25. STELLAR PHOTOMETRY AND POLARIMETRY (PHOTOMETRIE ET POLARIMETRIE STELLAIRES)

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I. INTRODUCTION

Most astronomical observers at some time become involved in photometric techniques even if the participation may be limited to a rough check of the brightness of an object for measurement at the telescope. The field is in fact so broad that much of the current work is more appropriate to the reviews of other IAU Commissions and it has become accepted that Commission 25 deals mainly with those subjects which are of common practical interest to photometrists and polarimetrists around the world. We are now at the beginning of a new stage, that of observation with space telescopes and it will be important to ensure that the transition to the new techniques of measurement is a smooth one. In our review, we restrict our discussion to stellar work, leaving to other Commissions the consideration of photometry and polarimetry of stellar systems, solar system objects and gaseous nebulae. We consider recent work concerning detectors, photometric and polarimetric systems, standard stars and sequences, catalogues of new material and related items of interest to observers. The reference numbering system of Astronomy and Astrophysics Abstracts is used where possible. We shall draw attention to some important conference volumes and to some major observing projects completed during the last 3 years and finally shall look briefly towards probable developments and future prospects for the times ahead.

Dr. M.S. Bessell, Dr. P.F. Chugainov, Dr. B. Hauck, Dr. A.R. Hyland, and Dr. J. Tinbergen contributed sections of the report. Thanks are also due to Sra. E. Bauer for her generous help in preparing the manuscript for publication.

II. ADVANCES IN TECHNIQUES OF PHOTOMETRY AND POLARIMETRY

(a) PHOTOMETRY (M.S. Bessell and A.R. Hyland)

(i) The Optical and Near Infrared

Over the last three years there have been several important innovations, but it has mainly been a time of consolidation in the use of computer controlled instrumentation and data reduction as well as a time of critical evaluation of the variety of panoramic detectors which are increasingly becoming all-purpose receivers at most observatories. A summary of specific aspects follows.

1. On-axis photoelectric photometry has benefitted from the availability of the high quantum efficiency GaAs and extended-red S20 photocathodes, and the precise broadband BVRI standards (such as those of Cousins) established using such photocathodes. The Varian GaInAsP photocathode is also available at several observatories as a replacement for the S1 photocathode for programs requiring good spectral sensitivity at wavelengths as red as 1.1 microns.

2. Development and wider utilization of two-dimensional detectors with single photocathodes has continued. These range from integrating devices such as the

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McMullan electronographic camera and the SEC Vidicon to photon counting devices such as the RCA Intensified SIT Vidicon, the Image Photon Counting Systems (IPCS) and the Photon Counting Array (PCA). An excellent review was published by Ford (26.031.539). The existing IPCS have been modified to improve their two-dimensional capabilities and new ones have been put into use. The two-dimensional PCA (Stapinski et al. 1981) has undergone much development, and a mosaic PCA has been proposed for the joint US-Canada-Australia STARLAB project.

3. Several cameras incorporating cooled Charge-Coupled Devices (CCDs) (with quantum efficiency > 50%) have recently been commissioned for general use.The CCD chips come from several manufacturers (e.g. General Electric, Fairchild, RCA and Texas Instruments). Development for faint signal photometry is continuing in order to improve the read-out noise, the violet sensitivity and the near IR-fringing but, even so, the existing systems have produced some spectacular pictures.

4. Parallel to the development of electronic panoramic detectors, there has been a renaissance in the use of the photographic plate. Hydrogen sensitized IIIa-J and IIIa-F plates and silver nitrate sensitized IV-N plates are extremely efficient detectors when used at the short focal lengths of large Schmidt telescopes and at the prime foci of 4m and 5m telescopes.

5. Modern densitometers such as the PDS and the highly specialized plate measuring machines at Minnesota (Humphreys and Landau 27.031.523) and at Edinburgh (Dodd and Dalton 27.034.045) can rapidly scan a whole plate or sections of a plate to provide arrays of digital data indistinguishable from that derived from the electronic panoramic detectors.

6. Much effort has gone into picture processing (i.e. the manipulation of arrays of digital data) to produce intensity maps and eventually, magnitudes of stars or integrated magnitudes of galaxies. The Interactive Picture Processing System (IPPS) at Kitt Peak (Wells 27.034.024) is probably the most highly developed system generally available. With the advent of the STARLINK computer network in the UK and in Australia and the acquisition of similar computers and peripherals at other institutions, we can look forward to rapid advances in picture processing over the next three years.

7. The higher quantum efficiency of the electronic panoramic detectors (20-70%) compared to that of photographic plates has not resulted in the anticipated increase in signal/noise for faint star photometry. This has been the major disappointment of the new detector revolution, and partly arises from the inability to maintain the stability of the two-dimensional sensitivity profile of the detector or to measure this profile under correct illumination with sufficient precision. The unintensified CCDs promise greater dimensional stability and this, together with a greater awareness of the engineering, observational and reduction problems associated with all aspects of two-dimensional photometry, should result in performances closer to theoretical expectations than hitherto obtained.

(ii) The Infrared

As regards new techniques in stellar photometry in the infrared, the present triennium has been remarkably quiet, with observational astronomers making good use of the highly sensitive InSb detectors to push short wavelength (1-5 microns) IR photometry to its limit and with precision approaching that of optical photometry. These detectors (generally 0.5 or 0.25mm in diameter and solid nitrogen or liquid helium cooled) have meant that operation becomes background limited down to 1.65 microns at all but the best sites. Values such as S/N = 3/1 in 30 min at J = 20 are now achievable.

One interesting advance has been the development of an integrating preamplifier system for InSb detectors (Baron and Allen 28.034.004) which removes the need for a high impedance feedback resistor in the circuit. This system, which is exceedingly versatile, is in use at the Anglo-Australian telescope and has produced remarkably good performance figures. It allows a great variety of chop cycle times (down to the reset time of the FET ~4ms) and has been used to investigate sky noise characteristics. Allen and Barton (1981) suggest that longer chop times at short wavelengths may provide better S/N than had otherwise been thought.

Unfortunately, the standard systems for infrared stellar photometry have not kept pace with improvements in detectors. It is now well known that colour terms apply to JHK photometry at different observatories (e.g. photometry at the Mount Stromlo system and that at the Anglo-Australian Observatory have been shown to have the transformation $(J-H)_{AAO} = 1.07\ (J-H)_{MSO}$ [Jones et al. 28.131.289]). It is expected that most other infrared photometric systems will similarly require transformations. Wamsteker (1981) and Engels et al. (1981) have published some standards and a large list of bright stars, which may be useful for comparison purposes, and Jones and Hyland have in press (MNRAS) a description of their present standard system. These studies however do not list any very red objects which are necessary to tie these systems together. A joint Cerro Tololo-Mount Stromlo investigation is underway to tie these objects together by almost simultaneous observations of both red and blue objects.

Panoramic detectors and arrays have still made no real impact in the IR. One paper by Lamy et al. (26.034.011) reports on the use of a Hamamatsu (PbS-PbO) TV tube out to 2.4 microns but the system is extremely insensitive and only very bright objects, such as α Orionis, are detectable.

New developments still awaited are the use of arrays of detectors, both linear and two dimensional. It surely cannot be too long before these become available for astronomical use. In the meantime, both the UK Infrared Telescope Group and Mount Stromlo Observatory are developing multi-detector photometry systems to obtain simultaneous colour data on both stars and galaxies. These instruments will be especially useful in the crowded fields in the Galactic plane, which are of great interest in regard to the stellar luminosity function of our Galaxy.

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(b) PHOTOMETRIC SYSTEMS (J.A. Graham)

There have been few innovations in photometric systems during the past triennium but improved standardization of photometry over a wider wavelength base will clearly be required as observation from outside the atmosphere becomes routine. D. Weistrop points out in a letter that the problem is already becoming more acute as more and more observations are made with CCD and other two-dimensional detectors and the need to calibrate these data will grow. Considerable effort has gone into standardizing photometry in the near infrared and we discuss this below. However, as Weistrop emphasizes, these photometric systems are often either not appropriate or do not extend to 1 micron. In the following sections we shall review work which has been done in the most widely used systems of optical photometry.

(i) UBVRI Systems

The most widely used photometric system continues to be the UBV system first proposed by Johnson and Morgan (1953). Although the spectral resolution is poor the

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large band-width of each colour makes it possible to obtain meaningful photometric information of faint stars quickly and efficiently. Johnson later added longer wavelength bands extending into the infrared region. The red bands R and I were defined by Johnson et al. (1966). While the UBV system seems to be reproducible with care, problems have arisen with the R and I bands, especially for very red stars (Kunkel and Rydgren 25.113.032). There appear to be several reasons for this. The Johnson RI system was defined with photomultipliers of lower sensitivity and different response characteristics than those commonly in use today. There is some uncertainty in the published band-pass function (Cousins 26.113.029). In addition, the original RI filters are no longer commercially available (Wisniewski 1979).

Photomultipliers with gallium arsenide photocathodes such as the RCA 31034 type have a high quantum efficiency from the ultraviolet to the near infrared which makes UBVRI photometry possible with a single photomultiplier as detector. Cousins (17.113.005) has used a photomultiplier of this type to define an RI system with passbands somewhat different from the Johnson system but which is more readily reproducible. Bessell (26.113.045) has proposed this as a standard system for both hemispheres. In this paper, he studies transformations to several alternative systems and provides temperature and absolute flux calibrations. Applications to photometry with photographic plates, electronic area detectors and digital spectra are also discussed. In our report, we shall follow Bessell and distinguish this system of RI photometry with subscript c.

(ii) The uvbyβ Strömgren System

This system, developed by Strömgren, Crawford and their collaborators continues in wide use. Eggen (25.113.056) has stressed that uncertainties evidently remain in the definition of the standard β system. A good discussion of the difficulties of Hβ index measurement from both theoretical and practical considerations is given by Schmidt and Taylor (26.031.514). Care is clearly necessary in making sure the filters are as well matched as possible to those of the original system or systematic errors depending on stellar temperature and interstellar reddening can enter.

An analysis of the Hauck-Mermilliod catalogue (27.002.006) has been published by Philip and Egret (27.113.026). The values of astrophysical parameters of 9604 stars of spectral types O through F have been estimated. Philip and Relyea (26.064.044) present a series of grids by which one can transform the dereddened indices (b-y) and (c_1) to T_{eff} and log g for Population I stars of spectral type A0 to F9. Philip (1981) has published a summary article dealing with determination of astrophysical parameters from uvby photometry. Heck (25.114.098) and Heck and Mersch (27.113.024) are concerned with the prediction of spectral type from uvbyβ photometry and the subsequent comparison with the observed spectral type. Because of the amount of data which is available for analysis, this method is ideal for the detection of stars with peculiar characteristics.

(iii) The Geneva Seven-Colour Photometric System

An important review article has been published by Golay (27.113.074). The Geneva photometry system has been applied to obtain T_{eff}, log g abundances, absolute visual magnitudes, peculiarities, interstellar extinction and light curves of all spectral types of stars. Comparison between observed and theoretical colours can be made through accurately defined transmission functions of the passbands. In his review, Golay applies the concepts of multicolour or multiparameter photometric boxes to discuss the sensitivity and selectivity of the system. Meyland et al. (28.113.013) discuss the intrinsic colours of the MK types in the Geneva system.

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(iv) The Vilnius Photometric System

Straizys (25.113.066) has summarized recent work done with this system. In collaboration with the Geneva Observatory, two combination-systems have been realized in the VILGEN and the GENVIL systems. The VILGEN system has much in common with the uvbyβ and RGU systems. Straizys and Bogdanovic (28.113.048) discuss transformations between the RGU and VILGEN systems. Further information about the Vilnius work may be found in the Commission 45 report.

(v) Walraven 5-Colour Photometry

J.W. Pel reports that the Leiden 0.9m reflector and the Walraven 5-channel photometer have become productive again after being moved from Hartebeestpoortdam, S. Africa to ESO, La Silla, Chile. All parameters of the Walraven system have been recalibrated and a new system of standard stars has been set up. The photometer sensitivity has been improved considerably and 1% accuracy for OB-stars down to $V = 15^m$ can now be reached on this telescope within 5 minutes. The present observing programmes cover open clusters, OB-stars, X-ray sources, pulsating variables in the Galaxy and the Magellanic Clouds. One of the first results from the photometer in its new set up is a determination of the metal content of the Small Magellanic Cloud Cepheids (Pel et al. 1981).

(vi) Other Systems

Harris and Canterna (26.113.036) present new observations on the CMT_1T_2 Washington System. Canterna and Harris (25.113.065) review and discuss applications.

McClure (25.113.057) reviews the status of the David Dunlap Observatory System.

Pavlovski et al. (27.113.062) describe the Hvar Observatory Winter Colour System which is based on cluster and standard star observations.

Wade et al. (25.113.034) establish a two-colour photometric system in the near infrared. The primary purpose is for the calibration of the Palomar near infrared atlas.

Wegner (26.113.053) derives transformation formulae which show that the Torun Photometric System differs very little from the International IPg, IPv System.

At the Utrecht Astronomical Institute, J.R.W. Heintze has developed a new narrow-band photometric system for the study of stellar continua. The system employs 6 filters of about 100 Å wide, situated at wavelengths with minimal line-blocking between 4720 and 8710 Å. Two additional filters measure Hα. The observing programmes concentrate on visual and near-IR lightcurves of Algol variables, and are carried out with a fully automated one-channel photometer which is presently mounted on the 40cm reflector at the Dutch Observing Station at Ausserbinn, Switzerland. Standard-star colours and filter profiles have been published by P. Provoost (27.113.016).

Couch and Newell (28.113.046) establish a photometric system for limiting J F photographic photometry. Additional papers are in preparation.

Jones et al. (1981) describe a narrow-band photometric system in the red which differentiates lower main sequence stars from giants.

Important papers by Wesselius et al. (27.113.040) and by de Boer and Wesselius (28.113.014) describe satellite ultraviolet photometry for main sequence blue stars and for blue stars in the Galactic halo. A five-band ultraviolet photometer is described and the data reduction procedures discussed.

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(c) POLARIMETRY (J. Tinbergen)
(i) Introduction

The business of our commission, stellar photometry and polarimetry, is, to an increasing extent, the point-object special case of the larger field of photometry and polarimetry (unqualified). In many applications, it merges imperceptibly into spectrophotometry and spectropolarimetry. I have written my report with these considerations in mind.

Throughout the electromagnetic spectrum, polarimetry (as distinct from photometry) is being transformed from a specialist occupation into a standard tool of observational astronomy, yielding valuable additional information over "scalar" photometry. At optical wavelengths, applications now range over low resolution spectropolarimetry of faint objects (Angel and Stockman 28.141.099); very high resolution spectropolarimetry of bright stars (Borra 27.116.001, Vogt et al. 27.034.001, Borra et al. 1981) including the Sun (Baur 1981); broad-band imaging polarimetry (Baur 1981, King et al. 1981); high precision broad-band polarimetry of bright stars (Tinbergen and Zwaan 1981) and planets; phase-locked polarimetry of the Crab pulsar (Jones et al. 1981).

For the optical spectral region, the rule of thumb "polarization modulator + (spectro) photometer = (spectro) polarimeter" holds. Crucial aspects of the implementation of polarimetry as a standard tool are:

1) the availability of suitable modulators.
2) the suitable specialized development of electronic multi-element detectors.
3) the acceptance of precision polarimetry as a legitimate use of large telescopes even though the objects studied may be relatively bright.

If polarimetrists claim observing time on the large telescopes on the grounds of photon requirements, the polarimetric community must ensure that photons collected by the telescope are also used efficiently. This of course means not only that we must develop efficient instrumentation but equally that we must use this instrumentation as efficiently as possible. The present report concerns progress in these two fields. Investigations using polarimetry, but not in any particularly novel way are the concern of other commissions.

(ii) Efficient Instrumentation and its Use

The multi-element (panoramic) electronic detectors offer the possibility of impressive multiplex gain in a number of situations, especially in spectropolarimetry and imaging polarimetry. It is imperative that these detectors be pressed into service for polarimetry. In current practice, this requires that they can be read out from one to several hundred times per second and that they have good dynamic range. After initial experience with a number of different detectors (see McLean 1980 for a review), it now appears that the most promising all round detector may be the CCD, as used in a special mode involving alternating accumulation of 2 charge images, which correspond to orthogonal polarizations, on

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the chip for long enough to avoid degradation on the readout. This idea, first suggested by Stockman, requires that the on-chip transfer efficiency for electric charge be very nearly unity. Experiments underway at Steward Observatory (Stockman), Bell Laboratories (Tyson 28.034.009), the Royal Observatory, Edinburgh (McLean), and probably elsewhere, should tell us to what extent this is so. If, contrary to expectations, the technique should fail, we shall have to be content for the time being with an intensifier based detector (e.g. Miller et al. 28.034.069, Tomaszewski et al. 28.034.038) with considerable loss in peak quantum efficiency and virtually no far red response. Intensifier-detector combinations of commercially available components are in use at a number of observatories while integrated devices, often developed for space use, may also be suitable when the aim is to raise the efficiency of a large and expensive telescope. Since I expect that these detectors represent a passing phase, I have made no attempt at an inventory of them for this report.

Since spectropolarimetry and imaging polarimetry cover most of the polarimetry to be done with the new detectors, there is also a considerable demand for modulators which a) produce square-wave modulation of light intensity (only 2 images to be stored and analysed for each Stokes parameter) and b) are either achromatic or large-field (preferably both). The photo-elastic modulator is fundamentally the best type of all, since it modulates only the polarization and does so by means of a device which itself has negligible permanent birefringence. A mechanical square-wave modulator of this kind has been operated for a number of years by Dollfus. A new prototype has been developed by Angel for use in modern electronically controlled instruments. Baur et al (1981) report the use of a KD*P crystal at a low frequency of square-wave modulation. A super-achromatic half-wave plate, chopped between 2 positions 45° apart (McLean), is the third type of modulator which may serve us well in the future.

Progress towards a precision 10 micron polarimeter (linear and circular) is described by Ekstrom et al. (1981). This paper is also worthwhile for its selected bibliography. For the foreseeable future, infrared polarimetry will probably be limited to relatively bright sources at a precision of 0.1% (Dyck and Lonsdale 1981, Ekstrom et al. 1981). No recent polarimetry in the space ultraviolet has come to my notice but progress is likely within the next few years.

For polarimetry to be conducted efficiently at the telescope, it is essential that photometers and spectrometers at the Cassegrain focus be equipped with polarization optics and suitable data handling. In this connection, it is worth mentioning the approach taken with the future 4.2m telescope of the Northern Hemisphere Observatory at La Palma. With this telescope, the straight Cassegrain focus is more or less reserved for instruments with polarimetric capability and a common polarization modulator for all these instruments is being defined.

(iii) Conclusion

Technically, we are approaching the situation where large-area achromatic modulators and highly efficient detectors can use a large fraction of the photons offered. Wherever the size of the telescope and brightness of the object permit, we can expect to be able to measure the linear and circular polarization to the precision of 10^{-4} or even 10^{-5} (degree of polarization scale), that has already been achieved in Solar polarimetry (Baur et al. 1981). To what extent we use this capability will in the not too distant future depend only on the astronomical priorities between polarimetry and other time-consuming types of observation. This is as it should be for a mature observational technique.

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III. STANDARD STARS AND SEQUENCES

(a) PHOTOMETRY (J.A. Graham)

During the past triennium, much attention has been given to the derivation of faint stellar magnitude standards for calibration purposes. Consequently, the largest effort has gone into establishing standard stars and sequences on broad band systems. Two special techniques have been used in extending magnitude sequences to the faintest limits.

One method is electronography and a review of progress in this field was given by Penny (1980) at the last General Assembly. Faint magnitudes with this technique derive essentially from the known linear response of the detector coupled with previously determined magnitudes for brighter stars on the electronograph. There have been some problems associated with non-linearities in the nuclear emulsions used at the final detection stage. Hawkins (26.113.001) tried to take these into account in deriving two electronographic sequences near the South Galactic Pole. White (28.113.017) pointed out that some of Hawkins's stars were clearly visible on both the Palomar and ESO Quick Blue Surveys, even though they had been assigned magnitudes fainter than the accepted limits. Hawkins (1981) has subsequently reanalyzed his observations and concluded that the fault indeed lay in the nuclear emulsion. Purgathofer (25.113.016) has also used electronography to extend two UBV sequences in Selected Areas 82 and 107.

The second method is that which was introduced by Pickering (1891) and revived by Racine (1969) for photographic photometry. A small non-dispersing but slightly deviating glass wedge is placed in the entrance beam of a telescope. Next to the primary images of relatively bright stars, secondary images are thus formed with a fixed magnitude difference which can be calibrated. Secondary images can then be compared directly with primary images of fainter stars and thus used to extend an established photometric sequence as far as the limiting magnitude on the photographic plate. The method works well provided that the telescope is in good optical adjustment and that primary and secondary images have similar structure. The precise value of the magnitude difference can depend on optical aberrations in the telescope, uneven reflectivity over the primary mirror surface and local seeing variations but it is generally found to remain constant to within a few hundredths of a magnitude if the wedge is fixed in place. A good description is given by Couch and Newell (1980) and some useful experience is related by Carney (25.154.015). Hawkins (1981) used Pickering-Racine wedge observations as a check on the scale of his electronographically derived magnitudes.

(i) UBVRI

Landolt has in progress an extensive UBV $(RI)_c$ standard sequence project. The new work supplements and extends his frequently used 1973 paper (10.113.087) in which he published UBV photometry for 642 stars in Selected Area fields along the celestial equator. The general magnitude range of these stars is $10.5 < V < 12.5$. Beginning in late 1977, Landolt began a program designed to augment the earlier photometry with $(RI)_C$ measurements and with a selection of fainter stars. Through use of the Cerro Tololo telescopes, he has now completed observations for 252 stars in the $7 < V < 12$ magnitude range and in the $-0.2 < (B-V) < +2.0$ colour range. These data are tied to Cousins (17.113.005) VRI standard stars in the E-regions and into the Landolt (10.113.087) secondary UBV standards. There are of the order of 10 observations each for these new standard stars. UBV $(RI)_C$ observations are in progress for another 200 stars in the magnitude range $13 < V < 17$. About half the necessary data are available.

A large amount of work on E-region stars in UBV $(RI)_C$ in being done both in South Africa and in Chile. The Harvard E-regions, situated around the sky at declination -45° are convenient reference fields for southern hemisphere observers. Cousins (28.113.004) presents standard star observations for 311 stars, 75% of them between $7^m.0$ and $9^m.0$. J.W. Menzies and J.D. Laing report the completion of UBV observations for 175 stars in the Harvard E-regions with $8^m.5 < V < 12^m$ The results are of very high quality making these stars suitable for use as standards on moderately large telescopes. The new data have been combined with those of Cousins for the brighter E-region stars to produce the list of UBV $(RI)_C$ standard stars which is used at SAAO. Laing has now almost completed a series of $V(RI)_C$ observations for the same stars. South African Astronomical Circulars No. 1 contains a number of important papers giving results of this work. Graham has in press (PASP) a paper giving UBV $(RI)_C$ photometry for 104 stars in the E-regions between magnitudes 7 and 16. Finding charts and positions are given. Already published (Graham 1981a, b) are two sequences near the galaxies NGC 300 and NGC 5128. A useful compilation of E-region photometry, with positions, is ESO Preprint 140 by Vogt, Geisse and Rojas. A.W.J. Cousins also writes from Cape Town about current work at the South African Astronomical Observatory. He is observing E-regions stars, mostly in the range $7.0 < V < 9.0$, in UBV to strengthen the ties between the "standards" in Mem. RAS 77 and the photometry done by Menzies and Laing in 1979. This will affect some of their zero points by a few thousandths of a magnitude. The observations should be completed by the end of the year. Another programme (B.S. Carter) is to provide zero point stars in the E-regions for JHKL photometry, to supplement the secondary standards observed by I.S. Glass (11.113.035). Dr. Cousins also mentions that he is at present studying whether there is any difference of colour equation between the E-regions with UBV photometry and the bright equatorial stars that represent the original Johnson system.

A large amount of work is still being done on the Johnson VRI system (Neckel and Chini 27.113.014, Moffett and Barnes 25.113.031, .051, Barnes and Moffett 26.113.004, Scharlach and Craine 1980). Further to the red, Wamsteker (1981) has described a JHKLM photometric system which is, to observational accuracy, identical to the Arizona system. JHKL photometry for early-type stars is published by Whittet and van Breda (28.113.001). An absolute flux for Vega in the K band has been determined by Selby et al. (28.113.009). Stetson (26.158.049) has published an especially valuable B, V photoelectric sequence in the field of the Draco dwarf galaxy which contains 34 stars covering a range $15^m.2 < V < 21^m.1$ and $0 < (B-V) < 1^m.6$. UBV sequences and catalogues in various fields are published by Rybka (25.113.070), Alcaino (27.158.180), Bunclarck et al. (27.113.015), Guetter (27.113.063), Lunel and Garnier (27.113.006), Soonthornthum and Tritton (27.113.020).

(ii) <u>uvbyβ</u>

E.G. Schmidt writes that he has been setting up a series of standard stars for uvbyβ photometry which he intends to finish during the coming year. The standards are all between visual magnitude 7 and 8.5 and have spectral types

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ranging from B0 to G0. They are all equatorial so that they can be used from both northern and southern hemispheres. Additionally, there are several heavily reddened stars near 6 hours and several near 18 hours which will provide a useful check on reddening effects. Heck and Manfroid (28.113.021) report uvbyβ observations for 330 equatorial and southern bright stars. Kilkenny (27.113.049 and 1981) has obtained uvbyβ photometry for a large number of early type HD stars.

(iii) Others

19 standard stars for the Washington (CMT_1T_2) system are published by Harris and Canterna (26.113.036). Primary standards for the photographic J, F system are listed by Couch and Newell (28.113.046). The Third Catalogue of Stars measured in the Geneva Photometric System has been compiled by F. Rufener and is now available. A convenient compilation of standard stars for several photometric system is to be found in the book "Problems of Calibration of Multicolor Photometric Systems" (ed. A.G. Davis Philip, Dudley Observatory).

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b) POLARIMETRY (J. Tinbergen)

Since the bibliography prepared for the last IAU General Assembly (Tinbergen 1980), the following new sources of good standards may be noted.

1) Breger reports that standard stars work at the University of Texas is resulting in improved values for the degree of linear polarization for a number of stars including some of Serkowski (1974). Best precision reached so far by Breger is 0.01% for a star of P(V) = 2.22%.

2) The paper by Wilking et al. (27.131.012) on the wavelength dependence of interstellar linear polarization shows that precision broad-band polarimetry of "interstellar standards" may be used for other broad wavelength bands and, to some extent, even for narrow-band work although this latter application still remains to be confirmed by detailed spectropolarimetry.

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IV. STELLAR PHOTOMETRY AND POLARIMETRY IN THE USSR (P.F. Chugainov)

Photographic photometry with the 1m Schmidt telescope is being continued at the Bjurakan Observatory. UBV magnitudes for 1700 blue stars have been determined by Oghanesian. UBV photometry of flare stars in the Pleiades has been carried out by L.V. Mirzoyan and by Chavushian et al. (1980). Photoelectric photometry and polarimetry of red supergiants have been undertaken by Abrahamian (1980a, b).

In the main Astronomical Observatory of the Ukranian Academy of Sciences, the catalogue of BV magnitudes is now prepared for 6000 stars down to V = $13^{m}.5$ in 5

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regions of 18 square degrees located in the interval of Galactic longitude 135° -206° and containing emission nebulae IC 1805, IC 1848, NGC 1499, NGC 2244, NGC 2264 (Voroshilov, Kolesnik, Kuznetsov, Shapovalov, Guseva). This work has been done in cooperation with the Abstumani Observatory where spectral types for the same stars have been determined. Photoelectric UBVR observations of about 300 bright stars (5^m-8^m) have been obtained with the 40cm reflector installed in the Caucasus at elevation 3100m (Goncharova, Kovalchuk, Voytenko, Pugach, Jurevich). Photoelectric photometry in the 13-band system is in progress (Goncharova, Kovalchuck, Pugach).

The Odessa Observatory is active in photoelectric observations in the WBVR system of stars of different types (non-variable stars, β CMa-, semiregular and irregular variables). The W-band of this system is that proposed by Straizys. The first part of the "Atlas and Catalogue of Stellar Magnitudes and Photoelectric Standards" (114 stars with $\delta \geq -30°$) has been prepared for publication.

At the Abastumani Observatory, the atmospheric extinction in 1968-1973 is being investigated by Abuladze (1980).

At the Astronomical Observatory of the Leningrad State University, about 300 stars (12^m-15^m) in young aggregates of the Orion nebula and NGC 2264 were observed with the photoelectric UBVR photometer. For about 100 stars in the same aggregates, photoelectric RI magnitudes were also obtained by Shulov et al. (1981). Photometric and polarimetric observations have been made of cool variable stars (Larionov et al. 1979, Silantjev and Hozov (26.116.002) Larionova 1981), Orion variables (Kopatskaya 1979, Derviz and Kopatskaya 1981), and symbiotic stars (Ivanova and Khudyakova 1980, Nikitin and Khudyakova (26.117.036)). Results of polarimetric observations are reviewed by O.S. Shulov (1981). Tests are being made of a new scanning photoelectric photometer enabling measurements in the 1.2-2.5 micron region.

The Radioastrophysical Observatory of the Academy of Sciences of the Latvian SSR is continuing photographic UBVR photometry of carbon stars. Photometric characteristics have been measured for 68 carbon stars in the zones $\ell = 94°$. $b = 9°$ and $\ell = 178°$, $b = -9°$ (Alksne and Alksnis (27.123.021), Duncans (1981)). [See also Photometricheskie Issledovania Uglerodnykh Zvezdi Rodstvennykh Im Objektov, 3, Prilojenie. 1981]. The infrared carbon stars IRC 10216, CIT6, CIT5, AFGL 2699, CIT13 as well as possible carbon stars in open clusters and in the field have been observed (Alksne and Eglitis 1980, 1981, Alksne and Alksnis 27.122.131, 1981a,b,c,d, Alksne and Daube 1981a,b, Alksnis 1981, Platajs (27.122.132), Platajs and Rozenbush 1980). Photoelectric observations of red giant stars in the Vilnius and VRI systems have been made with the 48cm and 55cm telescopes (Dzervitis and Pauper 1981, Dzervitis et al. 1981, Kijla 1981).

At the Institute of Astrophysics and Atmospheric Physics of the Estonian Academy of Sciences, photoelectric IJHK observations of different stellar objects have been made. Results for 100 red stars are already published by Pehk and Tuvikene 1981. The symbiotic star CH Cyg is observed regularly by Luud et al. (21.117.062). The close binary system VW Cephei is also being observed in the I and K bands. Pehk and Tuvikene discuss the reduction, absolute calibration and optimal program for the determination of atmospheric extinction.

An automatic photometer has been constructed at the Crimean Observatory. Pulse counting electronics and digital printout are featured. Thermoelectric refrigeration is used not only for the photomultiplier but also for the filters and the standard light source.

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V. IMPORTANT PUBLICATIONS (J.A. Graham)

New Techniques in Stellar Photometry and Polarimetry
Ed. M.F. McCarthy S.J. Ricerche Astronomiche Specola Vaticana 10, 1980

This special issue of the Vatican Observatory publications contains the proceedings of a scientific session of Commission 25 at the Montreal IAU General Assembly. Included are a number of useful articles but two should be especially emphasized, that by R. Albrecht, "TV Reduction Techniques for Stellar Astronomy" and the fine introductory review "A Photometrist's Guide to Polarimetry" by J. Tinbergen.

Problems of Calibration of Multicolor Photometric Systems
Ed. A.G.D. Philip 1979 Dudley Observatory (Schenectady, New York).

This volume contains the proceedings of a workshop held at Dudley Observatory in March 1979. It is specially notable for containing reviews of most of the commonly used photometric systems as well as reduction procedures and standard star lists.

A Photometric Atlas of the Orion Nebula
by A.D. Andrews 1981 (Armagh Observatory).

The Atlas contains 6 charts, scale 22".2/mm with overlays. It comprises a four-colour (UBVI) photometric and astrometric catalogue for 16777 stars to $V = 16^m$. Derived from GALAXY measurements of UK Schmidt plates at Royal Greenwich Observatory, it covers a region of 22 sq. degs. centred on the Trapezium and employs new photoelectric calibrations of standard stars obtained at Las Campanas (Univ. Toronto) Observatory. Transparent overlays identify all (281) standard stars and all objects in the catalogue. A total of 666 variable and emission stars are identified on a red ESO Schmidt plate and on hand-drawn charts for the inner nebulous region using the Dearborn Observatory charts.

The 'Atlas' contains an introduction to the Orion region, including recent spectrum-scanner observations millimètre and X-ray results, and an outline of the Schmidt-plate reduction techniques with FORTRAN programmes, selective colour-magnitude and two-colour diagrams, the results of a search for extreme blue and red stars and a discussion of future directions for research into this interesting young region. This work was partially financially supported by the IAU with a grant through Commission 25.

A True Visual Magnitude Photographic Star Atlas
Compiled by C. Papadopoulos and Charles Scovil.
3 volumes 1979, 1980 (Pergamon Press, Oxford).
An extremely useful atlas for preparing identification charts. The limiting magnitude of 13.5 makes it possible to show individual stars even in crowded Milky Way fields.

Astronomical Papers Dedicated to Bengt Strömgren
Eds. A. Reiz and T. Andersen 1979 (University Observatory, Copenhagen).
This volume is a tribute to Bengt Strömgren on his 70th birthday. It contains several good papers on uvbyβ photometry, a photometric system which he pioneered.

Photoelectric Photometry of Variable Stars - A Practical Guide for the Smaller Observatory.
D.S. Hall and R.M. Genet - IAPPP (Communications 1981; Fairborn, Ohio).
This book is a publication produced by the International Amateur-Professional Photoelectric Photometry Group. It contains a wealth of useful practical detail for those astronomers making a beginning in photometry and perhaps constructing their own equipment. Subjects such as, photometers, amplifiers, pulse counting equipment, auxiliary minicomputers and observing techniques are well covered.

ESO Workshop on Two Dimensional Photometry
Ed. P. Krane, K. Kjär 1979 (European Southern Observatory)
Image Processing in Astronomy
Eds. G. Sedmak, M. Capaccioli, and R.J. Allen. 1979 (Observatorio Astronomico de Trieste).
These two conference volumes contain several useful articles on the methods of stellar photometry with two dimensional detectors. The problems of stellar photometry in crowded fields are also discussed.

VI. NEW CATALOGUES (B. Hauck)

(a) PHOTOMETRIC CATALOGUES

During the period under review the number of photometric catalogues deposited in one of the Stellar Data Centres (Strasbourg, Moscow, Kanazawa, Washington) has greatly increased. All catalogues available at these centres are announced in the information bulletins or lists of these centres and thanks to the strong collaboration between these centres, everyone can have easy access to the data.

Many new data in various systems have been published, but this analysis will be restricted only to long lists and also to the catalogues resulting from the compilation of existing data.

UBV_ERI photometry (Eggen 25.002.006, 28.002.031) has been obtained for stars with a large proper motion. P.E. Zakharova has published (25.113.040) a catalogue of magnitudes and colour indices of stars in the UBV system in the region of the NGC 7762 cluster. Mermilliod (28.002.040) has compiled all the UBV data published between 1976 and 1979; 16200 measurements have been recorded. Nicolet (28.115.007)

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has plotted in a U-B vs B-V diagram all stars (~46000) contained in his previous UBV catalogue. Rufener (A.A. Suppl. Ser. 45, 207, 1981) has published the measurements of 14633 stars in the Geneva system.

Concerning the uvbyβ system, data for 1007 stars having a spectral type between A5 and G5 are given by Twarog (28.155.037) while homogeneous data for 19884 stars can be found in the Hauck-Mermilliod catalogue (27.002.006). Philip and Egret (27.113.026) have derived from this catalogue astrophysical parameters for 9604 stars of spectral type O to F.

Goy (28.002.023) has provided a catalogue of 971 O-type stars. Geneva photometry is given, where existing. RGU data for Milky-Way fields: Messier 35, Norma III, Sagittarius II and Cygnus 1-4 are given by Becker et al. (26.002.051). D.H.P. Jones et al. (MNRAS 194, 403, 1981) have observed 1251 stars in a new narrow-band system, while Cousins (28.113.035) publishes a catalogue with $V-R_{KC}$ and $V-I_{KC}$ values for 1425 stars.

Three catalogues giving homogeneous data from a compilation of the literature are now available: for the Vilnius system (North 28.002.002), Walraven system (Python 26.002.037) and Balmer lines (Mermilliod and Mermilliod 28.002.041).

Fracassini et al. (27.115.010) have derived from the Geneva catalogue apparent radii for 416 stars, while Cramer and Maeder (27.116.026) derive from the same catalogue data related to the surface magnetic field for 258 B-type stars.

Schmitz et al. (NSSDC Astron. Data Center Bull. 1 No. 2, p. 94, 1981) have established a computer data base on infrared astronomical observations.

Concerning the UV, two papers are to be mentioned: A. Code et al. (28.113.016), UV photometry from OAO filter photometry for 531 stars of diverse type and Henize et al. (25.002.067) which gives spectrophotometric data for 500 stars of mostly early spectral type.

A general spectrophotometric star catalogue has been prepared by Kharitonov et al. (25.002.020). Ardeberg and Virdefors (27.114.127) give also a catalogue of stellar spectrophotometric data.

Some catalogues are now in press (Meylan, DDO homogeneous data, A.A. Suppl. Ser.) or in preparation (Jasniewicz, R-I homogeneous data; Mermilliod UBV_E homogeneous data).

(b) REPORT FROM THE ASTRONOMICAL DATA CENTER NASA GODDARD SPACE FLIGHT CENTER (W.H. Warren Jr., T.A. Nagy and J.M. Mead)

This report lists photometric catalogues [Centre de Données Stellaires (CDS) Category II] which are new (code N), revised (code R) or have been fully documented (code D) for distribution since the last report. The codes indicate which of the above apply. Brief descriptions are given for new and revised catalogues. For complete bibliographic references, see the Status Report published in the Astronomical Data Center Bulletin 1, p. 146 (1981).

Catalogue	Code(s)
Two-Micron Sky Survey (Neugebauer and Leighton 1969) Originally received on a multifile tape, this catalogue has been modified to create one record per object and to add information useful for machine processing of the data.	RD
UBVRIJKLMNH Photoelectric Photometric Catalogue (Morel and Magnenat 1978)	RD

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The CDS tape has been modified by nines filling blank fields and converting the number of measurements field to numbers only. Source-catalogue statistics are summarized in the document.

General Catalogue of Variable Stars, 3rd Ed. RD
The tape as received from the CDS has been extensively corrected and modified, with data from the supplements added and the order rearranged to correspond to be published version.

13-Color Photometry of 1380 Bright Stars (Johnson and Mitchell 1975) RD
The spectral types have been updated and modified to be uniform with the data field.

A Catalogue of 10-Micron Celestial Objects (Hall 1974) D

Air Force Geophysics Laboratory Four-Color Infrared Sky Survey (Price and Walker 1976) D

Flare Stars,Gershberg (Shakhovskaya 1971) D

100-Micron Survey of the Galactic Plane (Hoffman, Frederick and Emery 1971) D

Catalogue of Stellar Ultraviolet Fluxes. Results of the SKYSCAN Experiment and TD-1 (Thompson et al. 1978) RD
The catalogue as received from D.G.I. Thompson was modified to replace asterisk-filled standard-error values with 99.99. Statistics for entries having no valid data or having small negative flux values are presented as a function of λ in the document.

Strömgren-Perry uvby Colors (1965) RD
Additional data from the Yale Catalogue of Bright Stars have been added to the tape records.

OAO 2 Ultraviolet Photometry: An Atlas of Stellar Spectra (Code and Meade 1978; Meade and Code (1980) ND
A tape of the catalogue formatted as in the above publications was supplied by the authors. The catalogue has been modified to place all data for individual stars together on the tape.

Non-Solar X-Ray Measurements (Arens and Rothschild 1975) RD
The catalogue was provided by Dr. R. Rothschild and has been modified from coded, compressed from to a standard record oriented format.

Dearborn Observatory Catalogue of Faint Red Stars (Nagy 1979) ND
The Machine-readable version of the catalogue was prepared at the Astronomical Data Center.

Interim Equatorial Infrared Catalogue 1 (Sweeney et al. 1978) ND
The catalogue was received from Mr. L. Sweeney and documented at the ADC.

Merged Infrared Catalogue (Schmitz et al. 1978) ND
The catalogue was received from M.M. Schmitz and is being distributed (with documentation) by him.

Catalogue of Stars Suspected of Variability: Table 1 RD

Catalogue of Stars Suspected of Variability: Table 2 RD

The tape received from the CDS was modified to combine the data from Tables 1 of Catalogues I and II and from Tables 2 of catalogues I and II. (The four tables were contained in separate files when received.) Additional data from the published catalogues were also added to the tape files and the various types of alternate designations were assigned their own field to simplify computer processing and searching.

VII. PROSPECTS

The last three years have shown no decrease in the amount of stellar photometry and polarimetry which is being carried out all over the world. The future is a bright one and several promising new trends are clearly discernable, some of which will make major impacts on the whole field. In this report, we perhaps have not emphasized sufficiently the degreee to which two-dimensional electronic detectors are becoming adopted in stellar work. This new approach is being investigated at many observatories but little in the way of firm data has been published. The two conference volumes referenced in section V contain many papers which give a good summary of the work in progress. The techniques are far from simple and basic problems must be addressed,such as photometric calibration, determination of the area response of the detector (flat-field calibration) and the handling of the immense amount of data with available computers. These difficulties all seem manageable although it will be a few years before such work becomes generally routine. As we noted in section III even the more straightforward methods of electronography can have problems which may lead to large errors in the final photometry. It is clear that the traditional methods will remain basic over many more years for calibration purposes at least.

Gazing into the future is always an uncertain activity and important developments are often unforeseen until after they have burst upon us. Yet, we can be sure that, with the launch of the Space Telescope, the next several years will bring many new advances in photometry and polarimetry at wavelengths which are difficult or impossible to observe from the ground. The advent of space astronomy will broaden the scope of our subject still more and will require greatly increased support from less expensive and more generally available observing facilities on the surface of the Earth. It is thus of vital importance that these continue to be maintained and developed if we are to follow up on the many exciting discoveries that will inevitably be made.

J.A. GRAHAM
President of the Commission