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Commission 25: Stellar Photometry and Polarimetry

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Abstract. Even a brief glance at astronomical journals indicates the breadth and depth of observational projects making use of photometric and polarimetric techniques. Examples of ongoing photometric and polarimetric research as related by Commission Members follows. I thank the Commission Members, acknowledged below, for their input.

Keywords. Photometry, Polarimetry

1. Photometry

1.1. *The Strömvil system*

Straižys and Philip write that the Strömvil 7-color system, consisting of four pass bands of the Strömgren system and three pass bands of the Vilnius system, has been calibrated in $T_{\rm eff}$, log g and [Fe/H] using photoelectric photometry of about 800 stars with known physical parameters (Kazlauskas *et al.* (2005)). Strömvil photometry of these stars was obtained in 2002–2005 with the University of Arizona 1.5 m telescope with support from an AAS Chretien Grant awarded to V. Straižys. Also in the Strömvil system, R.P. Boyle and A.G.D. Philip have obtained high precision CCD photometry of the open cluster M 67, containing the primary set of standards. They also have obtained Strömvil CCD observations in several globular clusters. The effect of the scattered light in the VATT telescope on flat-fielding was investigated and eliminated by a special blocking device. Now the CCD field corrections are of the order of 1% only. Observations of globular clusters of the southern hemisphere were started at Casleo in Argentina (Philip and Pintado). The suggestion is made that the Strömvil system will prove of importance for use at the large survey telescopes currently being designed. These telescopes include LSST and VST, and space survey telescopes, like Gaia (Straižys *et al.* (2004)).

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Stellar Photometry: Past, Present and Future, 2003 September 17–20, Vilnius (Celebrating the 250th anniversary of the Astronomical Observatory of Vilnius University). Proceedings, including 40 papers, are published in Baltic Astronomy, vol. 12 no. 4, 2003, eds. J. Sudžius, V. Straižys, A.G. Davis Philip.

1.2. *The Vilnius system*

Straizys writes that applications of the Vilnius 7-color system have been directed mostly to the investigation of dark clouds, star-forming regions and open clusters. The following dark-cloud areas were investigated: the Aquila-Serpens Milky Way Rift (Straižys *et al.* 2002a,c, 2003a), the dark cloud separating North America and Pelican nebulae (Laugalys & Straižys 2002), Barnard 1 dark cloud in Per (Černis & Straižys 2003), dark clouds at the Cam and Per border (Zdanavičius & Zdanavičius 2002, 2005a,b), Aries dark cloud (Kazlauskas *et al.* 2002; Straižys, Černis *et al.* 2002b; Straižys, Zdanavičius *et al.* 2004). The areas of the following open clusters were investigated: NGC 1750/58 (Straižys *et al.* 2003b), M67 (Laugalys *et al.* 2004), NGC 2395 (Zdanavičius *et al.* 2004), NGC 1647 (Zdanavičius *et al.* 2005c). Other works: KA10 area of the MEGA proper motion program (Bartašiute 2003), metal-deficient dwarfs (Lazauskaite *et al.* 2003), Population II visual binaries (Bartkevičius & Gudas 2002, 2003). A new calibration of the Vilnius system in terms of the physical parameters of stars is in progress. For this aim about 800 stars with well known temperatures, gravities and metallicities have been observed (Kazlauskas *et al.* 2005).

Multicolor photometry remains one of the main sources for discovery of stars with different spectral peculiarities in their spectra. By subsequent spectral observations a number of interesting stars have been discovered in the areas of the North America and Pelican nebulae, Taurus, Perseus, Serpens and Camelopardalis dark clouds and star-forming regions (Straižys, Corbally *et al.* 2002d; Straižys, Zdanavičius *et al.* 2004; Corbally, Straižys 2005, in preparation).

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1.3. *The "Gaia" orbiting observatory*

Straižys writes on an upcoming application of photometry. ESA in 2011 is planning to launch an orbiting observatory "Gaia" for an astrometric, photometric and spectral survey of one billion stars down to $V = 20$ mag. In 2004 December the photometry and classification working groups of the "Gaia" project finished the selection of optimum passbands for the two photometric systems for "Gaia". One is a broad-band system with the central wavelengths of 5 passbands at 431, 556, 655, 768 and 916 nm. The other is a medium-band system with the central wavelengths of 14 passbands at 326, 379, 395, 410, 467, 506, 515, 549, 656, 716, 747, 825, 861 and 965 nm. The broad-band system will be used for a crude classification of stars down to 20th mag in the absence of interstellar reddening. The medium-band system will be used for classification (parametrization) of stars down to 17–18 mag in temperatures, gravities and metallicities in the presence of interstellar reddening. The reddening will be determined together with stellar physical parameters for the majority types of stars. The system also will allow the identification of many types of unresolved binaries, emission-line stars, carbon-rich stars, white dwarfs, etc. Two passbands will measure the abundances of Ca and Mg, elements of the alpha-process. The system has been verified by a "blind testing", in which several groups of experts have made parametrization of the unknown set of star models of different temperatures, gravities, metallicities and reddenings, including a number of quasars of different types and red-shifts. More about the "Gaia" systems see in `http://gaia.am.ub.es/PWG/index.html`.

1.4. *UBVRI Broad Band Photometry*

Landolt continues work on UBVRI sequences around the sky centered roughly at +45 and −45 degrees declination, as well as enhancing sequences already published at the celestial equator. The stars in these sequences reach about $V = 16$. The two papers describing the enhanced sequences at the celestial equator and the new sequences at −45 degrees declination are in the writing stage. There will be some dozens of enhanced colors and magnitudes as well as additional new standard stars in the equatorial region. The sequences around the sky centered at −45 degrees declination contain about 100 stars. Initial data for the photometric sequences around the sky centered at +45 degrees declination were obtained at Kitt Peak National Observatory a number of years ago prior to the retirement of appropriate photometric equipment. The observational photometric data necessary to complete these sequences are in the process of being obtained at the Lowell Observatory.

1.5. *Photometry at Yunnan Observatory*

Sheng-Bang Qian writes that several small telescopes, for example the 1.0-m telescope at Yunnan Observatory, are being used to do time-series multiple-band photometric studies of close binaries. A 2.4-m robotic telescope will be built at Yunnan Observatory's LiJiang station by the end of the year 2005, and will be equipped with a wide-field CCD camera, a quick-read CCD camera, and a 16-channel photoelectric photometer. The new telescope will be used to study and search for variable stars in galactic star clusters and in the vicinity of external galaxies.

The type of close binaries under study include chromospherically active binaries (RS CVn-type), Algol-type eclipsing binaries, near contact binaries and overcontact binary systems (W UMa-type).

Current projects include a search for unseen third bodies in close binaries and its implications in the evolutionary link of close binary stars, the formation and dynamical evolution of overcontact binaries, and the merger of deep, low-mass ratio overcontact binary stars and the formation of single rapid rotating stars. Qian's group also has undertaken the long-term photometric monitoring of selected close binary stars.

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2. Polarimetry

2.1. *Instrumentation*

The Canada-France-Hawaii Telescope has commissioned a new spectro-polarimeter called ESPaDOnS. It is a cross-dispersed echelle spectrograph with polarizing optics (a very enhanced version of an instrument named Musicos at the Bernard Lyot Telescope in France at Pic-du-Midi). The new spectrograph can obtain spectra in all four Stokes parameters from 3700 Å to 1.05 μ, with resolving power 68,000 (in polarimetric mode). It has been used in mid year 2005 by several groups and works splendidly. The instrument Web page is `http://webast.ast.obs-mip.fr/magnetisme/espadons.html`.

2.2. *Polarimetry Studies*

Tinbergen writes that he has been working on polarimetric instrumentation for large telescopes, in particular for interferometry using full polarization and for using single telescopes like VLT and OWL to detect exoplanets by exploiting the high linear polarization of scattered light. He writes that in the coming decade, the astronomical community may expect to see significant new applications in visual/near-IR (imaging and spectro-) polarimetry. Astronomical awareness of polarization keeps growing and the large telescopes provide the necessary photon streams. New paradigms are being developed for full-polarization interferometry and for precision polarimetry with Nasmyth and similar telescopes.

R. H. Koch writes that he and D. Clarke (Glasgow) have in press in the Observatory a paper which reports on more than 900 color-filtered linear polarization measures obtained from 1967 through 1996 at the Flower and Cook Observatory. They have lowered the upper limits of polarization for 35 stars and it is possible that 8 of them have small non-zero polarizations. The remaining 27 objects show zero polarization within the errors of measurement.

2.3. *General Comments on Polarimetry*

John Landstreet graciously provided the following summary paragraphs, and writes:

Optical and infrared broadband point-source and imaging polarimetry (excluding spectropolarimetry from this brief survey) during the past triennium has two striking characteristics: a wide variety of exciting new polarimeters is being developed in combination with other techniques such as adaptive optics, and the variety of stellar objects studied covers most of the HR diagram. The use of polarimetry to probe the physical state of astrophysical objects appears to be becoming more and more widespread. The paragraphs below offer just a representative sample of activity from the past three years.

On the instrumental side, polarimetry is increasingly becoming possible on very small angular scales. Tamura *et al.* (2003) report the development of a near-IR polarimeter for the Subaru 8-m telescope, which is being used with the stellar coronagraphic imager with adaptive optics to obtain high-contrast images of faint objects near bright ones. Similarly, a near-IR imaging polarimeter is being used with the Lick Observatory laser guide star adaptive optics to detect faint light scattered from circumstellar material near Herbig AeBe stars (Perrin *et al.* 2004); since this light is polarized (by scattering) while the seeing speckles from the central star are not, differencing two orthogonally polarized images can reveal the faint scattered light. To achieve even higher angular resolution, long baseline optical interferometry is combined with polarimetry at the Sidney Stellar Optical Interferometer to study the circumstellar material around Mira-like red variable stars.

There are also very interesting instruments being developed which combine polarimetric capability with other modes of observation, a type instrument pioneered by the ESO VLT's FORS1. An example is Mimir, a combination near-IR imager, spectrometer and polarimeter for the Perkins Telescope (Clemens *et al.* 2004). Another instrument of this type is TRISPEC, which allows simultaneous three-band (optical and two IR bands) imaging or spectroscopy combined with polarimetry (Watanabe et al 2005).

The Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) was flown on two space shuttle missions, in 1990 and in 1995. All the observations obtained from these two missions are now available from the Vizier On-line Data Catalog VI/105 (Nordsieck *et al.* 2002).

The range of objects for which polarimetry provides useful constraints is extremely large. A representative sample of some of the kinds of objects observed in the last triennium has to include a number of observations of very young stellar objects. In addition to the observations of Herbig AeBe stars mentioned above, Maheswar *et al.* (2002) present linear polarization observations of a number of Herbig AeBe stars known either to be in binary systems or to have bipolar outflows. Near-IR imaging polarimetry of some low-mass young stellar objects in Oph and Tau is reported by Lucas *et al.* (2003). Outflows from luminous young stellar objects are studied with near-IR imaging polarimetry by Jones *et al.* (2004).

Among more evolved objects, 11 years of linear polarimetry has recently been reported of the optical radiation from the Mira variable R Lep by Raveendran (2002). Study of two Mira variables with the Sydney University Stellar Interferometer (mentioned above) in linearly polarized light has made it possible to separate the circumstellar dust scattering envelope from the bright central star (Ireland *et al.*, 2005).

Magnetic white dwarfs continue to be observed polarimetrically in continuum bands. Beuermann & Reinsch (2002) report high-time resolution, broad-band circular polarimetry of the magnetic white dwarf LP 790-29. They find no periodicities in their data and exclude rotation periods between 4 s and 1.5 hr.

Going to even more compact objects, the double pulses from the optical pulsar PSR B0656 + 14 have been observed in ten phase-resolved bins. The radiation in the bridge between the two pulses is apparently 100% polarized, but unpolarized during the rest of the cycle (Kern et al. 2003).

This is not more than a roughly representative survey of recent results; it demonstrates the vibrancy and value of this instrumental technique.

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3. Infrared Working Group

E. F. Milone reports that, during the triennium, follow-up work to that earlier reported on the IRWG infrared passband system project has been published (Milone and Young, 2005). This paper addresses the near-IR passbands part of the IRWG set, providing evidence for the greatly improved transformability and for the superior signal-to-noise ratio of the full passband system. A preliminary set of bright standard stars observed in the iz, iJ, iH, and iK near-IR passbands is provided as a basis for practical photometry. Because this system may permit near-infrared photometry to be performed at lower elevation sites than was previously possible, reprints of this paper have been sent to all observatories, where, to the authors' knowledge, either optical or infrared photometry currently is practiced. The authors acknowledge with gratitude the leadership and help shown by David Marcus of Custom Scientific, which made possible the realization of the near-IR component of these optimized passbands.

Although most of the simulation work as suggested in the Joint Commission meeting held at the Baltimore IAU in 1988 [and published in Milone (1989) has been completed, and some observations have been obtained, more work remains to be done. For example, the near-IR list of standard stars needs to be extended to more and fainter stars. Filters need to be obtained in the intermediate passbands iL, iL', iM, iN, in, and iQ, and observations made in them. While observations with good precision will be possible from lower altitude sites for iL, iL', and iN, for the iM and iQ passbands, data will have to be obtained at higher elevation sites due to the impaired atmospheric windows near 5 and 18 micro-meters. Simulations also need to be done with later generation MODTRAN atmosphere models to explore the effects of aerosols, and simulations could be carried out for the broken spectrophotometric passbands created by removal of auroral and airglow emissions. Finally, simulations with sources cooler than the coolest Kurucz models could be attempted.

The IRWG welcomes new members. If any photometrist not yet in the IRWG, or one who has been less active, has an interest in and would like to help out in carrying the passband project forward, he/she is encouraged to contact the chair.

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