Photo-electric scanning instruments will undoubtedly be developed rapidly and, with the use of multi-channel slits, may eventually rival photographic methods in speed as well as in accuracy. Certainly for the study of line profiles, or other purposes where only short stretches of the spectrum are to be investigated, high-dispersion photo-electric spectrophotometry will be used more and more. The relative advantages of photographic and photo-electric methods were discussed by T. Dunham, Jr. (**10**).

Several members of the Sub-Commission have recommended that calibration devices used for photographic spectrophotometry should be checked by photo-electric means since the response of photomultiplier tubes is linear over a large range of intensity. This should certainly be done where possible, although at the very low light levels that are often used in calibrating spectrographs, the sensitivity of some commercial photometers is not adequate.

The calibration devices at several observatories have already been checked by means of the step filters made available to the Sub-Commission by Minnaert and Kienle and re-calibrated at Heidelberg by Kienle. The thanks of the Sub-Commission are extended to Professor Kienle and Professor Minnaert for their co-operation in thus encouraging the use of standardized procedures in spectrophotometry.

K. O. WRIGHT
*President of the Sub-Commission*

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## 29*c*. SOUS-COMMISSION DES CLASSIFICATIONS STELLAIRES

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MEMBRES: Buscombe, Mlle Divan, D. S. Evans, Keenan, Morgan, Petrie, Ramberg, Mlle Roman, Strömgren, Thackeray.

### INTRODUCTION

The isolation of groups of stars having similar properties—and the subsequent study of relations between these groups—has proved essential to our understanding of the stellar universe. Naturally this categorization of stars has been accomplished in a variety of ways. Sub-Commission 29*c* is primarily concerned with the classification of stars on the basis of their spectra, whether the requisite spectral information is acquired by conventional photographic techniques or by more sophisticated photo-electric instrumentation.*

*Thus a classification of variable stars based on their light variations alone is not considered a concern of this Sub-Commission.

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As our knowledge of the stars has grown, the number of parameters needed for an adequate stellar classification has correspondingly increased. In the early days of astrophysics the surface temperature appeared to be the only certain variable among stars, though even then the carbon stars pointed to the possibility of variations in chemical composition. Later the existence of a large spread in luminosity (or surface gravity) at the same surface temperature was recognized; this provided an explanation for certain inadequacies of the earlier linear spectral classification and at the same time spurred the development of two-dimensional classification systems.

It should be remembered that a continuous variation (within definite bounds) in the two classification parameters just mentioned has always been strongly indicated; the assignment of objects to categories has never implied the existence of discontinuities (see Morgan, W. W., *P.A.S.P.* **72**, 153, 1960).

More recent spectroscopic work has revealed the existence of many 'abnormal' objects that cannot be fitted into even the most detailed two-dimensional classification scheme. It now seems highly likely that the hydrogen-to-metal ratio varies from one star to another, and there is even evidence that the chemical composition of the surface layers of some stars is markedly variable with time. These indications have necessitated the inclusion of additional parameters into our classification systems and have also demanded a re-evaluation of former interpretations of conventional spectral types and color indices. It further appears that, at least in the Galaxy, the stars that originated in the distant past were formed, in general, from material containing a smaller proportion of the heavy elements than those that originated more recently. It is unlikely, however, that this is the only reason for abundance variations—a star's place of origin might also be expected to affect its initial chemical composition.

There may be further parameters of stellar classification whose significance is at present only glimpsed: magnetic fields and angular rotation also vary widely among stars. New questions arise here: are high surface magnetic fields essentially limited to sharp-lined objects with peculiar spectra? and how dependent is the spectrum of a rotating star on the direction from which it is seen?

In view of the complexities stated above, it is the task of the classifier to devise means, as efficient as possible, that will permit the assignment of vast numbers of stars to unique positions in an adequate multi-dimensional classification scheme; it is the task of the astrophysicist and the stellar astronomer to investigate in detail the characteristics of a representative sample of 'typical' objects so classified. The crux of the problem rests in the phrase 'as efficient as possible'. It is clear that the more detailed the classification attempted, the more extensive, or at least the more ingeniously chosen, must be the observational data utilized.

## RECENT WORK IN STELLAR CLASSIFICATION

Activity in the field of stellar classification, especially in the application of methods previously devised, has been enormous during the past few years. The bibliography comprising Appendix 1 of this report, which lists 231 papers published during 1957–60, emphasizes this fact. Most of the papers included give detailed results, but some are general discussions, or refer to work not published in full. Comments referring to work in progress (from a small number of those active in this field) follow the various sections. The divisions of Appendix 1 are self-explanatory; it is hoped that the method of presentation adopted will prove useful, and it is also hoped that the list is not seriously incomplete. Many papers that are essentially photo-electric or astrophysical in motivation have been omitted, as have papers dealing with the classification of only one star.

As a glance at the bibliography shows, extensive objective-prism work in many countries has resulted in the recent classification of many thousands of stars; in many cases classification in more than one dimension has been attempted. The increasing use of the ultra-violet and infra-red spectral regions, and attempts to utilize very low dispersions, are among recent trends in this work. Much also has been accomplished with slit spectrographs: especially important has been the investigation of the brighter members of galactic and globular clusters and the Magellanic Clouds, and the revival of interest in the integrated spectra of stellar groups of all kinds. Much remains to be done, however, in the field of systematic classification. Accurate spectral types are still not available for a great many of the brighter stars, especially in the south, and, of the approximately 500 visual binaries for which orbits exist, less than one-half possess any spectroscopic indication of luminosity.

Modifications of present systems of classification have been under investigation in various quarters. Appendix II contains a suggested change in the luminosity notation of the MK system, which can be further discussed, if desired, at the Berkeley meeting.

Two developments deserving special mention are (*a*) the highly successful application of narrow-band photo-electric photometry to the classification problem by Strömgren and others, and (*b*) the discovery by Wilson and Bappu of the close correlation between Ca II emission width and luminosity for late-type stars. And, with previously unavailable spectral regions now awaiting imminent investigation, the developments of the future may be expected to be equally, if not even more, significant.

## SPECTRAL ATLASES

A very useful collection of illustrations of typical stellar spectra accompanies C. Fehrenbach's welcome summary article on the classification of normal stars in Volume 50 of the *Handbuch der Physik*. Two new spectral atlases are in preparation. A. B. Meinel (Kitt Peak National Observatory) reports that plate material in the photographic and ultra-violet regions for a grating spectral atlas is 80% complete. W. W. Morgan will play a major role in the arrangement of this atlas, which it is hoped to extend to the red and infra-red. D. H. Schulte is assisting in the observational work. C. Jaschek (La Plata) and J. Landi Dessy (Córdoba) are collaborating on the preparation of an atlas of southern standard stars at a dispersion of 42 Å/mm, covering the range $\lambda\lambda$ 3400–6700.

## INFORMATION CENTERS

With the great amount of work being carried out in the field of this Sub-Commission, some systematic (though unfortunately somewhat inadequate) efforts at data collection and storage are being made. General spectroscopic information centers exist at the Perkins and Lick Observatories and, for southern stars, at La Plata—and perhaps elsewhere. The writer will be happy to answer, or re-direct, inquiries concerning observational results on individual stars or other matters of interest to readers of this report.

WILLIAM P. BIDELMAN
*President of the Sub-Commission*

## APPENDIX I. BIBLIOGRAPHY (1957-1960)

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(Westerlund): Some 200 emission objects have been found in an area of about 100 square degrees centered on $\alpha = 12^h\ 30^m$ and $\delta = -61°$. The search for W-R stars and planetary nebulae in the Large Magellanic Cloud is being continued.

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(Mustel): In area studies, E. K. Kharadze and R. A. Bartaya have classified 4500 stars in regions of associations and diffuse emission nebulae, and E. K. Kharadze, J. P. Apriamashvili, and N. B. Kalandadze are classifying 7500 stars near the bifurcation of the Milky Way. Also, K. T. Stojanova has utilized spectra of very low dispersion (10000 Å/mm) for classification purposes. The limiting magnitude of all three programs is 12·5.

(Nassau): The joint program of the Hamburg and Warner and Swasey Observatories for the discovery of high-luminosity stars is continuing. Approximately one-half of the Milky Way zone has now been surveyed to the 13th magnitude, and upwards of 5000 high-luminosity stars have been classified by the participating observatories. The objective-prism study of sub-dwarf stars is also being continued.

It may be noted, in connection with our use of an ultra-violet-transmitting objective-prism, that what we see at low dispersion as the Balmer discontinuity is not necessarily what is defined and measured as 'D' by Chalonge and his collaborators. On objective-prism plates of the dispersion so far used ($\approx$ 580 Å/mm at H$\gamma$), the eye perceives that, in an A0 dwarf, the continuum drops substantially when the broad, strong hydrogen lines of the dwarf blend, a few lines beyond H$\zeta$. When the position of the Balmer limit is reached, the continuum is essentially smooth, *i.e.*, no 'Balmer discontinuity' is visible. In the super-giant, however, the weaker hydrogen lines do not thus depress the apparent continuum; and, whether or not the lines themselves are seen, the continuum survives nearly to $\lambda$ 3646 in much greater strength than it does further to the blue: a strong 'Balmer jump' is noted. The quantity D, on the other hand, is defined from observations at higher resolution of high-intensity points between lines that may be blended, especially in a dwarf spectrum, on objective-prism plates. Thus the two descriptions of the behavior of the Balmer discontinuity may well differ.

(Westerlund): In an area of about 100 square degrees centered on $\alpha = 12^h\ 30^m$ and $\delta = -61°$, about 150 OB stars have been recently identified. In addition, material needed for the completion of the infra-red survey of the Magellanic Clouds is substantially at hand to a limiting magnitude of about $I = 14$. An infra-red survey of a 10°-wide belt along the galactic equator covering longitudes 200°–340° is in progress. The limiting infra-red magnitude is 13. The region of the Coalsack has been surveyed in the infra-red; this region, and also another in Carina, are being observed regularly for study of the spectral variations of the red variables present.

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117. Morgan, W. W. and Mayall, N. U. A spectral classification of galaxies. *P.A.S.P.* **69,** 291, 1957.
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119. Osawa, K. Spectral classification of 533 B8-A2 stars and the mean absolute magnitude of A0 V stars. *Ap. J.* **130,** 159, 1959.
120. Preston, G. W. A spectroscopic study of the RR Lyrae stars. *Ap. J.* **130,** 507, 1959.
121. Sharpless, S. Red super-giants near $h$ and $\chi$ Persei and 30 Doradus. *P.A.S.P.* **70,** 392, 1958.
122. Slettebak, A. A spectrographic study of early-type stars near the north galactic pole. *A.J.* **65,** 500, 1960.
123. Slettebak, A. and Nassau, J. J. Peculiar and metallic-line A-type stars in a galactic zone. *Ap. J.* **129,** 88, 1959.
124. Smith, H. J. Spectra of bright-line stars in the Large Magellanic Cloud. *P.A.S.P.* **69,** 137, 1957.
125. Stephenson, C. B. A study of visual binaries having primaries above the main sequence. *A.J.* **65,** 60, 1960.
126. Thackeray, A. D. Comparison of globular clusters in the galaxy and in the Magellanic Clouds. *A.J.* **64,** 437, 1959.
127. Tifft, W. G. A system of three-color photometry, with applications to galactic structure in Cygnus. *A.J.* **63,** 127, 1958.
128. Walker, M. F. Studies of extremely young clusters. II. NGC 6530. *Ap. J.* **125,** 636, 1957.
129. Walker, M. F. Photo-electric observations of the galactic cluster NGC 6940. *Ap. J.* **128,** 562, 1958.

130. Walker, M. F. Studies of extemely young clusters. III. IC 5146. *Ap. J.* **130**, 57, 1959.
131. Walker, M. F. and Bidelman, W. P. The reddest giants in M 11 and NGC 7789. *P.A.S.P.* **72**, 50, 1960.
132. Wallerstein, G. The absolute magnitude of U Sagittarii and its membership in M 25. *P.A.S.P.* **69**, 172, 1957.
133. Wallerstein, G. Radial velocities and spectral characteristics of the population II Cepheids M 5 no. 42, M 5 no. 84 and TW Capricorni. *Ap. J.* **127**, 583, 1958.
134. Wallerstein, G. Note on the population II Cepheid region in the color-magnitude diagram of globular clusters. *Ap. J.* **128**, 141, 1958.
135. Wallerstein, G. Radial velocities of the brighter stars in M 25. *Ap. J.* **132**, 37, 1960.
136. Yoss, K. M. Space velocities of weak CN giants. *A.J.* **65**, 354, 1960.

(Bidelman): Material is available for the classification of approximately 100 stars of HD type A2 or earlier in the region of the south galactic pole, and for the classification of a considerably larger number of previously unclassified northern spectroscopic binaries with HD types in the range B8-A5. Spectra are now being obtained of a number of objects classed as $\lambda$4150 stars at the Warner and Swasey Observatory.

Classification of the spectra of 80 close visual binaries, mainly giant systems, is being carried out by J. A. Williams. A. R. Klemola has nearly completed a general survey, at low dispersion, of the spectra of faint blue stars at high galactic latitudes. The spectra of bright galaxies are being investigated by H. Spinrad. Substantial differences among the spectra of various galaxies have been found, especially in the appearance of the sodium D-line region.

(Buscombe): An additional 200 early-type stars in the Scorpio-Centaurus region have been classified by Miss P. M. Morris; she and Buscombe are classifying B stars of magnitudes 9-11 in selected area 193, certain B and A stars brighter than 8th magnitude in the south galactic pole region, and stars that may be members of M 7 and IC 2391. J. B. Whiteoak is classifying 7th- to 9th-magnitude B stars in a new association in Norma, and R. A. Bell has obtained extensive new material on southern white dwarfs.

(Evans): 130 additional southern stars have been classified in the 'fundamental data' program.

(Jaschek): The slit-spectrograph study of the brighter southern stars noted in the *Henry Draper Catalogue* as having spectral peculiarities is continuing.

(Keenan): Spectral types on the MK system are being determined for a number of the brighter stars of class M; these will appear in Vol. 3 of Kuiper's *Compendium*. Some of the older standards require revision, for most of the cooler stars are slightly variable in type as well as in brightness, and it is desirable to average the types from several spectrograms taken on different dates. Work on the classification of *Mira*-type variables continues. The problem is complicated by the occurrence of stars having peculiar intensities of the bands of AlO or YO.

(Przybylski): 150 of the brightest southern high-velocity stars have been classified at Mount Stromlo.

(Slettebak): Spectroscopic observations of both components of about 150 visual binaries have been completed. MK spectral types and rotational velocities are being estimated for all of the stars; this material will, among other things, bear on the question of the luminosities of certain types of peculiar stars.

(Thackeray): Spectral classification of 248 southern (galactic) stars, mainly of types B2 and earlier, has been completed. The magnitudes range from 8 to 11.

### 3a. *Classifications Employing Spectrophotometric or Other Measurements: Narrow-Band Photo-electric Work*

137. Barbier, D. Un programme de classification stellaire par photométrie photo-électrique. *Ann. Ap.* **23**, 431, 1960.

138. Borgman, J. Photometric criteria for the separation of different population types. *Ap. J.* **129**, 362, 1959.
139. Bouigue, R. Photométrie photo-électrique des étoiles rouges et des comètes. *Publ. Obs. Hte Provence* **4**, no. 17, 1958.
140. Crawford, D. L. Two-dimensional spectral classification by narrow-band photometry for B stars in clusters and associations. *Ap. J.* **128**, 185, 1958.
141. Crawford, D. L. Narrow-band photo-electric photometry for G and K giants. *A.J.* **65**, 343, 1960.
142. Crawford, D. L. Early-type stars used as standards in photo-electric H$\beta$ photometry. *Ap. J.* **132**, 66, 1960.
143. Deeming, T. J. The magnesium b lines in late-type stars. *M.N.R.A.S.* **121**, 52, 1960.
144. Dimov, N. A. and Nikonov, V. B. A photo-electric determination of the equivalent widths of H$\gamma$ in the spectra of early-type stars. *Publ. Crim. Aph. Obs.* **22**, 176, 1960.
145. Griffin, R. F. and Redman, R. O. Photo-electric measurements of the $\lambda$4200 Å CN-band and the G-band in G8-K5 spectra. *M.N.R.A.S.* **120**, 287, 1960.
146. Gyldenkerne, K. Photo-electric spectral classification of G and K stars. *Ann. Ap.* **21**, 26 and 77, 1958.
147. Kraft, R. P. Calibration of the G-band photometry. *Ap. J.* **131**, 330, 1960.
148. Kraft, R. P. The period-color relation for classical Cepheids. *Ap. J.* **132**, 404, 1960.
149. Strömgren, B. Summary of work on narrow-band photo-electric photometry. *A.J.* **63**, 199, 1958.
150. Strömgren, B. The composition of stars and their ages. *Observatory*, **78**, 137, 1958.
151. Strömgren, B. Composition differences between stellar populations. *Ric. astr.* **5**, 245, 1958.
152. Strömgren, B. Spectrophotometric classification of the population groups. *Ric. astr.* **5**, 385, 1958.
153. Strömgren, B. Intrinsic dispersion in early-type stars. *Ann. Ap. Suppl.* no. 8, p. 59, 1959.
Walraven, Th. and Walraven, J. H. A new photo-electric method of classification of luminosity and spectral type for O- and B-type stars. *B.A.N.* **15**, 67, 1960.

(Crawford): Work is continuing on narrow-band photometry of G and K stars, extending the work of Strömgren on age effects.

(Gyldenkerne): Problems of the photo-electric three-dimensional classification of G and K stars are currently under investigation at the Brorfelde Observatory.

### 3*b*. *Classifications Employing Spectrophotometric or Other Measurements: The Ca* II *Emission-Line Method*

154. Jaschek, M., Jaschek, C. and Feinstein, A. Note on the Ca II emission in Cepheids. *Bol. Asoc. Argent. Astr.* no. 2, 25, 1960.
155. Kraft, R. P. On the variation of the K2 emission width as a function of absolute visual magnitude in the spectra of late-type stars. *Ann. Ap.* **22**, 164, 1959.
156. Wilson, O. C. A color-magnitude diagram for late-type stars near the Sun. *Ap. J.* **130**, 496, 1959.
157. Wilson, O. C. Accuracy of absolute magnitudes derived from widths of H and K emission components. *Ap. J.* **130**, 499, 1959.
158. Wilson, O. C. Location of late-type high-velocity stars in the color-magnitude diagram. *P.A.S.P.* **71**, 338, 1959.
159. Wilson, O. C. and Vainu Bappu, M. K. H and K emission in late-type stars: dependence of line width on luminosity and related topics. *Ap. J.* **125**, 661, 1957.

### 3*c*. *Classifications Employing Spectrophotometric or Other Measurements: The Method of Chalonge*

160. Atanasijevič, I. and Chalonge, D. Classification de quelques étoiles dans les amas Ori I, NGC 2264 et dans les Pléiades. *J.d.Obs.* **41**, 97, 1958.

161. Berger, J. Classification d'étoiles doubles dans le système à 3 paramètres $\lambda_1$, D, $\phi_b$. *J.d.Obs.* **41,** 105, 1958.
162. Berger, J., Chalonge, D., Divan, L., Fringant, A.-M. and Westerlund, B. Diagrammes $\lambda_1$, D pour les populations I et II—comparaison au diagramme HR. *J.d.Obs.* **41,** 100, 1958.
163. Chalonge, D. Classification spectrophotométrique des populations stellaires. *Ric. astr.* **5,** 345, 1958.
164. Chalonge, D. Nécessité de trois paramètres pour la classification précise des étoiles des premiers types spectraux. *Ann. Ap. Suppl.* no. 8, 61, 1959.
165. Chalonge, D. Caractères spectrophotométriques de l'age. *Ann. Ap. Suppl.* no. 8, 71, 1959.
166. Chalonge, D. Détermination spectrophotométrique des types, des luminosités et des ages des étoiles. *Ann. Ap.* **23,** 439, 1960.
167. Westerlund, B. On the classification of early-type stars. *Ark. Astr.* **2,** 83, 1957.

(Chalonge): The three-dimensional classification system is being further applied by several investigators to stars in clusters, to double stars, and to various types of variable stars in order to check its application to the problem of absolute-magnitude determination. Additional observations of sub-dwarfs and metallic-line stars are also being obtained.

### 3d. *Classifications Employing Spectrophotometric or Other Measurements: Miscellaneous Methods*

168. Andrillat, Y. Étude spectrophotométrique des étoiles de Wolf-Rayet dans le rouge et le proche infrarouge. *Ann. Ap. Suppl.* no. 2, 1957.
169. Bartaya, R. A. Catalog of spectroscopic absolute magnitudes of 766 B and A stars in 44 Kapteyn areas situated along the galactic belt. *Bull. Abastumani astro-fiz. Obs.* no. 22, 25, 1958.
170. Bistrova, N. V. The reddening of stars in three parts of the sky. *Pulkovo Bull.* **20,** part 5, 74, 1958 (no. 158).
171. Boyarchuk, A. A. A comparison of the chemical composition of B and Be stars. *Publ. Crim. Aph. Obs.* **17,** 89, 1957.
172. Butler, H. E. and Seddon, H. Spectrophotometric measurements of stars of type B2. *Publ. R. Obs. Edinb.* **2,** 113, 1958.
173. Butler, H. E. and Seddon, H. Spectrophotometric measurements of stars of type B3. *Publ. R. Obs. Edinb.* **2,** 187, 1960.
174. Chopinet, M. Révision de quelques résultats sur les étoiles à grande vitesse. *J.d.Obs.* **43,** 127, 1960.
175. Elvius, T. and Lodén, K. Photometric and spectrophotometric measurements of stars in Kapteyn's selected areas 11-14. *Stockh. Obs. Ann.* **21,** no. 2, 1960.
176. Herman, R., Barin, Th. and Pendzel, M. Classement de 123 étoiles de type B. *Ann. Ap.* **22,** 540, 1959.
177. Iwanowska, W. The VO bands as a population criterion in the spectra of long-period variables. *Mém. Soc. Sci. Liège,* **18,** 277, 1957 (*Liège Inst. d'Ap. Repr.* no. 386).
178. Jaschek, M. and Jaschek, C. A search for families among metallic-line stars. *Z. Ap.* **50,** 155, 1960.
179. Kalandadze, N. B. Catalog of absolute magnitudes of 425 stars of spectral types G and K. *Bull. Abastumani astro-fiz. Obs.* no. 22, p. 45, 1958.
180. Kamijo, F. Low-dispersion spectra of some carbon stars. *Publ. astr. Soc. Japan,* **11,** 257, 1959.
181. Kopylov, I. M. The equivalent widths of absorption lines in the spectra of 109 O5-B7 stars. *Publ. Crim. Aph. Obs.* **20,** 123, 1958.
182. Kopylov, I. M. A two-dimensional quantitative spectral classification of 238 O5-B7 stars and the construction of a spectrum-absolute magnitude diagram. *Publ. Crim. Aph. Obs.* **20,** 156, 1958.
183. Kopylov, I. M. The sequence of $\beta$ CMa type stars. *Publ. Crim. Aph. Obs.* **21,** 71, 1959.

**184.** Kopylov, I. M. The equivalent widths of absorption lines in the spectra of 62 B8-F2 stars. *Publ. Crim. Aph. Obs.* **22,** 189, 1960.
**185.** Kopylov, I. M. A two-dimensional quantitative spectral classification of B8-F2 stars. *Publ. Crim. Aph. Obs.* **23,** 148, 1960.
**186.** Lynds, B. T. The spectra of the white dwarfs. *Ap. J.* **125,** 719, 1957.
**187.** Martin, N. Détermination de magnitudes absolues par la méthode d'Öhman. *Publ. Obs. Hte Provence*, **4,** no. 38, 1959.
**188.** Mustel, E. R. and Galkin, L. S. A spectrophotometric study of hydrogen lines in the spectra of peculiar A0 stars. *Publ. Crim. Aph. Obs.* **22,** 225, 1960.
**189.** Mustel, E. R., Galkin, L. S., Kumaigorodskaya, R. N. and Boyarchuk, M. E. A quantitative spectral classification of F0-K5 stars with well-determined distances. *Publ. Crim. Aph.Obs.* **18,** 3, 1958.
**190.** Oke, J. B. Determination of spectroscopic absolute magnitudes for late-type stars. *Ap. J.* **126,** 509, 1957.
**191.** Oke, J. B. The Hertzsprung-Russell diagram for the F5-K2 stars with the most accurate absolute magnitudes. *Ap. J.* **130,** 487, 1959.
**192.** Opolski, A. The spectrophotometric parallaxes of 42 visual binaries. *Ark. Astr.* **2,** 55, 1957.
**193.** Petrie, R. M. Luminosities derived from Hγ intensities. *A.J.* **63,** 181, 1958.
**194.** Petrie, R. M. A re-examination of the space motions and luminosities of the stars of the Cassiopeia-Taurus group based upon new radial velocities. *M.N.R.A.S.* **118,** 80, 1958.
**195.** Petrie, R. M. Spectroscopic absolute magnitudes of fifteen B stars of the Scorpio-Centaurus group. *P.A.S.P.* **70,** 460, 1958.
**196.** Ramberg, J. M. The space distribution of stars in selected Milky Way regions derived from photometric and spectrophotometric data. I. *Stockh. Obs. Ann.* **20,** no. 1, 1957.
**197.** Schalén, C. The interstellar reddening in Cygnus. *Ark. Astr.* **2,** 359, 1960.
**198.** Stableford, C. and Abhyankar, K. D. A spectrophotometric study of several β Canis Majoris variables. *Ap. J.* **130,** 811, 1959.
**199.** Underhill, A. B. A study of the Wolf-Rayet stars HD 192103 and HD 192163. *Publ. Dom. astrophys. Obs.* **11,** 209, 1959.
**200.** Wilson, R. Spectrophotometric measurements of stars of types O6-B0. *Publ. R. Obs. Edinb.* **2,** 61, 1958.
**201.** Wyller, A. A. Vibrational temperatures of five carbon stars. *Ap. J.* **125,** 177, 1957.
**202.** Yoss, K. M. Objective-prism equivalent widths of early-type stars. *A.J.* **62,** 42, 1957.
**203.** Yoss, K. M. The relationship between objective-prism cyanogen equivalents and space velocities of G5 to K5 giants. *A.J.* **63,** 61, 1958.

(Elvius): The Stockholm selected-area work is continuing in co-operation with Mrs Lodén, and a catalog for stars in selected areas 8-10 is in preparation. Mrs Lodén is now working on 10 other areas, using material obtained at the Boyden Observatory. An additional 11 areas have been added to the program through material obtained at Mount Stromlo.

(Lodén): A comparison has been made between the results obtained from measurement of broad-slit microphotometer records of low-dispersion objective-prism spectra and MK spectral classes and luminosities. No appreciable systematic deviations have been found. An attempt has also been made to determine spectral types in the MK system by visual inspection of objective-prism spectra of dispersion 120 Å/mm at Hγ. This can be done but is highly sensitive to the quality of the plate material. A somewhat more convenient method was found to be the visual inspection of narrow-slit microphotometer records of these spectra. Quantitative measurements of these records give more accurate results, but the increase in accuracy obtained is not in proportion to the greater amount of work involved.

(Petrie): Single-prism spectrograms of dispersion 51 Å/mm at Hγ have been analysed with a recording microphotometer. The program comprises spectra of 112 stars distributed over spectral types O9 to B9 and includes super-giant, giant, and main-sequence stars. The spectral region covered is from λ 3900 to λ 4900; all absorption lines clearly delineated on the tracings are included. The variations with spectral type and luminosity of line intensities and various line ratios are being determined; the resulting data will be used to classify the stars on the extensive program of faint B stars. The absolute magnitudes will be determined separately from the $H\gamma$ intensities. Visual estimates will be used for the routine classifications, but these will be made on the basis of the information derived from plots of the measured intensities. The classification system will be in agreement, on the average, with the MK system. This work is being carried out in collaboration with Jean McDonald Petrie.

(Schalén): Work has continued at Uppsala on an objective-prism spectral survey along the Milky Way. The region with $40° < l < 60°$ has already been finished by K. G. Malmquist, B. Ljunggren, and T. Oja; those with $80° < l < 100°$ and $10° < l < 40°$ are now under investigation. Ljunggren and Oja have studied the relation between the Uppsala and MK classification systems on the basis of about 400 stars. Also, spectral classes have been determined by Ljunggren in the region defined by $12^h\,05^m < \alpha < 12^h\,50^m$, $+28° < \delta < +39°$.

(Sinnerstad): Quantitative spectral classification using slit spectrograms of dispersion 75 Å/mm is being investigated at the Stockholm Observatory. From the measured equivalent widths and central depths of the hydrogen lines the early-type super-giants can easily be separated from stars of luminosity classes III-V, the hydrogen lines showing a discontinuity between the giants and the super-giants. A luminosity classification using the hydrogen-line intensity shows that if the same calibration curve is used for the entire spectral range O9-A0, the stars of luminosity class III come out at most 0·2 magnitudes brighter than those of luminosity class V.

(Westerlund): Material in the blue-violet for classification of stars in the region of the Magellanic Clouds has been obtained to a limiting magnitude of 12·5. In a few areas plates reaching beyond $V = 14$ have been taken.

### 4. *Papers Dealing with the Continuous Spectrum; Spectrum Scanning; Relation of Colors to Spectra, etc.*

**204.** Bahng, J. D. R. Multi-color photo-electric photometry of stars with composite spectra. *Ap. J.* **128**, 572, 1958.
**205.** Bless, R. C. Photo-electric spectrophotometry of A-type stars. *Ap. J.* **132**, 532, 1960.
**206.** Bonsack, W. K., Greenstein, J. L., Mathis, J. S., Melbourne, W. G., Neugebauer, G., Newburn, R. L., Olsen, K. H., Tifft, W. G., Wahlquist, H. D. and Wallerstein, G. The interpretation of photo-electric colors for stars of types B-F. *Ap. J.* **125**, 139, 1957.
**207.** Bonsack, W. K. and Stock, J. Monochromatic colors of O-, B- and A-type stars. *Ap. J.* **126**, 99, 1957.
**208.** Code, A. D. The energy distribution of sub-dwarfs. *Ap. J.* **130**, 473, 1959.
**209.** Code, A. D. Energy distribution curves of galaxies. *P.A.S.P.* **71**, 118, 1959.
**210.** Guérin, P. Réalisation et possibilités d'emploi d'un spectrophotomètre stellaire photo-électrique à compensation. *Ann. Ap.* **22**, 611, 1959.
**211.** Lamla, E. Die Intensitätsverteilung im kontinuierlichen Spektrum von Sternen der Spektralklassen B-M. *A.N.* **285**, 12, 1959.
**212.** Lamla, E. Über die Erkennbarkeit unaufgelöster Doppelsterne aus dem spektralen Intensitätsverlauf. *A.N.* **285**, 27, 1959.
**213.** Lamla, E. Über die spektrale Intensitätsverteilung und die Leuchtkraftverteilung von Sternsystemen. *A.N.* **285**, 33, 1959.
**214.** Lindholm, E. H. Remarks on the variation of $E_{U-B}/E_{B-V}$ with reddening and spectral class. *Ap. J.* **126**, 588, 1957.
**215.** Meinel, A. B. and Golson, J. C. Spectral classification from ratio spectra. *P.A.S.P.* **71**, 445, 1959.
**216.** Melbourne, W. G. Line-blanketing effects on A-G dwarfs. *Ap. J.* **132**, 101, 1960.
**217.** Oke, J. B. Standard stars for photo-electric spectrophotometry. *Ap. J.* **131**, 358, 1960.
**218.** Preston, G. W. and Spinrad, H. On the intrinsic colors of the RR Lyrae stars. *P.A.S.P.* **71**, 497, 1959.
**219.** Rozis-Saulgeot, A.-M. Étude du diagramme gradient-indice de couleur. *Ann. Ap.* **22**, 177, 1959.

**220.** Wallerstein, G. and Carlson, M. On the ultra-violet excess in G dwarfs. *Ap. J.* **132,** 276, 1960.
**221.** Westerlund, B. Relative spectral gradients as measured in high-dispersion grating spectra. *Publ. Dom. astrophys. Obs.* **10,** 425, 1958.

5. *General Papers; Calibration Problems, etc.*

**222.** Babcock, H. W. Magnetic fields of the A-type stars. *Ap. J.* **128,** 228, 1958.
**223.** Bidelman, W. P. The space distribution of middle- and late-type super-giants in the region of the galactic system near the Sun. *Comparison of the Large-Scale Structure of the Galactic System with that of Other Stellar Systems,* N. G. Roman, ed. (*Symp. IAU* **5**) Cambridge University Press, 1958, p. 54.
**224.** Blaauw, A. The calibration of spectroscopic absolute magnitudes of early B-type stars. *A.J.* **63,** 186, 1958.
**225.** Fehrenbach, C. Les classifications spectrales des étoiles normales. *Handb. Phys.* **50,** 1, Springer-Verlag, 1958.
**226.** Keenan, P. C. Stellar spectra in the red and near infra-red. *P.A.S.P.* **69,** 5, 1957.
**227.** Keenan, P. C. Stars with peculiar spectra. *Handb. Phys.* **50,** 93, Springer-Verlag, 1958.
**228.** Luyten, W. J. Intercomparison of spectroscopic and spectrophotometric methods. *A.J.* **63,** 194, 1958.
**229.** Morgan, W. W. Systems of spectroscopic luminosity criteria. *A.J.* **63,** 180, 1958.
**230.** Petrie, R. M. A comparison between the Victoria system of absolute magnitudes for the B stars and other systems. *A.J.* **63,** 189, 1958.
**231.** Petrie, R. M. The accuracy of spectroscopic distances of B stars. *P.A.S.P.* **72,** 462, 1960.

## APPENDIX II SUGGESTION CONCERNING LUMINOSITY CLASS NOTATION

by Philip C. Keenan and W. W. Morgan

Since modern methods of classification sometimes allow luminosities to be estimated more accurately than they can be expressed in the original MK luminosity classes, the following notation for extending and sub-dividing the classes is suggested:

| | Main Classes | Sub-divisions |
|---|---|---|
| Super-giants | Ia-O | Ia-O |
| | I | Ia Iab Ib |
| Bright Giants | II | IIa IIab IIb |
| Giants | III | IIIa IIIab IIIb |
| Sub-giants | IV | IVa IVab IVb |
| Main Sequence (Dwarfs) | V | Va Vab Vb |
| Sub-dwarfs | VI | VI |

The main classes would probably satisfy the needs of observers working with quite low dispersion, while the finer sub-divisions of the last column could be brought into use whenever they are needed. Thus if a giant star is classified Ko III in one catalog and Ko IIIab in another, it is indicated that the first observer can tell merely that the star belongs to the giant branch, while the second is estimating that it lies within about half a magnitude of the middle of the branch. The sub-divisions would not necessarily be indicated for all the stars in any one catalog, but used only for those (*e.g.*, G8 to K3 giants) in the regions of the HR diagram where the classes are far enough apart and enough standards have been established to justify their use.

The use of the additional indications 'a' and 'b' is suggested in order to avoid the plus and minus signs that have been employed inconsistently by some observers and have led to quite a bit of confusion. If still further sub-division is required, hyphens between the subclasses (*e.g.* IIIab-IIIb) could be used and would be self-explanatory.

Luminosity class Ia-O has been added to provide a place for the very brightest stars, with $M_v \approx -9$, that have been observed in the Magellanic Clouds and other galaxies. The question of sub-dividing class VI, the sub-dwarfs, should perhaps be left open now until the observers working with this group find that differences in their luminosities can be recognized spectroscopically.

The notation of the table is suggested informally now in the hope that other observers will try it out, and it is hoped that many of the stars that have served as MK standards will soon have their luminosity classes sub-divided. An example is $\beta$ Geminorum, which with moderate dispersion can clearly be seen to be a little fainter than the average class III giant. We classify it as Ko IIIb. The setting-up of standards cannot be done hastily, for on the spectrograms of moderately small scale that will normally be used, several exposures are needed to average out the photographic fluctuations that distort the intensity ratios (whether estimated or measured) of the lines that serve as criteria.