Commission 25: STELLAR PHOTOMETRY AND POLARIMETRY
Photométrie et Polarimétrie stellaires

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1. INTRODUCTION

This is a summary of the essential work that was published since the previous report (McLean, 53.113.028), not a complete review. Most papers are cited by their volume, section, and reference number in *Astronomy and Astrophysics Abstracts*. Papers presented at the very successful IAU Colloquium 136 in Dublin (see report in IAU *Information Bulletin* 69, p. 26) are simply cited as (Dublin); they have just been published by Cambridge University Press.

The drafts of the sections below were edited by A. T. Young, who thanks the individual contributors, and is responsible for the published versions.

CCD techniques have almost completely replaced photography in photometry and polarimetry (52.012.014; 52.012.015). However, a surprising number of CCD instruments turn out to have nonlinearity and other problems of the sort long familiar to photographic photometrists. CCDs also pose transformation problems that can trap the unwary. The high detective quantum efficiency of these detectors has enticed users to press to the faintest possible limits, where systematic errors can lie hidden in the sky noise. There remain disturbingly large systematic problems in flat-fielding, despite strenuous efforts to overcome these difficulties. There are also technical problems in applying the modulation techniques of high-precision polarimetry to CCDs. Much remains to be done in all these areas.

The development of automatic photoelectric telescopes is also having a revolutionary effect on photometry. While the first generation of APTs involved only small telescopes and low-precison photometers, current ones are in the 1-meter class and have high-precision instruments that can produce excellent results. The high speed of these instruments offers the possibility — not yet fully exploited — of determining time-dependent extinction with great accuracy. Increasing numbers of these instruments are now competing with human observers.

Several meetings have dealt with these new developments. Besides the Joint Commission Meeting at Buenos Aires, Russ Genet's annual meetings on APTs have reported their progress (54.012.002), and a workshop on APTs was held at Kilkenny in conjunction with the Dublin Colloquium. Dave Philip's meeting (54.012.027) covered the scientific results of stellar photometry. The Dublin Colloquium reviewed the whole field. It seems safe to say that we now have powerful technologies available, but have not yet learned how to use them fully.

Finally, we must congratulate Dr. Alan Cousins on his 90th birthday! He has continued to establish standard stars for the benefit of Southern-hemisphere observers. In our enthusiasm for the newer technologies, we should not lose sight of what he has done by carefully applying the older ones.

J. Bergeron (ed.), Reports on Astronomy, Vol. XXIIA, 229–238.

2. PHOTOMETRY

(prepared by C. Sterken)

2.1 Instrumentation

Though CCDs are used more and more for photometry, new photoelectric photometers are being built at various places. Some of these designs are rather bulky, but there seems to be an increasing interest in portability, and lighter and versatile instruments are in high demand.

Several new photometer designs were reported, such as the high-speed two-star photometer by Rao et al. (52.034.100 and 54.034.168) and Venkatesha and Seetha (54.034.169), and multichannel photometers (Walker, 54.034.185, and Sullivan, 54.034.189).

A four-channel *WBVR* stellar photometer for observing bright stars described by Konilov and Krylov (51.034.018) was used for measuring 15 000 stars. A multicolor photometer described by Schoembs (54.113.021), and the four-star photometer by Le Contel (55.013.058) are novel designs. Caton and Hawkins (52.034.168) also describe a new two-star photometer. Higbie et al. (52.034.186) trace the design of a new imaging photometer instrument. Bell and Yoss (54.36.122) describe a multiband procedure that permits simultaneous star and sky exposures, and rapid acquisition of data over the entire sky. The method is faster, and more accurate, than the single-channel approach.

2.1.1 Photometry with scalar detectors. Bessell (54.36.364) reviews reduction techniques and effects of atmospheric extinction in stellar photometry. Tobin and Wadsworth (54.36.363) draw attention to the method and necessary equipment for the determination of photometer deadtime correction from measurements in daytime.

2.1.2 Photometry with CCDs. Gilliland (54.36.124) reviews recent efforts to set empirical limits on the precision of time-differential CCD photometry of rich stellar fields. Stetson (52.036.033) describes a computer program that generates the magnitude corrections required to relate profile-fitted or small-aperture magnitudes to total magnitudes, by means of the aperture-growth technique.

Jønch-Sørensen and Knude (52.113.017) present preliminary results of CCD-*uvby* photometry of field stars in four cardinal directions of the galaxy. Richtler (52.113.016) presents Strömgren colors of CCD photometry zero-point stars in the Magellanic Clouds and M67. Anthony and Twarog (54.113.012) illustrate the feasibility and value of CCD photometry in the *uvby* system.

Labhardt et al. (54.036.183) address the problems encountered in deep CCD photometry in the *UBV* system, particularly reproduction of the system and transformation to the standard system, in addition to the determination of instrumental magnitudes from model image profile fitting or from aperture photometry. Zickgraf et al. (52.113.036, 52.113.037) present *UBVR* sequences for CCD photometry in M83, NGC 5128, NGC 2403 and M81. Standardizing CCD images in the M67 "dipper asterism" is possible by using Cousins *VRI* data for 19 standard stars provided by Jones and Taylor (52.113.038). Jiang et al. (55.036.172, 55.036.173) apply a Schmidt telescope equipped with CCD to *BVRI* photometry.

Boyle et al. (52.113.001) present CCD photometry in the Vilnius system for 321 field stars in Lyra ($V \leq 17.5$).

2.1.3 Automatic Telescopes. Sterken and Manfroid (54.036.127) discuss some effects that have negative influences on the precision of automatically performed measurements.

Young (1992, in *Automated Telescopes for Photometry and Imaging*, p. 73) demonstrates that, since it is technically impossible to make identical instruments, one cannot avoid the general transformation problem. Thus, instead of using undersampled photometric systems, one must measure complete information on stellar spectra, using an appropriate well-sampled system (of 5 or 6 bands in the blue and visual region). Such will enable accurate transformations that are valid for all objects, no matter how pathological their spectra are. This is only possible when turning to the use of time-efficient automatic telescopes.

2.1.4 Atmospheric extinction. Methods for extinction determination are described by Schwarzenberg-Czerny (A&A 252, 425) and Forbes (1992, Southern Stars 35, 1). Poretti and Zerbi (1993, A&A in press) propose an analytical method for extinction determination that handles variable extinction. Reimann et al. (1993, A&A in press) analyse the variability of the extinction coefficient on the basis of data covering two decades. Sterken and Manfroid (1992, A&A 266, 619 with a sequel by Manfroid 1993) describe the evolution of atmospheric extinction at La Silla from *uvby* data covering almost 15 years. They find three episodes of enhanced extinction caused by volcanic aerosols (respectively due to the El Chichón, Nevado del Ruiz and Pinatubo eruptions), and — besides the well-known small-amplitude seasonal variations — also a short-timescale pseudo-periodic variation. Additional extinction effects caused by the Pinatubo eruption have been observed and described by Kilkenny and Westerhuys (Dublin).

Dravins et al. (Dublin) report on atmospheric scintillation variations on time scales of 100 ms to 100 ns.

2.1.5 Transformation. Young (1992, A&A) re-examines photometric transformation theory and demonstrates the importance of high-order terms that have previously been neglected, which have an appreciable magnitude because they depend on high-order moments of passband response profiles that are not well represented by a Taylor series. These transformation errors due to neglected high-order terms are likely to be larger for narrow-band photometry and spectrophotometry than for wideband systems. Transformation equations should at least be quartic, and this requirement is independent of spectral resolution.

Manfroid and Sterken (54.036.123 and 1992, A&A 258, 600) analyze systematic errors due to color transformations, and illustrate the reliability of transformations, emphasizing reduction methods, the validity of homogenisation procedures, and the choice of standard stars that define the system. Manfroid (1992, A&A 260, 517) discusses physical constraints on color transformations and transformation schemes, and gives directions to minimise those errors. Manfroid et al. (1992, A&A 264, 345) evaluate the impact of extrapolation errors in different color transformation schemes.

Alfaro and Delgado (54.113.031) analyse standard *uvby* indices of B stars in 17 young open clusters in order to determine systematic differences caused by interstellar reddening. Their results show that such systematic errors in c_1 increase with increasing amount of reddening, and they suggest that transformation procedures should incorporate reddening terms.

2.2 Standard stars

Voroshilov (52.113.025) discusses variability of some *WBVR* photometric standards. Menzies et al. (53.113.009) present $UBV(RI)_c$ photometry of equatorial standard stars and find systematic differences for $(B-V)$ and $(U-B)$ between the *UBV* system defined by Cousins's E region standards and that used by Landolt, who has just published equatorial *UBVRI* standards between mags. 11.5 and 16 (AJ 104, 340, 1992). Watanabe et al. (53.113.037) give values of $U-B$, $B-V$ and V for 223 stars selected from Nicolet's catalogue.

Osborn et al. (52.113.028) established a set of 63 standard stars in the bandpasses of the International Halley Watch system for cometary photometry. New Washington-system standards, suitable for observation with a CCD, were presented by Geisler (51.113.040). These stars are in four fields, each field including stars with a wide color range sufficiently faint to be observed with large telescopes.

2.3 Photometric Systems

Crawford (54.113.011) reviews the concept of Strömgren's *uvby* system, and elucidates its strong and weak points.

Pel (154.113.029) compares the systematic accuracy in four photometric systems (at the Schenectady conference).

Kiselman et al. (52.036.040) discuss the possibility of combining four filters of the HST Wide Field/Planetary Camera into a *uvby*-like photometric system. They calibrated the system (using ground-based observations) and obtained good estimates of effective temperatures and metallicities. Anthony-Twarog et al. (53.113.008) extended the standard *uvby* system with a FWHM 90 Å filter centered on CaII H and K. The extension is designed for application to stars where the m_1 index has reduced sensitivity, and leads to an alternative index for m_1.

Mendoza (54.113.009) discusses the $\alpha(16)$, $\Lambda(9)$ photometric system for normal stars, and also for WR, Be and other peculiar objects.

Straizys (52.113.043) reviews different medium-band systems from the viewpoint of determination of physical parameters, and demonstrates the abilities of the Vilnius system in the determination of spectral types, absolute magnitudes, metallicities, and different types of peculiarities in interstellar reddening.

2.4 Synthetic Photometry

Bessell (52.113.039) derived a good representation for the Johnson-Cousins *UBVRI* passbands by comparing synthetic photometry with observations. A major source of $(U-B)$ transformation problems can be traced to mismatched B bands. He also discusses suggested CCD filter combinations. Gocherman (54.036.294) attempted to reconstruct several *UBVRI* systems on the basis of flux-calibrated spectra.

Stift (52.036.043) presented a theoretical investigation of the influence of photometric passband effects on the parameters of close visual binaries obtained by area-scanning. He demonstrated that the use of broadband filters can lead to considerable errors in the observed distances and/or position angles.

Tripicco and Bell (54.113.034) explore the properties of the DDO system. Paltoglou and Bell (54.113.043) present a grid of synthetic surface brightness magnitudes for the 14 bandpasses of the Hubble Space Telescope Faint Object Camera. The synthetic colors have been used to examine transformations between ground-based and Faint Object Camera *UBV* and *uvby* systems.

2.5 Spectrophotometry

Papaj et al. (52.114.051) present mean energy distributions of samples of stars hotter than B5, and derive a new set of $(B-V)_0$ colours. The derived spectrophotometric standards are free of reddening effects in the visual and far-UV regions.

Taylor and Jones (52.113.012) present Cousins *VRI* photometry from Gunn and Stryker scans, and find systematic deviations in $R-I$, which are attributed to a declination effect in the Gunn-Stryker scans. They also find the Gunn-Stryker synthetic colours unexpectedly noisy. Glushneva (54.113.013) reviews spectrophotometric catalogues and stresses the need for increasing the number of standard stars and for elaborating the differences between catalogues in order to determine systematic differences.

2.6 Calibration

Reglero et al. (52.113.029) extend the *uvby* photometric calibration to spectral types later than G0 by using both the *uvby* and β systems to G5-K7 (V to III) stars. North and Kobi (54.113.019) compare the (T_{eff}, log g) calibrations of the *uvby*β system published by two different authors, and point out the existence of systematic differences. Gray (54.113.032) derives an empirical calibration of the *uvby*β system for the A, F and early G supergiants.

Arellano Ferro and Parrao (52.113.023) carried out an extensive compilation of non-Cepheid F0-G8 supergiants in open clusters and associations. On the basis of these data, the authors provide a reddening formula for F0-G3 supergiants that provides $E(B-V)$ within ±0.003, and an absolute magnitude calibration that predicts M_v with an estimated accuracy of ±0.5 for the most luminous F-G supergiants. Blackwell and Petford (54.113.013) derive the relationship between stellar integrated fluxes and the photometric indices B, V, I and K. Boyarchuk et al. (51.113.046) improve the absolute calibration of *UBV* photometry by comparing spectrophotometric energy distributions and catalogued *UBV* data.

Buser and Fenkart (52.113.024) present a new extended calibration of the 2-color and color-magnitude diagram and the metal-abundance parameter for the dwarf stars of the Basel-Potsdam 3-color photographic *RGU* survey of the galaxy.

Korotina et al. (52.113.013) propose a method for determining fundamental properties of late-type giants using Geneva photometry, and provide a catalog of T_{eff}, log$g$ and $[Fe/H]$ for 982 G5-K5 giants. New calibration of blanketing parameters Δm_2 (Geneva) and δm_1 (Strömgren) in terms of $[Fe/H]$ is given by Berthet (52.113.009). Kobi and North (52.113.010) give a new calibration of the Geneva d, m_2, and B_2–V_1 parameters, which allow estimation of T_e, log$g$, and $[Fe/H]$ of A4 V-III to G5 V stars.

Geisler et al. (54.113.036) present an improved metal-abundance calibration for the Washington photometric system.

2.7 Catalogs and Data Bases

An extension of the Geneva Catalogue of about 4200 additional stars, together with a statistical discussion and a bibliography has been presented by Cramer (54.113.016).

Oblak (51.113.022) gives *uvby* photometry for 367 southern stars of the Hipparcos Input Catalogue. Hauck and Mermillod (54.113.018) have collected from the literature all available *uvby*β data in a single file, and publish a homogeneous partition of this database. Arellano Ferro et al. (51.113.010) report *uvby*β photometry for 110 bright F0-K0 supergiants.

Kilkenny and Laing (52.113.048) give photoelectric UBVRI observations for 336 stars ($V \leq 11.5$) from the Hubble Space Telescope Guide Star Photometric Catalogue. Menzies et al. (52.113.052) report on $UBV(RI)_c$ photometry of TD1 satellite stars, many of which would be suitable for use as very blue standards. Abuladze (54.113.014) compiled a catalogue of 366 photoelectric *UBV* standard stars.

2.8 Books

Straizys's *Multicolor Stellar Photometry* (55.003.084, Pachart Publishing House) gives a detailed description of almost all photometric systems with their advantages and disadvantages, and a detailed description of the Vilnius system. Sterken and Manfroid's textbook *Astronomical Photometry, A Guide* (Kluwer 1992) covers the principles of astronomical photometry, and explains reduction and transformation methods. The Proceedings of IAU Colloquium 136, *Stellar Photometry — Current Techniques and Future Developments*, edited by Butler & Elliott, and a book on the history of photometry by Budding, have just been published by Cambridge University Press. We also call attention to the Schenectady *Precision Photometry* proceedings (54.012.027).

3. REDUCTION SOFTWARE

A general photometric reduction program has been distributed by ESO as the PEPSYS context of the MIDAS data-reduction system. It is intended for reductions in any system; information about the *UBVRI* and *uvby*β systems is built-in. Besides handling extinction and transformations, it includes a program for planning observations, an extensive User's Guide, and other documentation.

MIDAS is available free of charge to astronomical institutions, and runs on a wide variety of VAX/VMS and UNIX systems, including PC architectures running LINUX. For further information, send e-mail to resy@eso.org.

At the Dublin Colloquium, Peter Stetson announced that he has a reduction program that runs under IRAF. Potential users can obtain further information from him.

Both of these packages include multi-night reductions, time-dependent extinction, physically-based color terms, and other details that are often omitted or treated inadequately in "home-grown" reduction programs. They should be far superior to previous-generation programs like SNOPY. It is hoped that the widespread availability of standard reduction programs of high quality will help improve the consistency of photometry.

4. POLARIMETRY

(prepared by J. Landstreet)

4.1 Introduction

Polarimetry continues to grow as a technique that can provide useful information and constraints on the geometrical organization of complex objects, on the nature, location and sizes of scattering particles, and on magnetic field structures. There are now well over a dozen polarimeters in active service, some at major national observatories; polarimetry is gradually ceasing to be a specialized technique understood only by a few, and is becoming a generally available tool. More than 50 papers now appear each year that report some substantial optical, infrared or ultraviolet polarimetric result. In what follows, I offer a rather haphazard overview of some of the major polarimetric observations and modelling programmes, and a few specific projects of particular interest.

4.2 Current active research areas

4.2.1 Planetary atmospheres. Tinbergen has reported a study of 22-degree halos in the terrestrial atmosphere. Such halos reveal the presence of birefringent diffraction due to crystals in our atmosphere, and should provide a means of detecting such crystals in planetary atmospheres (54.082.002). This may indeed be the case for Venus (see Können et al., Icarus 102, 62, 1993). Polarimetry has long been used to study Mars (52.097.013), where crystal clouds in the atmosphere are detected.

4.2.2 Other Solar system objects. Eaton, Scarrott and collaborators, using the Durham imaging polarimeter, have found that imaging polarimetry of comet tails clearly reveals presence of a dust component that is barely visible on direct images. Their polarimetric images permit the study of the spatial distribution and nature of scattering particles (53.103.037). In a related study, the properties of the dust of the tail of comet P/Halley have been studied using a polarimeter on the Vainu Bappu Observatory 1-m telescope (53.103.094).

4.2.3 Clouds in star-forming regions and pre-main sequence stars. A large group of collaborators, using the UK IR Telescope and an IR polarimeter, have obtained IR polarization images of the Orion Molecular Cloud to study the distribution and nature of scattering matter around the new stars (53.131.080, 53.131.053). This work has been extended to other bipolar nebulae such as R Mon (53.131.113), GL 2591 (54.131.305), and several others (54.131.306).

Gledhill, Rolph, Scarrott and Wolstencroft and collaborators have been studying polarization of compact nebulae and circumstellar disks with the Durham imaging polarimeter (51.121.008, 51.121.012, 51.131.066, 53.131.056, 53.131.103, 53.131.128, 54.131.314, 54.112.098, 54.131.328, and MNRAS, 257, 485). These studies reveal locations of (often hidden) very young stars as well as giving information about the structure and particle sizes in the reflecting clouds and disks. A general review of this work may be found in 51.131.228.

Bastien and collaborators, using the optical polarimeter of the Observatoire du Mont Megantic, continue to study polarization of T Tau stars induced by the presence of scattering in circumstellar disks. They have carried out extensive modelling of such disks (51.121.028, 52.121.055, 54.063.036, 54.131.168, 55.121.010).

Polarization images in the IR of the nebula around T Tau have been obtained by Weintraub, Kastner and their collaborators, using the IR imager and polarimeter at Kitt Peak National Observatory (55.121.048). The data have been used to model the geometry of the disk around the star. Several other T Tau's have been observed (see also 55.131.083).

4.2.4 The Sun. Landi Degl'Innocenti, Bommier and Sachal-Brechot have carried out considerable theoretical analysis of the of the polarization of the Hanle effect in solar resonance lines (52.063.037, 53.063.050, 53.063.051, and 53.063.049). Faurobert-Scholl has also studied this problem in the case of partial frequency redistribution, especially with application to the Ca I 4227 A line (53.063.063, 55.063.090).

4.2.5 Envelopes around hot stars. A particularly exciting development has been the successful Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), which has produced the first ultraviolet linear polarization spectra of a number of different types of hot stars and made possible a first exploration of the new information provided by such data. Observations are now available for hot supergiants (54.116.084), Be stars (54.116.092), and Wolf-Rayet stars (55.116.025). This experimental team has also been active in using optical linear polarization data to study the circumstellar environment of WR stars (52.116.048, 54.116.085, 55.116.011, ApJ 398, 286, and ApJ 401, L105).

The Montreal group of Moffatt, Drissen and Robert and their collaborators have been systematically exploiting linear polarimetry as a tool for modelling the winds and circumstellar environments of a number of WR stars, both single and in binary systems (51.117.065, 52.116.014, 55.116.009, and ApJ 397, 277).

Marlborough and his collaborators have been active in modelling the effects of scattering matter around hot stars. They have recently examined the polarized radiation produced by electron scattering in the winds of B[e] supergiants (53.064.042), and discussed the constraints which polarization data can provide for Be stars (55.112.039).

4.2.6 Magnetic fields of main sequence stars. The Zeeman analyser on the cassegrain echelle spectrograph of the 3.6-m ESO telescope has been used extensively by Mathys to obtain a wealth of data on the magnetic fields of Ap and Bp stars. Careful modelling of the spectropolarimetric data yield considerably stronger constraints on the magnetic geometries of the stars studied than have previously been obtained (54.116.002).

Donati, Semel and Rees and their collaborators have developed an extremely sensitive and precise method for obtaining high spectral resolution circular and linear polarimetry of magnetic stars. Such measurements have made possible the detection of very weak Ap star fields (52.116.001), and have particularly been used to detect and map fields on stars in active RS CVn binary systems (51.117.230, A&A 265, 669, and A&A 265, 685). This is the first time fields in such systems have been been detected, and the work provides by far the most convincing modelling of field structure in any cool star.

Bohlender, Landstreet and collaborators have continued their series of magnetic field strength measurements of magnetic Ap and Bp stars using the Western Ontario Balmer-line Zeeman analyser. Longitudinal field measurements and modelling have been presented for two mass-losing He-wk stars (51.116.010) as well as for a number of individual He-str (52.116.004, 53.116.017), Si (51.116.026, 55.116.019, and A&A 269, 355), Cr (52.116.003), and λ Boo (52.116.045) stars. This subject has been reviewed in detail by Landstreet (55.116.026).

In a very interesting new development, Leroy has begun publishing results from an extensive series of measurements of the transverse magnetic fields of a number of cool, large-field magnetic Ap stars. These are derived from broad-band linear polarization measurements made using the Sterenn polarimeter at the Observatoire du Pic-du-Midi (Leroy et al., 1993 A&A in press, Leroy 1993 A&A in press). These data provide extremely useful constraints on the gross geometrical structure, particularly the inclination and obliquity angles, of the stellar field.

4.2.7 Evolved stars. The intrinsic linear polarization of cool giants, which is produced either by asymmetric scattering in the stellar atmosphere or by circumstellar material, has been studied by LeBertre and Schwartz (A&A 229, 138) using the Pisco polarimeter at ESO, and by Raveendran (53.064.037, 53.112.052) with the 1.0 m telescope of the Vainu Bappu Observatory.

4.2.8 Magnetic fields in white dwarfs. Bailey, Ferrario, Hough, Wickramasinghe and collaborators, using the Hatfield Polytechnic polarimeter, have obtained broad-band filter polarimetry of a number of AM Her systems (close binary systems containing a white dwarf with a megagauss field; see 51.117.222, 53.117.073, 54.117.191, 55.117.228, and MNRAS 259, 583). Such data are very useful for modelling magnetic field structure.

Piirola, Reiz and collaborators have used a Finnish 5-channel polarimeter at ESO to study the time and wavelength dependence of circular and linear polarization in the very-large-field single magnetic white dwarf PG 1031 +234 (55.126.098) as well as in the AM Her system VV Pup (52.117.020).

The observed wavelength dependence of circular and linear broad-band polarization in strongly magnetic (B > 100 MG) white dwarfs certainly contains much useful information about the field structure in these stars, but has so far proven very difficult to interpret. A very interesting theoretical work by Whitney (53.063.053, 53.063.060) studies the simplest dichroism, that of free electrons, and succeeds reasonably well in fitting observations of one of the largest-field stars.

The polarimeters at Steward Observatory continue to provide much useful data on magnetic white dwarfs. New rotation ephemerides have been obtained for 4 magnetic white dwarfs showing broad-band continuum polarization (53.126.011). A weak field of some 2.3 MG is found in the most massive known single white dwarf (Schmidt et al. 1992, ApJ 394, 603).

4.2.9 Supernovae and supernova remnants. The optical polarization of the Crab SNR long ago provided direct evidence of synchrotron radiation from this intriguing object. Recently, an optical polarization study has been reported for a Crab-like SNR in the LMC (51.125.029). Further studies of the Crab itself continue to reveal details of the magnetic field structure and electron distribution in that remnant (52.125.055, 53.125.019). Polarimetry of SN 1987A has been analysed by Jeffreys (54.125.172); it appears that most of the polarization is due to asymmetric electron scattering.

4.2.10 The interstellar medium. The polarizing effect of aligned grains in the interstellar medium provides important information about the nature of these solid grains. New developments in the study of this polarization include determination of the wavelength dependence of polarization in the IR (51.131.004, 52.131.007, 55.131.039, 55.131.263), polarimetric studies in the visible of circular polarization and of the diffuse interstellar bands (52.131.194, ApJ 398, L69), and for the first time spectropolarimetry of the ultraviolet wavelength dependence of interstellar polarization by the WUPPE experiment team (55.131.020). The new data have provided considerable insight into variations in the ISM of grain composition and size distribution.

Polarimetry, particularly in the IR, has also been used to study the structure of the galactic magnetic field, both on a large scale (55.131.089) and near the galactic centre (54.155.096).

Leroy has recently completed measurements at Pic-du-Midi of linear polarization of a large number of nearby, intrinsically unpolarized stars to show that the local ISM out to a distance of at least 50 pc in all directions from the sun is remarkably free of dust (1993 A&A, in press).

4.2.11 External galaxies. A recent review of magnetic fields in galaxies by Wielebinski and Krause (51.157.149) naturally gives considerable prominence to the results of optical linear polarization studies of external galaxies.

Systematic studies, using the Hatfield Polytechnic polarimeter, of the nature of the polarization of Seyfert galaxies has recently been reported (51.158.256, 51.158.257). Polarimetry of starburst and interacting galaxies is reported in 54.157.274. The data suggest that the observed polarization is often produced by transmission through aligned grains, but in some cases scattering from the nucleus is also important.

Polarization images of a number of highly active galaxies have been studied by the group associated with the Durham imaging polarimeter. The polarization properties of a large sample of BL Lac objects ("blazars") are discussed in 51.158.227. More detailed studies of individual objects have yielded much information about polarizing mechanisms, such as reflection of central jets and aligned grains, in such objects as 3C368 (51.158.045), Cyg A (52.158.127), NGC 1068 (53.158.073), M82 (54.157.272) and NGC 4151 (MNRAS 257, 309). Optical polarization of intermediate and high redshift galaxies has revealed strong polarization of light which in the rest frame is in the ultraviolet; it appears that scattering from a beamed central source dominates the luminosity at these wavelengths (55.158.175).

Numerous groups in the U.S. have been using polarimetry to probe the geometrical structure and the nature of the central powerhouse and its immediate environment for a variety of active galaxies. There has been so much activity in this area that it is difficult to give even an overview. Studies of Seyfert galaxies include 51.158.085, 54.158.325, ApJ 397, 452, and ApJ 399, 50. Blazars are discussed in 51.158.085, 54.158.325, ApJ 400, 115, and ApJ 400, L17. Observations of quasars are reported in 51.159.086, 52.159.083, 53.159.054, ApJ 396, L19, ApJ 398, 454, and ApJ 400, 96. Optical polarization of radio galaxies is discussed in 53.158.013 and 54.158.013.

5. Report of the Working Group on Infrared Extinction and Standardisation

(prepared by E. F. Milone)

The Working Group, set up by President Ian McLean after a joint meeting of commissions 25 and 9 at the Baltimore IAU, and funded by University of Calgary and NSERC Research Grants, has followed recommendations put forward at that meeting as described in (51.012.122). We have examined the profiles of past and present versions of the passbands of the Johnson JHKLMNQ broadband photometric system along with atmospheric window transmissions calculated by MODTRAN, and have used a series of stellar flux models from Kurucz to probe the atmospheric extinction under different water vapor, height, and airmass conditions. The curvature of the resulting extinction line describes the sensitivity of each response function to variations in water-vapor extinction. On the basis of our simulations, and an extensive set of experiments to optimise S/N without seriously degrading the reproducibility and transformability, subject to field trials we recommend a set of passbands which should improve both extinction and standardization from all sites, and enable transformable infrared photometry from lower altitude sites than is currently the case, at least for the shorter passbands. The progress of a subcommittee of the working group has been reported at Dublin, and a detailed account of the work has been submitted to AA.

We have changed the specifications for the new N filter from the list which was circulated earlier at IAU Colloquium 136. The current one is broader (2 microns) and should meet the demands of those who want greater throughput, without greatly compromising the improved atmospheric transmission. The list of the new filters, optimized for minimum distortion due to water vapour, is shown in the table below. It should be noted that the designations 'z', 'J', etc. represent the windows, and are not intended to be confused with the previous and now completely unstandard Johnson designations. The filter nomenclature should be decided by the commission. It should also be noted that prior to formal adoption, while even though the list is labeled 'final', slight alterations in the specifications cannot be ruled out prior to the field trial tests any or further experimentation which may be required.

The triangular shapes of these filters aid transformability in most circumstances, but some flattening between 50% and 80% appears not to be badly detrimental. In any case, they need good blocking to the blue and red — 10^{-5} is preferred to 10^{-4} — especially for the thermal filters. The improvement in signal *to noise that we expect is dependent on this, because we assumed no leakage in our simulations. Some of* the working group prefers even stronger blocking but if the throughput is diminished by more than a few tenths of a magnitude, we will have more trouble convincing people working at longer WLs to use the new filters. Blocking is particularly important in K for new imaging work. The filter specifications are for cold filters: LN_2 for the short and LHe for the long. We would like to stay on the low side of the increasing slope of theta, which measures the distortion of stellar flux through the filters.

Since passbands in the longer wavelengths are more costly to manufacture, letters expressing interest in these filters to OCLI (attn. Mike Larro) and Barr (attn. Roger Heatley) from potential purchasers can only help to make them available.

Meanwhile, pending further funding, we plan to investigate further the effects of sky emission and aerosol scattering on the signal/noise ratio.

Final List of Recommended Passbands.

All wavelengths (μm) have nominal tolerances of 1%

Band	50% points lower	50% points upper	80% points lower	80% points upper	5% points lower	5% points upper	100% Peak
iz	0.996	1.069	1.016	1.047	0.970	1.099	1.032
iJ	1.201	1.280	1.225	1.254	1.170	1.315	1.240
iH	1.555	1.707	1.585	1.672	1.514	1.754	1.628
iK	2.100	2.288	2.141	2.240	2.047	2.353	2.196
iL	3.483	3.757	3.554	3.686	3.374	3.882	3.620
iL′	3.763	4.037	3.834	3.966	3.654	4.162	3.900
iM	4.618	4.732	4.652	4.698	4.564	4.784	4.675
in	8.873	9.196	8.968	9.101	8.731	9.339	9.030
iN	10.100	12.100	10.369	11.832	9.756	12.444	11.100
iQ	17.106	18.712	17.439	18.329	16.656	19.231	17.900

6. Report of the Working Group on Standardization of Filter Systems

(prepared by A. T. Young)

Investigation of the tolerances available from filter manufacturers has shown that passbands cannot be reproduced with enough accuracy to preserve the precision of good modern observations. Furthermore, existing undersampled systems do not measure enough information about stellar spectra to allow conventional transformations to preserve the inherent accuracy of a good instrumental system. To deal with this problem, this WG was asked to specify filters that would permit accurate transformations.

Subsequent investigation of transformation problems indicates that cosine-squared passband profiles, with bands placed so that each band has neighbors centered at the midpoints of its sides, are nearly ideal. However, the sharp-cut glasses in fact make edges that are much steeper than anything that is available for the long-wavelength sides of passbands; so *narrow*, symmetrical bands cannot be made with colored glasses. Broad, symmetrical passbands are possible. The cosine-squared profiles can be achieved better as a function of frequency than wavelength, if colored glasses are used.

Trial filter syntheses show that colored glasses can approximate such passbands between about 340 nm and 600 nm, provided that the FWHM is near 4000 cm^{-1}. This corresponds to about 100 nm at 500 nm, comparable to the width of the existing B and V bands. In the near UV, the FWHM is about 50 nm, similar to U. The whole UBV region can be completely sampled with about 7 filters. Typical total thicknesses are less than 1 cm, and peak transmittances of 50% or more are possible — similar to the existing U and B. There may be some difficulties with very thin elements, and/or with unstable glasses. It appears that satisfactory glass filters can be made, but the cost may be fairly high.

The alternative is interference filters. A new type of filter, using ion-assisted deposition of oxide coatings, is now commercially available. These are said to be completely immune to the ageing effects that have plagued conventional interference filters. However, because of the smaller range in refractive indices of the oxides used, compared to conventional coatings, many more layers are required. Consequently, the new filters are about twice as expensive as the older type. But they have the additional advantage of a much smaller temperature coefficient than glass filters.

Discussions are continuing with filter manufacturers to determine exactly what is possible in the two types of filters. Realistic tolerances must be balanced against cost. By the time of the General Assembly, it should be possible to make definite recommendations.

Until improved filters are available, transformations to existing systems will be optimal if the mean-square difference between standard and instrumental filters is minimized. The main difficulty is the very loose tolerance on sharp-cutoff glasses, which is typically ±6 nm but as large as ±10 nm for some glasses. The typical tolerance corresponds to a range of a factor of 4 in glass thickness, which is unacceptable.

That means that filter specifications should be stated in terms of spectral transmittance, not glass type and thickness. Individual pieces of such glasses must be polished, measured spectrophotometrically, and ground to the required thickness to meet a much tighter spectral transmittance specification than the catalog tolerance. Even with the bandpass colored glasses, it is advisable to use spectral-transmittance rather than thickness specifications.

The sharp-cutoff components of the *UBVRI* filters should be closely matched to the standard cutoffs. There is confusion in the literature, in addition to uncertainty about the original response functions. In particular, Johnson's recommended Schott glass for the V filter is incorrect; it should be GG 515, in accordance with Hardie's Table 3 in *Astronomical Techniques* and Bessell (52.113.039), not GG 495 as is often recommended. There is no Schott glass that closely matches the Corning/Kopp 5030 used to define the B passband; this has contributed to the difficulties in transforming B.

For the *uvby* system, there is no alternative to interference filters. Filter specifications should include the detailed transmittance curves tabulated in Crawford & Barnes (4.113.050), not just central wavelength and halfwidth values. The transformation problems described in several papers by Sterken and Manfroid indicate that much tighter filter specifications are needed than have generally been adopted in the past. Discussions with filter manufacturers indicate that nominal commercial tolerances can be improved by a factor of 2, with only a modest increase in price. Such tightening of specifications seems well justified.