25. COMMISSION DE PHOTOMETRIE STELLAIRE

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INTRODUCTION

The past three years have seen a large and steady output of useful photometry. There have been no spectacular developments but there have been gradual improvements in the techniques employed which have led to some improvement in the quality of much of the work published. On the other hand, some of what has been published could undoubtedly have been improved by a little more attention to detail and a rather more generous use of standard stars and sequences. Stellar Photometry has become too big a subject to review adequately in a short report so that the following paragraphs have had to be confined to a few general remarks and a brief survey of such work as has been reported to the Commission. I am particularly indebted to Prof. V. B. Nikonov for his comprehensive summary of recent photometric work carried out in the U.S.S.R.

STANDARD MAGNITUDES

The problem of the standardization of magnitudes and colours observed with a wide variety of instruments still remains and grows ever more complicated as the variety of colours and band-widths in which observations are being made increases. For ordinary photometry the International Photographic and Photovisual System, the U, B, V System, the P, V, I System, the R, G, U System and the S System are still in use but the U, B, V System and, more particularly, the B, V System are being increasingly used as new programmes are commenced.

The V System, which is common to the International, P, V, I and U, B, V Systems, seems especially well suited for adoption as standard. Experience has shown that very satisfactory reductions to it are possible even when the natural system of the observations differs somewhat from the normal in equivalent wave-length and/or in band-width. Measures near B are more sensitive to differences in the equipment so that reductions of the observed colours to $B - V$ are correspondingly more complicated and may vary with the luminosity class and the degree of reddening. So far the number of individual stars that have been observed at more than one observatory in U is rather small but it does appear that there is some difficulty in reproducing U accurately even when aluminised reflectors and the right nominal filters are used. For those about to start a new programme, the U, B, V System has the great merit that the colours and absolute magnitudes corresponding to the various spectral types, the reddening line, the intrinsic line, the line of zero age etc. are already fairly well determined. (**1, 2, 3**).

At the Cape much use has been made of $(U - B)_c$, a refractor ultra-violet-blue system which seems to have many of the useful properties of $U - B$ but appears easier to reproduce from instrument to instrument as it refers to a more restricted part of the spectrum. Some of the properties of the V, $B - V$, $(U - B)_c$ System have been described by Cousins, Eggen and Stoy. (**4**).

Very little first-class work on standard magnitudes in the Northern Hemisphere has been published since the last report so that the most comprehensive and convenient exposition of the *U*, *B*, *V* system remains that given by Johnson in the *Annales d'Astrophysique.* (**5**). This list will undoubtedly soon be supplemented by the publication of work already in progress at various observatories and, in particular, of the programme of cluster photometry that has been carried out jointly by the Lowell and U.S. Naval Observatories. (**6**). These data include about 2000 stars observed photo-electrically and 15 000 stars observed photographically along the entire Milky Way north of $-25°$ declination. Each cluster has been compared individually with the standard stars using the original filters with which the *U*, *B*, *V* System was established. Publication is also expected soon of the programme of the Crimean and Cracow Observatories that aims at finding for every Selected Area north of $-15°$ declination precise magnitudes on the *U*, *B*, *V* System for two stars near the sixth visual magnitude having spectral types A and K. (**7**). Some work on the programme for fainter *U*, *B*, *V* standards formulated by the Stockholm Symposium on 'Coordination of Galactic Research' has been done by Hardie at the Arthur J. Dyer Observatory, by Crawford at Kitt Peak and by Haffner at the Boyden Observatory in the south. Some standard stars have been observed regularly in the course of routine observations of selected groups of stars such as cepheids, clusters etc. while numerous photo-electric standard sequences have been set up in connection with photographic observations of special regions. Such observations when properly co-ordinated should prove a fruitful source of useful working standards.

In the southern hemisphere work on the *U*, *B*, *V* and other standard systems has been done at the Boyden, Cape, Leiden, Radcliffe and Mount Stromlo Observatories. Many of the bright southern stars have been observed at two or more of these observatories. At the Cape practically all non-variable stars south of $+5°$ declination and brighter than HR 5·0 have been observed with the 18-inch aluminised reflector and the results reduced to the *U*, *B*, *V* System. The external standard error of this series of observations appears to be $\pm 0^m{\cdot}009$ for *V* and $\pm 0^m{\cdot}006$ for $B - V$. Most of the stars south of $+10°$ declination that occur in Johnson's list (**5**) were included in the programme and indicate that the zero point of the southern results is within $0^m{\cdot}01$, and the colour coefficients within 0·01, of the standard system. There are zero-point differences depending on right ascension of this order between different observers and it is not possible to define the colour equation more precisely because of the limited number of red stars in Johnson's list that are convenient for observation from the Cape.

Cousins has made a critical intercomparison of all the data available for these bright and other well-observed southern stars and has prepared the list given in the Appendix. This shows *V* and $B - V$ for a selection of stars south of $+16°$ declination and is intended to serve as a provisional supplement to Johnson's list of standards, many of which are included. The values given are based on observations made by Arp, Eggen, Harris, Hogg, Irwin, Johnson, Naur, Oosterhoff, Roman, Willstrop, Walraven and the various Cape observers. The average probable error of these magnitudes and colours as judged from the agreement between the various series of observations is about $\pm 0^m{\cdot}005$ and they should be sufficiently reliable to serve in the determination of zero point and extinction. Systematically, however, the data for these stars can not be regarded as having quite the accuracy as that for the E Regions.

Cousins has recently co-ordinated 24 series of accurate magnitude observations of stars in the nine E Regions and has given the results in the form V, $B - V$, $S'Pg$, SPv, $S'CI$ and $(U - B)_c$. These data are available to those immediately interested as *Cape Mimeogram* No. 11; for general circulation they will appear as a *Royal Observatory Bulletin.* About 840 stars are included in the mimeogram but the data for those fainter than 12·0 are somewhat fragmentary. While not containing examples of every type of star, the E Regions have the advantage of being suitable for both photo-electric and photographic use. They also include a sufficient number of stars to meet most of the requirements envisaged by Becker for 'zero-point systems' and for 'standard areas for the comparison of systems', (**8**), at least between the seventh and twelfth magnitudes. The zero points of all nine regions have been carefully checked.

Whether the northern and southern systems are completely identical cannot be decided from the latitude of the Cape Observatory on the basis of the available northern standards. To settle this question it will be necessary to make observations from a more northerly site where a larger selection of Johnson's stars can be observed under favourable conditions, or for precise observations of more of the equatorial stars to be made from one of the northern observatories. Southern measures, believed to be on the *U*, *B*, *V* System, are now available for about 170 stars north of $-10°$ declination as compared with about 70 measured by Johnson and his collaborators south of $+10°$. Later-type stars are better represented in the southern sample.

Kron reports that the primary system of standards for the *P*, *V*, *I* System of photometry is given in a forthcoming paper by Mayall and himself on the photometry of star clusters (**9**). The *P*, *V* values for 24 carefully selected stars of the Polar Sequence have been so adjusted that they provide a good ultra-violet-free approximation to the old International System. These are the primary standards of the system. Accurate working standards that can be used from either hemisphere are provided in the Harvard C and D Regions.

As there are no reliable photo-electric standards available for the *R*, *G*, *U* System, the observers at the Hoher List Observatory have started to set up sequences photographically down to about magnitude 15·3 using diffraction gratings to establish the scale. The first is near the North Pole and others are to be set up in various parts of the sky. Writing from the Cambridge Observatories, Argue says:

'So far we have confined ourselves to the *R*, *G*, *U* System and have been seriously handicapped by lack of standard magnitudes, intrinsic colours and so on. This system was used since it has been claimed as capable of distinguishing between intermediate- and late-type giants and dwarfs. In our Praesepe survey we have not been able to confirm this. To us the system seems little different from the *U*, *B*, *V* System in this respect and we are considering abandoning it in favour of *U*, *B*, *V* for which extensive material has now accumulated. There is need for an accurate photo-electric spectrophotometric investigation of the whole problem. Meanwhile it would be helpful if Commission 25 could find out whether other workers propose using *R*, *G*, *U* and whether there are projects for establishing photo-electric standards.'

Photo-electric photometry is capable of giving very accurate results, but only if proper precautions are taken. At very few observatories can the atmosphere be regarded as perfect with the extinction constant throughout the night and the same in all azimuths. At other observatories it seems essential to observe a generous selection of standard stars to measure variations in the atmospheric extinction. In any case a wide variety of standard stars is desirable to provide adequate reduction equations and to guard against possible variations of individual standards.

The possibility of variation in even the best of standards must be considered. In his report Kron remarks:

'The C and D Region measures have been used by my associates and myself for some ten years, now. The results of this persistent use indicate that the stars themselves are variable to a degree that is both surprising and disappointing, the latter especially to one who has tried hard to establish and use accurate stellar standards of magnitude and colour. All stars seem to vary by at least $0^{m}{\cdot}02$ or $0^{m}{\cdot}03$, but the redder stars, of from $P - V = 1{\cdot}00$ and on, are much worse, possibly by a factor of five in some cases. Still redder stars are more variable, I

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think, while the general variability of the M stars, especially those of high luminosity, is well known. The danger of relying on only a few standard stars for any given project is clear. The only way out is always to make observations on a generous number of standard stars, thus getting weight via a comprehensive mean for the practical application of the use of photometric standards. Local standards set up for special purposes should be especially generous in number, and should be checked now and then against the primary standards.'

Johnson and Iriarte in their study of the Sun as a variable star (**10**) also point out possible variations of a few hundredths of a magnitude in their 'Ten-Year Standards'. On the other hand Cousins summarizing his experience in co-ordinating the E Region magnitudes says:

'There are nearly 240 stars in the E Regions that have been observed in five or more independent series, with different instruments and each giving *S′Pg* with an internal standard error of $\pm 0^m{\cdot}010$ or less. A few stars were recognised as variable and others were suspected, but only 10% of the stars had extreme ranges exceeding $0^m{\cdot}03$ between the different determinations. The average range for the others is $0^m{\cdot}020$. The observations extend over ten years in most cases and it seems reasonably certain that comparatively few stars have varied by as much as $0^m{\cdot}025$ during that period.'

It is clear that this fundamental point of the degree of stability that can be expected from standard stars requires further investigation. Kron has indicated the need to avoid certain types of stars which appear to be more prone to variation than others, e.g. the super-giants, stars of very early or very late spectral type. Another factor that might affect the apparent degree of instability is the manner in which the observations are cleared of the effects of atmospheric extinction.

Extinction problems and methods of determining extra-atmospheric magnitudes have been discussed by several astronomers including Nekrasova, Nikonov, Polosuchina and Rybka (**7**), Eelsalu (**11**), Kharitonov (**12**) and Matjagin (**13**). Wallenquist has studied the extinction at the new Kvistaberg Station of the Uppsala Observatory and Hardie at the Arthur J. Dyer Observatory. Concerning his work Hardie writes:

'Several years ago we started using standard *U*, *B*, *V* stars for extinction purposes as outlined in a paper in the *Astrophysical Journal* (**130,** 663, 1959). This has resulted in substantially better photometry and in very stable zero-points. Our attention is now focussed on the colour term in the extinction, and although our results confirm a factor of about 0·03 on the basis of $B - V$ colours, our preliminary results show that the corresponding term for the $U - B$ extinction has the opposite sign in general, but is not as simple a function of colour-index as in the $B - V$ case. Whereas theoretical considerations such as those of King would not lead us to expect simple linear relations in either case, it has been comforting to find that, for $B - V$, empirical results show that a linear expression is adequate for reasonable accuracy in transfer and zero-point work. On the other hand, it has been disconcerting to find that, for the $U - B$ extinction, the colour dependence has yet to be determined properly for adequate accuracy.'

At the Cape no attempt is made in the routine photometry to reduce the results to 'outside the atmosphere'. Instead all observations are made as nearly as possible to a constant altitude and small differential extinction corrections are applied where necessary. The effects of changes in the extinction are thus kept to a minimum and a knowledge of the precise behaviour of the atmosphere becomes of secondary importance.

INSTRUMENTATION

Of particular significance for photometry has been the bringing into active operation of a number of new telescopes including those at Kitt Peak and the 36-inch of the Leiden Southern

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Station. This latter instrument was specially designed for photo-electric photometry and seems to be proving exceptionally efficient in use (**14**). Simultaneous observations are made in five-colour regions selected from a spectrum formed by quartz lenses and prisms. Three of the regions have equivalent wave-lengths which are approximately those of U, B, V while the other two, denoted by W and L, are situated in the more remote ultra-violet (equivalent wave-length 3220 Å) and between U and B (equivalent wave-length 3900 Å) where the higher members of the Balmer Series are crowding together. With refrigerated tubes the useful limit of this instrument is magnitude 15. Its principal programme is initially the observation of all O – B 2 stars in the HD and HDE south of the equator. Other observatories that have started, or intend to start, photometric work include the Tokyo, Kyoto and Kagawa University Observatories in Japan, the new Catania Observatorio Astrofisico in Italy and the Cordoba Observatory in the Argentine. At Kyoto the photo-electric photometers to be attached to the new 40-cm reflector will be adapted for U, B, V, R and IR observations.

B. P. Abrashevsky of the Crimean Observatory and A. P. Kundsinch of the Astrophysical Laboratory of the Latvian Academy of Sciences have designed a fully automatic stellar photo-electric photometer with programmed operation which is being tested out at the Laboratory's observatory near Riga. Other members of the Crimean Observatory have designed new integrating photometers and have adapted the same principle to a stellar photo-electric polarimeter with which stars down to magnitude 11 can be observed with a 40-cm telescope. A photo-electric polarimeter permitting the determination of all four parameters of polarisation, including a measure of the elliptical polarization, has been designed at the Astrophysical Institute of the K.S.S.R. Academy of Sciences by Fesenkov (**15**). A photon-counting technique is being developed at the Burakan Astrophysical Observatory by Grigorian.

Guazzoni, Masani and Potenza have built a five-colour photometer for the Milan Observatory. Prismatic dispersion is used and the wave-length intervals selected for measurement are (1) shorter than 3650 Å, (2) 3650 – 3900 Å, (3) 3900 – 4200 Å, (4) 5200 – 5700 Å and (5) longer than 7500 Å. Somewhat similar photometers are being constructed at other observatories, the limit being reached, perhaps, at Mount Palomar where a simultaneous multi-colour instrument to take up to ten, or even twenty channels, of which U, B, V will be three, is being designed. This instrument will be about six metres long and will be mounted at a folded Cassegrain focus. The dispersion will be provided by a liquid prism. At Cambridge, experiments in photo-electric photometry using narrow bands selected with a spectrograph at the coudé focus of the 36-inch reflector continue (**16**). At the Arthur J. Dyer Observatory dichroic filters are being tested as band separators for simultaneous three-colour observations. At the same observatory preliminary work has been done in the near infra-red on a band between Hα and the water bands near 9300 Å, both of which are excluded by high-efficiency filters having sharp cut-offs. This band allows the best exploitation of the Sl photo-cathodes.

At Stockholm, Ramberg has started photometry of the bright stars in the region 1 – 3 μ using PbS cells in the Cassegrain focus of the 40-inch reflector. He plans to extend the measurements to longer wave-lengths using other photo-conductive and thermistor cells. An infra-red photometer using a PbS cell has also been constructed at the Sternberg Astronomical Institute by Moroz who has used it for observing the Crab Nebula (**17**). Parijsky and Gindilis, also at the Sternberg Institute, have studied a radioactive dye having a continuous emission in a broad spectral interval. Such radioactive dyes may be of great interest in photo-electric colour work and in stellar spectrophotometry.

Experiments in photographic photometry using Schmidt cameras continue at Cambridge, Hamburg, Hoher List and elsewhere. At the latter observatory, Schmidt has found that the mean errors of the magnitudes increase linearly with magnitude and concludes that the errors

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of individual measurements can be kept small if the measurements are not carried too close to the limiting magnitude of the plate. This result refers, presumably, to measures made with an iris-diaphragm photometer. It would be of interest to know if it would also hold true were the images near the plate limit measured with a Schilt-type photometer with a suitably chosen diaphragm.

One of the principal advances in photographic photometry has been the development of methods by which the readings of the microphotometer can be reduced automatically. At Hamburg, for example, the angular position of the wheel attached to the iris diaphragm of the Haffner iris-photometer is mechanically coupled to a Heliopot precision potentiometer which via a Beckman digital voltmeter encodes the iris reading. The position of the star image and the setting of the iris is done manually and then pressing a button punches the three-digit iris reading on to an IBM card. The cards are manipulated so that each star has one card on which the measurements of up to twelve plates can be punched. The punched star measurements are reduced with an IBM 650 by a programme which first computes the calibration curve and colour equation for each plate using the photo-electric standard stars on it, and then the magnitudes and colours with their errors for each star. E. Høg proposed and constructed the digitising equipment. E. Brosterhus wrote the programmes for the computer and has measured 62 000 star images at a rate of 380 stars per hour. The reductions on the IBM took 16 hours. Analogous procedures adopted at Cambridge have been described by Argue (**18, 19**).

A useful summary of standard photographic photometry techniques has been prepared by Stock and Williams for publication in the *Compendium on Astronomy* edited by Kuiper. The effect of sky fog on in-focus photometry has been discussed by Matjagin (**20**).

OBSERVATIONS

So many photometric observations are being made all over the world that it is not practicable to do more than to indicate something of their scope and variety. Further details of many of the programmes mentioned are likely to be found in the reports of the other Commissions to which they more nearly appertain.

Photo-electric U, B, V sequences consisting of about 20 stars down to magnitude 14 and intended as a basis for more extended photo-electric and/or photographic photometry have been, or are being, established in Selected Areas 141, 158 and 193 by the Boks at Mount Stromlo (**21**) and in Selected Areas 91, 103, 115, 116, 126, 150, 166, 190, 192 and 193 by the Stockholm observers at the Boyden Observatory. These latter are also establishing similar sequences in 159 fields situated in three galactic bands ($b = +2^\circ\!.5$, 0° and $-2^\circ\!.5$, $7^h\,30^m <$ $< \alpha < 18^h\,00^m$). Velghe, also working at the Boyden Observatory, is planning to get U, B, V sequences to magnitude 12·5 in Selected Areas 172 and 195, while Elvius at Mount Stromlo is getting photo-electric sequences in Selected Areas 68, 92, 138, 164, 165, 188, 200, 201, 204, 205 and 206 to help in the reduction of the photographic and spectrophotometric material he has gathered with the Schmidt Telescope at the Uppsala Southern Station. At Stockholm, Elvius and K. Lodén have published *IPg* and *IPv* magnitudes, spectral classes and spectrophotometric absolute magnitudes for 759 stars in Selected Areas 11 – 14. The photometry extends down to magnitude 14 and maps of the $1^\circ\!.5 \times 1^\circ\!.5$ areas are given (**22**). A similar investigation of Selected Areas 8 – 10 is being made but with the photographic photometry based on photo-electrically observed sequences. At Leiden, Kooreman is extending his photographic photometry of the southern Selected Areas down to magnitude 13·5 for a number of the Areas (**23**).

Ramberg of Stockholm is continuing his photometric and spectrophotometric survey of selected regions in or near the Milky Way. The survey in the Lacerta region has been completed (**24**) and he is now working on the Norma region using material gathered at the Boyden Observatory. Selected regions of the Milky Way are also being investigated at various observatories in the U.S.S.R. At the Crimean Observatory the determination of photographic magnitudes, colours and spectral types for stars down to magnitude 12·5 continues and during the past three years data referring to approximately 22 000 stars in eight areas have been published. The centres of these areas are $20^h\ 05^m$, $+36°$ (**25**); $18^h\ 10^m$, $-15°$ (**26**); $20^h\ 44^m$, $+45°$ (**27**); $20^h\ 16^m$, $+42°·5$ (**28**); $18^h\ 54^m$, $+5°$ (**29**); $21^h\ 24^m$, $+58°·5$ (**30**); $02^h\ 30^m$, $+58°$ (**31**); $01^h\ 30^m$, $+60°·5$ (**32**). Similar work for areas centred on $05^h\ 32^m$, $+2°$ and $22^h\ 28^m$, $+58°$ is being done at the Wilnius Astronomical Observatory by Strajzis and Mashnauskas using plates obtained at the Crimean Observatory. At Kiev, Gordeladse, Lukazkaja, Voroshilov and Kolesnik have obtained three-colour magnitudes down to 13·5 for 5000 stars in three areas centred at $19^h\ 50^m$, $+5°$; $18^h\ 50^m$, $+6°$ and $20^h\ 40^m$, $+45°$ while Fedorchenko has obtained two-colour magnitudes down to 13·5 for 1000 stars in an area centred on $18^h\ 55^m$, $+15°$ and photographic magnitudes down to 13 for 7000 stars in an area centred on $18^h\ 50^m$, $+15°$. Voroshilov has also derived photographic and photo-red magnitudes down to 14 for 7000 stars in an area centred on $18^h\ 50^m$, $+5°$. At the Abastumani Observatory photovisual magnitudes have been determined for 1685 stars in an area centred on $17^h\ 32^m$, $-25°$ (**33**). At the Sternberg Institute photographic magnitudes have been determined for nearly 300 faint stars in the neighbourhood of ξ and σ Orionis (**34**), infra-red photographic magnitudes and colours for more than 100 stars in the α Cygni region (**35**) and colours for early type stars in the region of P Cygni (**36**). At Odessa, Dragomiretzkaja has continued her work on the determination of photographic magnitudes for the Virtanen-Vyssotsky standards (**37**).

In the course of infra-red surveys of regions in Cygnus (**38**), Aquila (**39**), the Southern Coal Sack (**40**) and the Large Magellanic Cloud (**41**), Westerlund has measured infra-red magnitudes for about 2400 stars. He has also measured B, V, R and I magnitudes down to $V = 16$ for about 1400 stars in the Large Magellanic Cloud on plates taken with the Uppsala Schmidt and the 74-inch reflector at Mount Stromlo.

The Magellanic Clouds are receiving ever increasing attention. Various sequences in, or near, them have been set up by Arp (**42**), the Boks (**21**), Cousins, Eggen and Sandage (**43**), Gascoigne, Hogg and Wesselink (**44**) while much general photographic and photo-electric photometry of the Clouds has been done by these and other observers. At the Royal Greenwich Observatory, Woolley has started a very extensive programme which is to be based mainly on material from the Cape and Radcliffe Observatories (**45**).

Clusters have also been intensively observed. Mention has been made of the Lowell programme (**6**). In the U.S.S.R. photographic magnitudes and proper motions have been measured at the Pulkovo Observatory for 5750 in the regions of NGC 1513, 1960, 2099 and 6705 (**46**) and for 14165 stars in the regions of NGC 129, 457, 581, 752, 869 (= *h* Per), 884 (= χ Per), 1907, 1912, 2168, 6833, 6855, 7092 and 7209. Magnitudes and colours have been measured at the Sternberg Institute for 1253 stars in the regions of NGC 752 and 6940 (**47**); for nearly 850 stars in NGC 2264 (**48**); for 75 stars near IC 1369 (**49**); for 81 stars in the outer part of NGC 5272 (= M 3) (**50**) and for 1325 stars in the regions of NGC I 1369, I 1805, 2175, 2237, 2238 and 6618 (**51**). Photographic magnitudes for 392 stars in the region of NGC 6866 (**52**) and infra-red magnitudes and colours for 250 stars in the Orion Nebula (**53**) have also been measured at the Sternberg Institute. Plate material from the Abastumani, Crimean and Engelhard Observatories is being used at Sverdlovsk to find photographic and photovisual magnitudes for stars in open clusters. Results have been published for NGC 1513 (**54**), NGC 1605 (**55**) and NGC 1664 (**56**). In the Southern Hemisphere, Eggen, working at the Radcliffe Observatory, has set up U, B, V sequences near NGC 2477, 5470, 6383, 6397, 6405, Mel 66 and ω Centauri, while at Mount Stromlo sequences have been established near

NGC 2539, I 2391, 3228, 4755, 5281, 6025 and Mel 227 by Hogg, near NGC 6397 by Gascoigne, near NGC 4852, 6193 and in Carina by Westerlund and near NGC I 2602 by Whiteoak. In most cases the photo-electric sequences have been used for reducing complementary photographic observations. At the Rutherfurd Observatory two-colour photometry of about 1000 stars in NGC 6397 is in progress using plates obtained by the Cordoba Observatory while Belserene has completed some photographic colour magnitude work on ω Centauri (**57**).

Certain categories of individual stars are receiving much attention. Thus early-type stars have been observed at the Sternberg Institute where Vorontsov-Velyaminov and his colleagues have determined photographic magnitudes for nearly 1200 O and B stars, at the Boyden Observatory where Velghe is making three-colour photo-electric observations of 200 early-type stars in the Vela region, at the Radcliffe and Cape Observatories where a joint programme has provided magnitudes and colours for many of the faint O and B stars observed spectroscopically at the Radcliffe Observatory (**58**), at the Crimean Observatory where U, B, V colours have been observed for 125 O to A stars (**59**), and at several other observatories. Faint blue stars in high galactic latitudes have been observed by Iriarte at Flagstaff (**60**). P. O. Lindblad is observing late-type giants at Stockholm, while Westerlund at Mount Stromlo has observed some bright southern super-giants (**61**) and is now working on southern M giants, on A-type stars near the South Galactic Pole and on OB and Be stars near the Southern Coal Sack. Photo-electric $B - V$ and $U - B$ colours have been determined at Tokio by Osawa and Hata for the 533 bright B8 – A2 stars between $+10°$ and $+40°$ that Osawa classified on the *MK* System while at the Yerkes Observatory (**62, 63**). Osawa has also observed the colours of some metallic-line stars (**64**). Bright stars have been observed at the Cape, by Hogg (**65**), by Willstrop (**66**) and by Eggen who, during his two visits to South Africa, used the various telescopes at the Radcliffe and Cape Observatories to make three-colour photo-electric observations of a wide variety of objects including a considerable number of dwarfs, known and suspected sub-dwarfs, sub-giants, irregular variables, contact binaries and members of special populations and groups. Routine photo-electric observations at the Cape include the determination of V, $B - V$, $(U - B)_c$ for nearby stars, stars of large proper motion and stars which have been observed spectroscopically at the Radcliffe Observatory. These latter include 120 A-type stars near the South Galactic Pole and a selection of 315 eighth magnitude late-type stars (**76**). $(U - B_c)$ colours have been found for many of the 2000 HR stars which had previously been observed only in blue and yellow. Cousins has determined V and $B - V$ for the comparison stars of a number of important southern variables (**68**). The whole of the Cape photo-electric photometry up to the end of 1960 is being condensed into a single homogeneous list to be published as a *Royal Observatory Bulletin*. At the Lick Observatory, Whitford and Sears are engaged on six-colour photometry of high-velocity stars.

The Cape photographic photometry includes the determination of *SPg* and *SPv* magnitudes for the 65 000 stars in the *Cape Photographic Catalogue for* 1950·0 (**69**). The work is complete for zones north of $-72°$ and the plates for more than two thirds of the zones between $-72°$ and $-80°$ have been measured. For the zones south of $-72°$, standard sequences in the three F Regions at $-75°$ are being used. Each sequence has approximately fifty stars in the range of magnitudes being measured and their magnitudes and colours have been established photo-electrically.

At Indiana, Irwin has been reducing the V, $B - V$ and $(U - B)_c$ observations he made at the Cape and Radcliffe Observatories in 1955. These were mainly of southern cepheids but observations of 42 E Region and 117 bright southern stars are included. U, B, V observations of northern cepheids and of some standard stars have been made in California by Oosterhoff (**70**). Two-colour photo-electric observations of a number of northern cepheids have been made at Heidelberg by Bahner and Mavridis (**71**) and 29 cepheids have been observed photographically in blue and red light by Birney at the Georgetown College Observatory. A selection of southern RR Lyrae stars has been intensively observed photo-electrically at the Cape by Kinman.

MISCELLANEOUS

Work on the 'General Catalogue of Magnitudes' proposed at the Moscow Meeting has progressed steadily. At the Cape work has been concentrated on collecting all photo-electric observations on suitable cards and on investigating the relationship between the various series of precision observations. At Cracow, Rybka has continued his work on the reduction of the Harvard visual magnitudes of stars brighter than 7·5 to a uniform photometric system and, in this connection, has studied the systematic differences between the various series of Harvard observations (**72**). He is also investigating the magnitudes of the Potsdam Durchmusterung.

At the Sternberg Astronomical Institute, Sharov has published a catalogue giving the colours of 150 near-by stars (**73**) and Parenago and Sharov have compiled a catalogue of more than 7000 photo-electric colours for O – A5 stars and have used it in studies of light absorption within the Galaxy. Some problems relating to systematic errors of photometric catalogues have been discussed by Dragomiretzkaja (**37**).

Willstrop, of the Cambridge University Observatories, during a visit to the Cape has made careful measurements in cgs units of the extra-atmospheric radiation in four narrow spectral regions for a series of bright stars of known V and $B - V$ (**66**). Martynov has reviewed the data available and has deduced revised values for the lux and for the stellar magnitudes of the Sun and the Moon (**74**).

In a series of papers in the *Lowell Observatory Bulletins*, Johnson has discussed the luminosity and intrinsic colours of early-type stars and how the form of the main sequence varies with the age of the stars (**1, 2, 3**) Sandage and Eggen have investigated the blanketing effect of weak Fraunhofer lines and the resulting ultra-violet excess for sub-dwarfs (**75**). Eggen has discussed many subjects of interest to photometrists in his series of papers on Stellar Groups (**76**). At La Plata, Feinstein has investigated the intrinsic colours for luminosity classes I, II and II – III. He finds that between F0 and F5 super-giants are bluer than dwarfs of the same type but for types later than F5 they are redder. Stars of Classes II and II – III appear to have the same colour as those of Class I between F2 and G0, and as those of Class III for the later spectral-types (**77, 78**). At Athens, Mavridis has studied the $(U - B)$, $(B - V)$ diagram for early-type stars to investigate their intrinsic colours and how the form of the reddening paths vary with spectral-type and luminosity class (**79**).

POLARIMETRY

A recent comprehensive survey of stellar polarimetry will be found in *Lowell Observatory Bulletin* No. 105 which gives a report of the conference on the 'Polarization of Starlight by the Interstellar Medium' which was held at the Lowell Observatory in February, 1960. Work which has been reported to Commission 25 and which is not already mentioned in this summary includes Kharitonov's photo-electric polarimetric observations of 34 stars connected with reflection nebulae (**80**) and a discussion of the causes of systematic errors in photo-electric polarimetry by Xanfomaliti (**81**).

R. H. STOY
President of the Commission

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APPENDIX

Supplementary Standard Stars for V and B − V

Magnitudes and colours with internal probable errors of less than $\pm 0^m.01$ are now available for over five thousand southern stars. The following list has been compiled by selecting those stars which have been observed in at least two independent accurate series and for which the determinations of V do not differ by more than $0^m.02$. Where data from additional, less accurate, series of observations have been included, stars for which the external probable error of the mean exeeds $\pm 0^m.01$ for either the magnitude or colour have been discarded. A few stars observed by Johnson have been included although no second accurate determination of $B - V$ is available. Doubles have not been rejected unless their duplicity is likely to interfere with their use as zero point and extinction stars.

The spectral classifications are from various sources including the Yerkes, Canberra, Cape and Radcliffe Observatories. Those unaccompanied by a luminosity classification are mainly from the Henry Draper Catalogue. A 'J' in the last column indicates that the star has been observed by Johnson or his associates, an 'E' that the star is in one of the E-regions, while an 'R' calls attention to a note at the end of the table. Only the very brightest E-region stars have been included in this list.

HD	HR	V	$B-V$	Spect.	Notes	HD	HR	V	$B-V$	Spect.	Notes
886	39	2·83	−0·23	B2 IV	J	3 326	151	6·05	+0·30	A3	
2 070	—	6·81	+0·60	G0		4 065	185	6·05	−0·03	A0	R
2 151	98	2·79	+0·62	G2 IV		4 128	188	2·04	+1·02	K1 III	
2 261	99	2·39	+1·08	K0 III	R	4 247	197	5·23	+0·34	A5	
2 696	118	5·18	+0·12	A3 V		6 178	293	5·50	+0·08	A2 V	

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HD	HR	*V*	*B − V*	Spect.	Notes
6 595	322	3·30	+0·89	G8 III	E R
6 668	325	6·36	+0·24	A2	
7 570	370	4·96	+0·58	F8 V	E
9 270	437	3·62	+0·97	G8 III	J
9 362	440	3·94	+0·99	K0 III-IV	E
10 700	509	3·49	+0·73	G8 V	J
11 171	531	4·65	+0·34	dF1	
12 311	591	2·86	+0·28	F0 V	
14 228	674	3·56	−0·12	B8 V	
15 318	718	4·27	−0·06	B9 III	J
16 582	779	4·07	−0·22	B2 V	
16 970	804	3·46	+0·09	A2 V	R
17 094	813	4·27	+0·31	F0 IV	J
18 331	875	5·16	+0·09	A1 V	J
20 280		9·13	+1·22	K7 V	
20 630	996	4·83	+0·68	G5 V	J
21 120	1030	3·60	+0·89	G8 III	J
22 049	1084	3·73	+0·89	K2 V	J
22 484	1101	4·28	+0·58	dF9	
23 249	1136	3·52	+0·92	K0 IV	
23 308		6·49	+0·52	F5	
23 484		6·99	+0·88	K0 V	
24 512	1208	3·23	+1·62	M0 III	
26 612	1302	4·93	+0·34	F0	E
27 376	1347	3·56	−0·12	B8·5 V	R
28 319	1412	3·41	+0·18	A7 III	J
29 305	1465	3·26	−0·11	A0 III*p*	
30 652	1543	3·19	+0·45	F6 V	J
30 836	1552	3·68	−0·17	B2 IV	J
33 111	1666	2·79	+0·13	A3 III	J
33 872	1699	6·56	+1·62	K5	
35 468	1790	1·64	−0·23	B2 III	J
36 512	1855	4·61	−0·27	B0 V	J
36 591	1861	5·34	−0·20	B1 V	J R
36 673	1865	2·59	+0·22	F0 I*b*	
36 861	1879	3·39	−0·19	O8	J R
37 501	1936	6·31	+0·84	K0	
38 678	1998	3·54	+0·10	A3 V	J
39 533		6·86	+0·92	G5	
41 700	2157	6·34	+0·52	F8	
44 402	2282	3·02	−0·20	B3 V	
47 205	2429	3·96	+1·06	K1 IV	
47 240	2432	6·15	+0·15	B1 I*b*	J
47 442	2443	4·43	+1·15	K1 III	
47 670	2451	3·17	−0·11	B8 III	E
47 839	2456	4·66	−0·25	O7	J R
48 099	2467	6·36	−0·05	O6	J
48 383	2475	6·11	−0·14	B5	
49 095	2500	5·91	+0·48	dF6	
49 705	2524	6·45	+0·86	G5	R
50 241	2550	3·26	+0·21	A5	
52 698		6·71	+0·90	K0 V	
53 975	2679	6·48	−0·10	O8	J
54 605	2693	1·83	+0·68	F8 I*a*	
54 662	2694	6·21	+0·03	O6	J
60 098	2885	6·68	−0·12	B5*p*	
63 118	3020	6·02	−0·08	B5	
64 722	3088	5·69	−0·16	B3	
65 810	3131	4·61	+0·08	A2	
66 811	3165	2·25	−0·28	O5*f*	
69 267	3249	3·52	+1·48	K4 III	J
71 155	3314	3·89	−0·02	A0 V	J
73 744		7·60	+0·60	G0 V	
74 273	3453	5·90	−0·22	B5	
74 280	3454	4·29	−0·20	B3 V	J
74 956	3485	1·95	+0·04	A0 V	R
76 566	3562	6·26	−0·17	B3	
78 548	3629	6·10	−0·16	B5	
78 643		6·76	+0·57	F8	
79 351	3659	3·43	−0·20	B3 IV	R
79 469	3665	3·88	−0·06	A0 V*p*	J
80 007	3685	1·67	0·00	A0 III	
80 404	3699	2·24	+0·18	F0 I*b*	
81 797	3748	1·98	+1·44	K3 III	
82 455		8·64	+0·66	G5 V	
83 443		8·22	+0·82	K0 V	
83 754	3849	5·06	−0·16	B3	
86 523	3943	6·04	−0·14	B5	R
87 901	3982	1·36	−0·11	B7 V	J
89 080	4037	3·31	−0·09	B8 IV	
91 316	4133	3·85	−0·14	B1 I*b*	J
91 706	4149	6·10	+0·50	dF7	
92 036	4162	4·88	+1·62	K5	
93 497	4216	2·68	+0·90	G5 III	R
101 266		9·28	+0·66	G5 IV	
102 647	4534	2·13	+0·09	A3 V	J
102 964	4546	4·45	+1·31	K0	E
105 707	4630	3·00	+1·33	K2 III	
106 068	4644	5·92	+0·29	B2	
106 625	4662	2·59	−0·11	B8 III	J
107 209		6·80	+0·25	B3	
108 767	4757	2·95	−0·05	B9 V	R
109 379	4786	2·65	+0·89	G5 II	
109 867	4806	6·24	+0·06	B2	
110 379	4825	2·74	+0·36	F0 V	R
112 842		7·04	+0·22	B5	
115 659	5020	2·98	+0·92	G5 III	
115 892	5028	2·76	+0·05	A2 V	
116 658	5056	0·97	−0·23	B1 V	J
118 098	5107	3·37	+0·11	A3 V	

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HD	HR	V	$B-V$	Spect.	Notes
118 716	5132	2·29	−0·23	B1 V	
120 709	5210	4·31	−0·13	B5 IV	R
121 743	5248	3·82	−0·22	B2 V	
122 408	5264	4·25	+0·10	A3 V	J
122 980	5285	4·35	−0·20	B2 V	
123 139	5288	2·06	+1·02	K0 III	
124 850	5338	4·07	+0·52	F6 III	
126 354	5396	4·34	+0·42	F8	E R
128 674		7·38	+0·68	G5 V	
128 898	5463	3·18	+0·24	F0 III	R
129 056	5469	2·30	−0·21	B1 V	E
129 116	5471	3·99	−0·18	B3 V	
130 109	5511	3·74	−0·01	A0 V	J
130 807	5528	4·32	−0·16	B8 V	
130 841	5531	2·75	+0·14	A3 V	J
131 923	5566	6·34	+0·71	dG7	
132 058	5571	2·67	−0·23	B2 V	E
133 242	5605	3·89	−0·14	B5 IV	E R
133 955	5626	4·05	−0·18	B3 V	R
135 742	5685	2·61	−0·11	B8 V	J
138 769	5781	4·54	−0·19	B3 IV	R
140 573	5854	2·64	+1·16	K2 III	J
141 003	5867	3·67	+0·06	A2 IV	J R
141 004	5868	4·43	+0·60	G0 V	J
141 637	5885	4·62	−0·05	B3 V	
141 891	5897	2·83	+0·30	F0 V	
142 114	5904	4·59	−0·09	B3 V	R
142 669	5928	3·88	−0·20	B2 V	
142 860	5933	3·85	+0·48	F6 V	J
143 699	5967	4·89	−0·14	B4 V	
145 482	6028	4·58	−0·16	B3 V	
146 791	6075	3·23	+0·96	G8 III	
148 184	6118	4·31	+0·30	B3 V*e*	
149 757	6175	2·57	+0·02	O9·5 V	J
151 680	6241	2·28	+1·15	K2 III	
154 363		7·73	+1·16	K5 V	J
155 125	6378	2·43	+0·06	A2 V	R
155 203	6380	3·33	+0·40	F0 IV	E
155 826	6398	5·96	+0·58	dF9	
157 056	6453	3·28	−0·21	B2 IV	
157 792	6486	4·18	+0·28	F0	
157 881		7·54	+1·36	K7 V	J
159 217	6537	4·58	−0·04	AO	E
159 876	6561	3·54	+0·27	F0 IV	
161 096	6603	2·76	+1·16	K2 III	J
161 471	6615	3·02	+0·51	F1 *Ia*	
161 868	6629	3·75	+0·04	A0 V	J
162 374	6647	5·90	−0·12	B8	
163 917	6698	3·34	+1·00	K0 III	
164 259	6710	4·62	+0·38	F3 V	J
168 723	6869	3·26	+0·94	K0 III-IV	J
169 916	6913	2·84	+1·04	K2 III	
171 443	6973	3·85	+1·34	K3 III	
176 687	7194	2·60	+0·08	A2 III	
177 565	7232	6·15	+0·72	G5 IV	
177 724	7235	2·99	0·00	A0	J
177 756	7236	3·44	−0·09	B8 V	
178 524	7264	2·90	+0·36	F2 II	R
181 577	7340	3·93	+0·23	F0 IV	
184 915	7446	4·95	−0·01	B0·5 III	J
187 642	7557	0·78	+0·22	A7 IV-V	J
188 114	7581	4·12	+1·08	K0	E
188 512	7602	3·72	+0·86	G8 IV	J
189 140	7627	6·13	+1·64	M0 III	
192 947	7754	3·56	+0·94	G8 III	
194 433	7808	6·24	+0·96	K2 IV-V	R
196 171	7869	3·11	+1·00	K0 III	
197 051	7913	3·41	+0·16	A5 IV	
198 001	7950	3·77	0·00	A1 V	J
202 447	8131	3·92	+0·53	F8, A3	R
204 075	8204	3·74	+0·99	G4 *Ib?*	
207 971	8353	3·00	−0·12	B8 III	
209 750	8414	2·93	+0·98	G2 *Ib*	
209 952	8425	1·74	−0·14	B5 V	E
210 418	8450	3·52	+0·08	A2 IV	R
210 441		6·60	+1·00	G8 IV	
211 416	8502	2·85	+1·39	K3 III	
213 009	8556	3·96	+1·03	G5	E
213 051	8558	3·65	+0·41	F2 III	R
213 998	8597	4·03	−0·09	B8 V	
214 759		7·39	+0·80	K0	
215 104	8644	4·84	+1·02	K0	
215 648	8665	4·20	+0·50	F7 V	J
215 789	8675	3·49	+0·08	A2 V	
216 735	8717	4·90	0·00	A0 V	J
216 956	8728	1·15	+0·09	A3 V	
218 045	8781	2·49	−0·05	B9 V	J
218 329	8795	4·51	+1·56	M2 III	J
219 615	8852	3·69	+0·92	G9 III	
219 688	8858	4·38	−0·16	B3 V	
219 877	8868	5·55	+0·40	dF0	R
222 226		7·00	+0·30	A5	
222 368	8969	4·13	+0·51	F7 V	J
222 603	8984	4·49	+0·20	A5	
223 466	9026	6·41	+0·12	A0	
224 360		7·70	+0·45	F5 V	
224 990	9091	5·02	−0·15	B5	
225 132	9098	4·54	−0·05	A0 IV	

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Remarks

HD 2 261	Close double,
4 065	double, 1″
6 595	double 1″·5
16 970	double 4″
27 376	Close double
36 591	double 2″
36 861	= 1879/80, double 4″
47 839	double 3″
49 705	double 1″·5
74 956	double 3″
79 351	Two spectra
86 523	Faint companion
93 497	double 2″
108 767	Faint companion
110 379/80	= HR4825/6; double, 4″
HD 120 709/10	= HR5210/1; double, 8″
126 354	Close double
128 898	Faint companion
133 242	= HR5605/6; double, 2″
133 955	Close double
138 769	double 2″
141 003	Faint companion
142 114	double 3″
155 125	Close double
178 524	Close double
194 433	double 1″
202 447/8	Composite spectrum
210 418	Two spectra
213 051/2	= HR8558/9; double 3″
219 877	Faint companion

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