plates taken with the 6° -prism combination, however, they are visible in Barnard's star, M5 V.

Infrared spectra of some of the stars observed photometrically in (302) are also being investigated by Pesch. Studies of the available spectra appear to indicate that the Haro-Chavira objects are predominantly M-type stars rather than carbon stars.

(Stephenson): Plates covering the blue and visual spectral regions have been used by C. B. Stephenson and C. L. Terrill for the classification of 34 additional unusual objects; 26 of these are new S or M-S stars.

The vicinities of the stronger X-ray sources are being searched from the 8th to the 15th magnitude for peculiar spectra, at dispersions of 300 to 1100 Å/mm.

C. L. Terrill is working up the infrared plates of about 50 late-type variable stars accumulated with the Burrell Schmidt over the past ten years. New observations to fill phase gaps in the earlier material are also being made.

(The): Surveys of M stars are in progress in the direction of the south galactic pole, near the open cluster M6, and in four regions in and around the Eta Carinae Nebula. Almost all of the plates necessary for extending McCuskey's work on the stellar luminosity function to the southern hemisphere have been obtained.

B. Hidajat has classified about 950 stars later than M5 as well as about 300 stars of classes B8-A2 and G8 III-K2 III in an area of 25 square degrees at $l = 359^\circ$, $b = -10^\circ 6'$.

(Velghe): An infrared survey of cool stars at $l = 77^\circ$ and $0^\circ < b < +22^\circ$, based on plates taken at the Warner and Swasey Observatory, is in progress. Also a study of criteria for the classification of M, S, and C stars in the visual and infrared at various dispersions is continuing.

2. *Classifications Employing Visual Inspection of Slit Spectrograms*

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Unpublished Work

(Bidelman): J. Robinson has obtained slit spectra in the visual region of more than 100 of the brighter early-type stars in a 60° by 60° region at the anticenter. Several new bright- $H\alpha$ stars were found. Several other spectral classification programs are under way with the 37-inch reflector.

A comprehensive re-discussion of the problem of the spectral classification of the carbon stars, with special reference to possible luminosity effects, is currently being made by C. P. Gordon. Her investigation is based on spectra in the visual region of approximately 115 stars at dispersions of 88 to 103 \AA/mm as well as spectra in the blue of some 30 additional objects.

(Blanco): At the Flagstaff Station of the U.S. Naval Observatory J. Priser, H. Guetter, and V. Blanco have undertaken the classification of all the parallax and comparison stars in the observatory's astrometric program. Present plans call for the classification of 322 parallax stars and about four comparison stars in each case. The stars range from $m_v = 12.0$ to 16.5.

J. Christy has assigned MK classes to 24 OB stars in the anticenter direction. Approximately 260 stars selected from the Appendix to IAU Symposium No. 1 (*Co-ordination of Galactic Research*, 1955) are being classified by H. Guetter. For classification work the U.S. Naval Observatory now has a new Cassegrain spectrograph similar in design to the Mt Wilson 60-inch Cassegrain one, and a reducing camera with objective gratings designed by A. Meinel.

(Heard): Fifty-seven stars in the field of the α Persei cluster have been classified on the MK system. This work will appear in a joint paper with the late R. M. Petrie.

(Jaschek): A survey of southern B5-A0 stars brighter than magnitude 6.5, an extension of (153), is in progress. Of a total of 1100 stars, 550 have already been observed at $H\alpha$ at a dispersion of 180 \AA/mm . Nine emission objects were found during the survey, four being previously known.

Spectral classification of southern HR stars at 90 \AA/mm is continuing.

(Keenan): Classification criteria that can be used for late-type stars on plates ranging from 10 to 100 \AA/mm are being re-examined. Spectrograms at 10 \AA/mm permit the use of a number of atomic-line ratios to determine whether the MK subtypes previously established from the intensity of TiO bands are consistent for stars of high and low velocities.

(McCarthy): Image-tube spectra of three of the faint Pleiades stars listed in the Vatican catalogue show dwarf characteristics.

(McCuskey): In collaboration with N. Houk 115 OB stars brighter than $m_{pg} = 11.5$ in the LF5 region in Cassiopeia are being observed at 130 \AA/mm .

An emission-like feature near $\lambda 6400$ noted in low-dispersion objective-prism spectra of M stars is being investigated by R. K. Honeycutt with the slit spectrograph at a dispersion of 390 \AA/mm . This feature is probably not a true emission but instead appears to be associated with the incipient appearance of the red ZrO band at $\lambda 6474$.

(Meinel): New ultraviolet spectral criteria for the classification of middle-type stars are being established by D. C. Barry, who is utilizing primarily plates taken with the new Steward Observatory Cassegrain spectrograph.

(Morgan): Attention has recently been drawn to the importance of the concept of 'coeval sequences' in stellar associations and clusters. Even if investigation is restricted to 'young' star clusters, the spectra of O and B stars sometimes differ greatly from cluster to cluster; this effect is sometimes encountered between differing parts of the same stellar association. For the most precise spectral classification, it now becomes necessary to refer newly-classified spectra to some one of a series of coeval sequences. A short discussion of this subject is included in M. Hack's *Memorial Volume for Otto Struve* (in press).

A paper by R. F. Garrison entitled 'Some Characteristics of the B and A Stars in the Upper Scorpius Complex' is also awaiting publication.

(Schmidt-Kaler): Some 30 dwarf Be stars as well as 12 B- and A-type foreground stars in and around M₃₁ are being classified on David Dunlap Observatory spectrograms.

(Sharpless): The possibility of using 300 Å/mm infrared spectra of carbon stars for purposes of spectral classification is being investigated. It is hoped to shed light on the question of the apparent clusterings of these objects. Infrared classification of symbiotic stars is also planned.

(Slettebak): Spectral types of 77 A-type stars near the north galactic pole have been determined by A. Slettebak and R. Wright.

(Stephenson): N. B. Sanwal has completed the classification of nearly 200 visual binaries of small angular separation expected to include an off-main-sequence component. The purpose of the program was the estimation of mass as a function of position in the H-R diagram. Comparison of the results with theoretical evolutionary tracks is consistent with, but does not demand, the conclusion that evolution up to the red-giant stage takes place at constant mass.

In another program involving binary stars, visual binaries containing B-type stars are being observed. Some 40 or 50 such systems will ultimately be studied.

The brighter B to F supergiants of the *Luminous Stars* catalogues are being observed, with emphasis on those reported as having H α in emission; the latter are observed both in the blue and at H α . Curiously enough, most of these have not shown bright H α on our slit spectrograms.

S. Wyckoff is observing approximately 80 late-type variables in the infrared at 390 Å/mm using a grating blazed for this spectral region. Satisfactory spectra of stars as faint as $m_v = 14$ can be obtained with the 36-inch reflector in three-hour exposures.

(van den Bergh): *UBV* photometry and MK spectral classifications are currently being obtained by R. Racine for approximately 100 stars situated in reflection nebulae.

(Westerlund): A new system of classification for Wolf-Rayet stars has been devised by L. F. Smith, now at the University of California, Los Angeles. For WC stars her system agrees, in principle, with that of Hiltner and Schild (149). For WN stars it is substantially different; the differences lie in the attitudes adopted towards the spectra of binary stars. In Miss Smith's system, it is considered that the spectrum of a Wolf-Rayet star in a binary system is modified only in the strengths of the emission lines with respect to the continuum. The spectrum may still be classified according to the relative strengths of the emission lines, and it is given a classification explicitly indicating its binary nature.

(Yamashita): Seventy-five carbon stars for which Victoria spectrograms exist have been classified in the C system. Intensities of the various molecular bands have been measured. Three new CH stars and three possible members of this group were found. Plots of the temperatures obtained by Mendoza and Johnson versus the C subtypes seem to indicate that there are two groups in the carbon stars. No other characteristic difference, however, has been found spectroscopically between these two groups.

A total of 269 bright M-type stars have been classified in the MK system. The relation between the assigned luminosity classes and Mt Wilson spectroscopic absolute magnitudes shows considerable scatter.

3a. Classifications Employing Spectrophotometric Measurements: Narrow- and Intermediate-Band Photoelectric Work

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Unpublished Work

(Blanco): H γ photometry and MK classifications for about 100 early-type stars in the I Lac and α Per associations are being carried out at the U.S. Naval Observatory by H. Guetter.

(Gyldenkerne): Narrow-band photometry has been continued for late-type stars. Most of the data has been obtained by Copenhagen and Brorfelde staff members working at the Lowell Observatory in Flagstaff.

For the G and K stars P.U.B.S. Jacobsen made tests of the transmission bands of the k , n , m , g classification indices. Observations in an improved system have been carried out for bright stars and calibration objects. In collaboration with P. Dickow and P. Rasmussen the new system has been investigated preliminarily along the lines followed in (239). The improved third parameter C' correlates linearly with $[\text{Fe}/\text{H}]$ determined by Wallerstein and Helfer in a range from the Hyades value to about 1.0 smaller. The scatter in the relation does not exceed the measurement uncertainty. The photometric accuracy of C' corresponds to a mean error of ± 0.03 in $[\text{Fe}/\text{H}]$. The photometric accuracy of the absolute magnitudes is estimated to be ± 0.03 (m.e.).

B. Helt has observed about a hundred bright Mo-M6.5 giants and supergiants with the classification indices described at the Stockholm Symposium in order to investigate this two-dimensional classification method thoroughly. The color-index differences $m_2(4370, 4800, 5350)$ (spectral-type index) and $m_4(4510, 4970, 5500)$ (mainly luminosity-dependent) are being used in extended observations of bright stars and selected variable stars. Photoelectric scans have been obtained to study the possibility of an improvement of the classification sensitivity of these indices.

(McNamara): Dwarf cepheids, W Ursae Majoris variables, and RR Lyrae stars are currently being observed in the Strömgren four-color system. Narrow-band filters have been employed

to measure the β index and $(U-B)_0$ color indices of the β Cephei variables. These data have been used to define the period-luminosity relationship of these stars. Globular clusters are also being studied by narrow-band methods: the strength of the G band and $H\gamma$ are used to obtain information on spectral type, and a metal-index indicator is also measured.

(Redman): P. J. Andrews has completed the measurement and discussion of $H\alpha$ intensities in about 1000 OB stars, 300 of which were measured at the Radcliffe Observatory. For class V stars the $H\alpha$ strength is about as accurate an absolute-magnitude criterion as is $H\beta$ or $H\gamma$, and for supergiants (where the line is partly in emission) it is more accurate. Stellar age appears to have but little effect on the hydrogen line-absolute magnitude relation, but stellar rotation introduces a considerable scatter.

Intensities of three Si III lines and of $\lambda 4471$ of He I have been measured both photoelectrically and photographically by J. B. Hutchings in various O and B stars, especially those of high luminosity. He has also measured $H\gamma$ profiles. Model atmospheres are being discussed using these measurements.

The $\lambda 6305$ Sc I line has been measured by R. F. Griffin in 300 G and K stars using a 1.5 Å bandwidth. The line shows a very steep increase in strength with diminishing temperature.

It is our experience that satisfactory discussion of narrow-band measurements is hampered by lack of calibration data, especially masses and absolute magnitudes in class III stars, and by lack of detailed theoretical models of late-type atmospheres in general.

(Schmidt-Kaler): Strömngren four-color photometry of 36 globular and 41 open clusters is being carried out utilizing different apertures, and also $H\beta$ photometry for 15 globular and 41 open clusters.

(Sinnerstad): Recently I have been working on intermediate and narrow-band photometry of early-type stars. The instrument used is a two-channel photometer attached to the 1-m reflector of the Stockholm Observatory. Measurements have been carried out in Strömngren's u, v, b, y system and in two other systems defined by the following filter characteristics:

I		II	
λ max	half-width	λ max	half-width
3530	70	3540	70
3860	100	3740	90
4240	80	4030	30
5010	70	4510	70

The first system is identical with that used in the ζ Aurigae program of 1963-64. In the second system, which aims at deriving luminosity criteria directly applicable to Schmidt spectra, the filters 3540, 4030 and 4510 yield a measure of the magnitude of the Balmer discontinuity, while the filters 3740, 4030 and 4510 yield a measure of its effective location.

Most of my effort has been devoted to determinations of line intensities by means of simultaneous measurements and the narrow-band techniques. Up to May 1966 $H\beta$ was measured in 131 stars of spectral types O6-F8.

An extensive observational program for measuring the line intensities of $H\gamma$, $H\beta$ and He I $\lambda 4471$ with the same techniques is now going on in collaboration with J. Arkling. On the program are B0-B5 stars brighter than $7^m.5$ with an extension to fainter magnitudes in some associations such as I Ori and I Gem. The linear relation between the preliminarily measured intensities of $\lambda 4471$ and the equivalent widths as determined on high-dispersion spectrograms indicates a scatter of ± 0.11 E.A. The Mg II $\lambda 4481$ line influencing the $\lambda 4471$ measurements contributes to this scatter. As the Mg II line, however, is rather weak in main sequence B0-B5 stars and mainly varies with spectral type, no serious effects are likely to be introduced in the determinations of helium abundance.

(Strömngren): An interesting application of narrow-band methods to the study of the A-type stars has recently been made by R. C. Henry, who has photoelectrically determined K-line strengths in numerous normal and metallic-line stars. A number of stars classified as Am were found to have normal K-line strengths.

(van den Bergh): A seven-color system with intermediate-width bands centered at $\lambda\lambda 3500, 3800, 4150, 4250, 4500,$ and 4861 wide and narrow is currently being applied by R. McClure to the study of stars, globular clusters, and galaxies at David Dunlap Observatory.

(Westerlund): The following three photometric systems have been used to assist in the solution of particular astrophysical problems. It is assumed that a pre-classification has been carried out either by objective-prism techniques, by two-color photography, or even by U, B, V photoelectric photometry. The aim is to obtain accurate and detailed information for a large number of faint objects for which moderate-dispersion slit spectra can not be obtained without using an excessive amount of observing time:

The photometric systems are:

- I. (a). A six-color narrow-band system, in which the effective wavelengths of four colors agree well with those in Strömgen's four-color system. The peak transmission wavelengths and the half-widths of the filters are: $y, 5480\text{Å}, 100;$ $b, 4700, 100;$ $v, 4090, 100;$ $u_1, 3780, 30;$ $u, 3640, 100;$ $u_2, 3550, 100.$
- (b). The six-color system with a red (R) and an infrared (I) wide-band filter added: $R, 7000\text{Å}; I, 8800\text{Å},$ approximately.
- (c). y, b, v, u_2 from I(a) with narrow-band filters added for measuring $H\beta$ and selected He I and He II lines. For certain programs narrow-band observations of the interstellar K line and of $\lambda 4430$ are added.
- II. A five-color narrow-band system for studies of Wolf-Rayet stars. The filters are chosen so that emission features are avoided as far as possible. The colors are: $r, 5995, 100;$ $v, 5180, 130;$ $b, 4270, 60;$ $u, 3640, 100;$ $u', 3500, 80.$
- III. A seven-color narrow-band system for studies of planetary nebulae. The filters are: lines, $N_1; H\beta; H\gamma; \lambda 3727;$ continuum, $5300, 140; 4200, 70; 3500, 90.$

Details can be found in a contribution to the February 1966 Groningen ESO colloquium.

(Williams): I have devised an intermediate-band system of five bandpasses between $\lambda 4400$ and $\lambda 7500$ from which three indices are formed. The first indicates the strength of weak lines; the second the strength of medium-strong lines; and the third a color temperature for the star. The system was constructed from an analysis of the distribution of weak-line, medium-strong-line, and strong-line strength with wavelength in the Sun. The system should be applicable to F- and G-dwarf stars. Observations are now being obtained of stars that have been analyzed spectroscopically in order to verify the action of the indices and to calibrate them. It is planned to observe a large number of F- and G-dwarf stars to obtain the distribution of M/H ratios and microturbulent velocities in these stars.

3b. Classifications Employing Spectrophotometric Measurements: Multicolor Work

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Unpublished Work

(Bahng): Infrared photometry of late-type stars is being carried out in three bands with interference filters and a lead-sulfide detector. The effective wavelengths of the bands are 1.21, 1.59, and 2.15 μ . Preliminary results are:

The energy distribution of G, K, and M stars in the infrared shows a considerable deviation from that of a black body. The deviation is most apparent at the 1.59 μ band, in a sense that there is an excess continuum emission in this band relative to the other two bands. This is interpreted as due to the H⁻ opacity minimum in the atmospheres of these stars. There is some indication that the three-color observations in the infrared may be used to establish a luminosity criterion; but more observations, particularly of dwarf G, K, and M stars, are needed to be certain of this.

The infrared colors of carbon stars show a poor correlation with the Keenan-Morgan temperature class for stars of C₄ or later.

(Canavaggia): Additional results of the work of Mlle J. Rousseau will soon be forthcoming.

(Elvius): Multi-band photoelectric measurements of relatively bright stars are being made by L. Häggkvist with the refractor of the Uppsala Observatory.

3c. Classifications Employing Spectrophotometric Measurements: Miscellaneous Methods

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Unpublished Work

(Chalonge): Work in progress includes the classification of blue halo stars brighter than $m_v = 11$, companions of O stars in binary systems and clusters (Mlle M. L. Burnichon), faint stars of h and χ Persei (Mlle L. Divan), little-reddened stars of the Orion association (Mlle M. L. Burnichon) and stars of the cluster NGC 2264.

(Elvius): A large number of spectral plates of various Selected Areas have been obtained with the Schmidt telescope of the Uppsala Southern Station; for details see the Report of Commission 33. A field in S. A. 19, including the cluster NGC 7654, has also been investigated.

The region around the radio source Centaurus A is being studied by A. Elvius on the basis of spectral plates obtained by C. Roslund.

(Henize): W. Hughes has measured equivalent widths of $H\gamma$ and $H\delta$ for 20 B-type members of the I Lacerta association from 4° -prism plates taken with the Michigan Curtis Schmidt. These results were compared with values obtained from $17\text{Å}/\text{mm}$ coude spectrograms. It was concluded that (1) the equivalent widths for strong lines can be measured from the objective-prism plates to somewhat better than $\pm 15\%$, and (2) measuring the equivalent widths gives somewhat better results than simply determining the central depths, if the prism plates are taken in good seeing.

(Schmidt-Kaler): Spectral scans from $\lambda 3500$ to $\lambda 4500$ of about 50 supergiants of classes F to K and of five cepheids, obtained with a resolution of 20Å with the David Dunlap Observatory 74-inch telescope, are now being utilized for quantitative spectral classification.

4a. Data Relevant to Spectral Classification: Continuous Spectra

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Unpublished Work

(van den Bergh): A catalogue of absolute energy distributions of 154 stars is being prepared for publication in collaboration with G. L. Hagen.

4b. Data Relevant to Spectral Classification: Line Spectra

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Unpublished Work

(Slettebak): Studies are presently under way on the axial rotation of A-type stars in the north galactic pole region. Rotational velocities are also being determined for members of the Scorpio-Centaurus association and the η and χ Persei clusters.

5. Papers Dealing with the Relation of Colors to Spectra

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6. Papers Dealing with Calibration Problems

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457. Conti, P. S., Deutsch, A. J. 1966, Color anomalies and metal deficiencies in solar-type disk-population stars. *Astrophys. J.*, **145**, 742.
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460. Graham, J. A. 1965, The absolute magnitude of some galactic Wolf-Rayet stars. *Observatory*, **85**, 196.
461. Hodge, P. W., Wallerstein, G. 1966, A suggested revision in the distance to the Hyades and its implications. *Publ. astr. Soc. Pacif.*, **78**, 411.
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463. Kelsall, T., Strömgren, B. 1966, Calibration of the Hertzsprung-Russell diagram in terms of age and mass for main-sequence B and A stars. *Vistas in Astr.*, A. Beer and K. Aa. Strand, eds., **8**, 159.
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Unpublished Work

(Schmidt-Kaler): An analysis of the OB stars classified in the Hamburg-Warner and Swasey Observatory *Luminous Stars* volumes indicates the following:

The stars classified OB⁺ or OB with continuous emission at the Balmer limit (ce) but no H α emission represent a natural group with $\bar{M}_v = -5.3$, $\sigma_M = \pm 0.6$, $(\bar{B}-\bar{V})_0 = -0.28$, $\sigma_{B-V} = \pm 0.04$, comprising MK types O5-9 and O9.5-B1 Iab-IV. It is a group of rapid rotators *without* large shells, in contrast to the dBe stars. A calibration of the remaining groups is given in the following table:

Group		M_v	$(B-V)_0$
OB ⁻ ce	no H α em.	-3.9	-0.28
OB ⁺ no ce	"	-6.2	-0.24
OB	" "	-5.0	-0.26
OB ⁻	" "	-3.9	-0.27

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