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PHOTOELECTRIC STANDARDS OF THE STRÖMVIL PHOTOMETRIC SYSTEM

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Abstract. About 350 stars of various temperatures, luminosities and metallicities have been observed in the medium-band seven-color *Strömvil* photometric system. A part of these stars is used for the preliminary calibration of color indices in terms of temperature and absolute magnitudes. The calibration is based on the temperatures, determined by the infrared flux method or from angular stellar diameters, and the absolute magnitudes determined from the *Hipparcos* parallaxes.

Key words: stars: fundamental parameters, multicolor photometry – Strömvil photometric system

1. THE STRÖMVIL SYSTEM

The *Strömgren* system with the mean wavelengths 350, 411, 467 and 547 nm was introduced for determination of temperatures and luminosities of B–A–F and early G stars and metallicities for A–F–G stars (Strömgren 1963a,b, 1966). Later on, the system was supplemented by two additional narrow passbands, measuring the intensity of the Hβ line in order to obtain a more precise determination of luminosities of B-type stars (Crawford & Mander 1966).

Straižys, Crawford and Philip (1994) have demonstrated, that the addition to the *Strömgren* photometric system of three passbands at 374, 516 and 656 nm from the *Vilnius* system makes the combined *Strömvil* system more universal. The system becomes capable of classifying stars in spectral classes and luminosities (or determining their temperatures and surface gravities) everywhere in the HR diagram. This property of the *Strömvil* system is especially important in CCD photometry, since a photometric classification of stars as faint as 20 mag becomes possible. The *Strömvil* system was recommended for the photometric classification of faint stars where it is difficult or even impossible to obtain narrow-band Hβ photometry and where the classification of G–K–M stars is needed in the presence of interstellar reddening. The *Strömvil* system is as good as the parent systems in determining the metallicities and peculiarities of stars.

The parameters of the passbands of the *Strömvil* system are given in Table 1. Fig. 1 compares the response functions of the *Vilnius* and *Strömgren* photometric systems. A collection of the u,P,v,b,Z,y,S passbands forms the *Strömvil* system.

About 2000 stars have been observed both in the *Vilnius* and the *Strömgren* systems. These stars were used for the investigation of the properties and for the preliminary calibration of photometric parameters of the combined system (Straižys et al. 1996). The behavior of peculiar stars in the *Strömvil* system is described by Straižys, Høg and Philip (1997) and Straižys (1999a). The *Strömvil* system is proposed to be set in the *Gaia* orbiting observatory of ESA planned for launch in 2009–2010 (Straižys & Høg 1995, Høg, Knude & Straižys 1999, Straižys 1999a). For this purpose the response functions of the system were modified to rectangular shape in order to increase the limiting magnitude. Three passbands in the infrared spectrum (at 815, 880 and 938 nm) were added for measuring the height and position of the Paschen jump in early-type stars and for the identification of M-type and carbon-rich stars (Straižys 1998, 1999b).

Here we present the first photoelectric observations in the *Strömvil* system and preliminary calibration of its color indices in terms of temperatures and absolute magnitudes.

Table 1. Mean wavelengths and half-widths of passbands of the *Strömvil* photometric system.

	u	P	v	b	Z	y	S
λ_0 (nm)	350	374	411	467	516	547	656
$\Delta\lambda$ (nm)	30	26	19	18	21	23	20

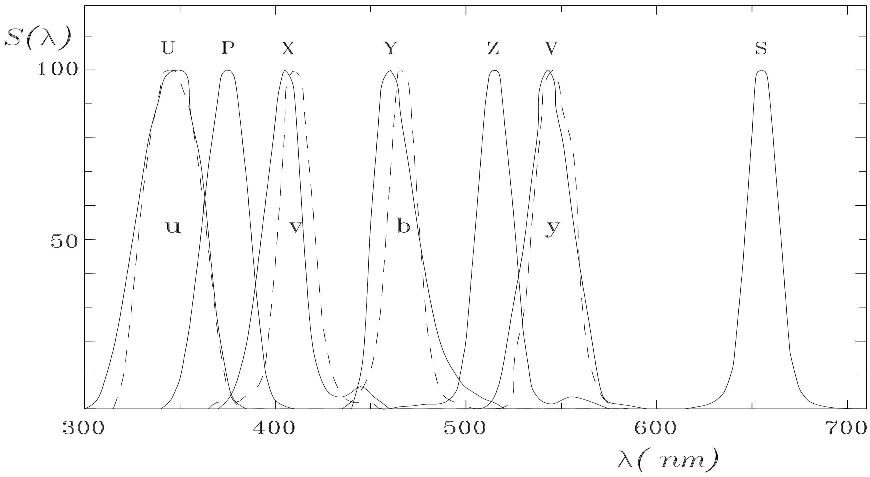

Fig. 1. Comparison of passbands of the *Vilnius* (solid lines) and *Strömgren* (broken lines) photometric systems.

2. OBSERVATIONS

Photoelectric photometry of 250 stars with known temperatures, luminosities and metallicities was obtained with a two-channel photometer on the 1.5 meter telescope of the Steward Observatory on Mt. Lemmon. The photometer, fabricated at the Vilnius University, Lithuania, uses two multialkali Hamamatsu R1463P phototubes for measuring the star and the background at the same time. Also, it uses fast change of the filters (exposures in one filter usually last 1 s) to exclude small changes of the atmospheric extinction.

Also, about 100 stars have been observed in a number of selected areas (mostly in open and globular clusters) as photoelectric standards for CCD photometry obtained earlier with the 1.8 meter telescope of the Vatican Observatory and with the 1 meter telescope of the U.S. Naval Observatory at Flagstaff.

3. CALIBRATION

The accuracy of photometric determination of stellar physical parameters, such as effective temperatures, gravities, absolute magnitudes and metallicities, depends primarily on the calibration of the photometric parameters – color indices, interstellar reddening-free quantities Q, ultraviolet and violet excesses, etc. For this calibration the most accurate stellar physical parameters should be used.

During the last decade a number of stars with well-known effective temperatures and absolute magnitudes has increased considerably. Most of the effective temperature determinations are based on the Blackwell-Shallis infrared flux method (Blackwell et al. 1980) and on the angular diameters of stars determined by interferometric methods and the lunar occultation method. We have collected about 600 single stars of solar metallicity with the temperatures determined by these methods from the papers of Underhill et al. (1979), Underhill (1980,1984), Tsuji (1981), Remie & Lamers (1982), Saxner & Hammarbäck (1985), Glushneva (1985), Leggett et al. (1986), Di Benedetto & Rabbia (1987), Arribas & Roger (1988), Arribas & Roger (1989), McWilliam (1991), Di Benedetto (1993), Blackwell & Lynas-Gray (1994, 1998), Taylor (1994), Alonso et al. (1996), Dyck et al. (1996), Evans & Teays (1996), Evans et al. (1996) and Flower (1996).

For supergiants, the temperature data from Achmad et al. (1992), Venn (1993, 1995), Alfaro et al. (1997) and Giridhar et al. (1997), determined by the method of model atmospheres applied for spectroscopic and photometric measurements, have been also used. In the case of several temperature determinations available, they were averaged.

Absolute magnitudes for the stars were determined from their *Hipparcos* parallaxes: only those having the relative parallax error <15% were used. Among them the supergiants of luminosity class I and bright giants of luminosity class II are almost absent. Therefore, the calibration list was supplemented by 135 stars of luminosities I and II with absolute magnitudes collected from the literature

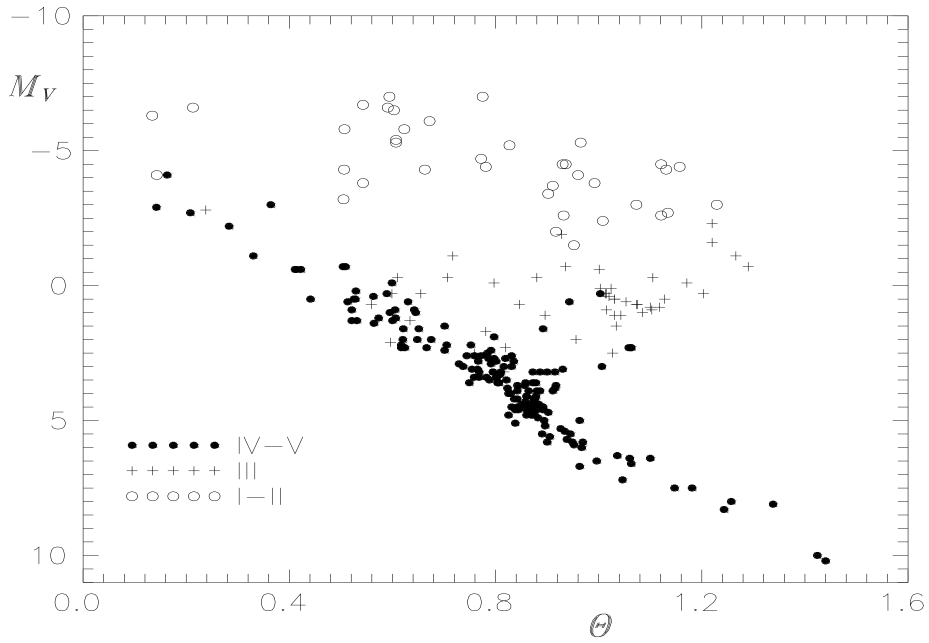

Fig. 2. HR diagram for the 257 stars used for calibration. On X axis the function $\theta = 5040/T_{\rm eff}$ is plotted.

and determined from their membership in clusters and associations (Walker & Millward 1985, Hill et al. 1986, Arellano Ferro & Parrao 1990, Slowik & Peterson 1993, 1995), from K line emission width (the Wilson-Bappu effect, Wilson 1976), and from some other luminosity-sensitive spectral criteria (Arellano Ferro et al. 1991, Arellano Ferro & Mendoza 1993, Mendoza & Arellano Ferro 1993).

The final calibration list contains 2100 stars. For the preliminary calibration we used 257 stars either observed in the first observing run or having common Vilnius and Strömgren photometry. The second run will take place later this year. All these stars with their temperatures and absolute magnitudes are plotted in Fig. 2.

For the calibration of every color index (or Q-parameter), three-dimensional diagrams "photometric quantity – effective temperature – absolute magnitude" were plotted. After that, an optimum surface with the matrix smoothing was covered on each diagram by the

Surfer software. Examples of such diagrams are shown in Figs. 3–6 for color indices, most sensitive to temperatures and/or luminosities in certain ranges of the physical parameters. These plots make easier to understand the reasons why one or another color index is preferable for the classification of stars in certain temperature and luminosity range.

The next steps will be the calibration of interstellar reddening-free Q-parameters in terms of temperature, luminosity and metallicity and the estimation of the accuracy of photometric classification of reddened stars.

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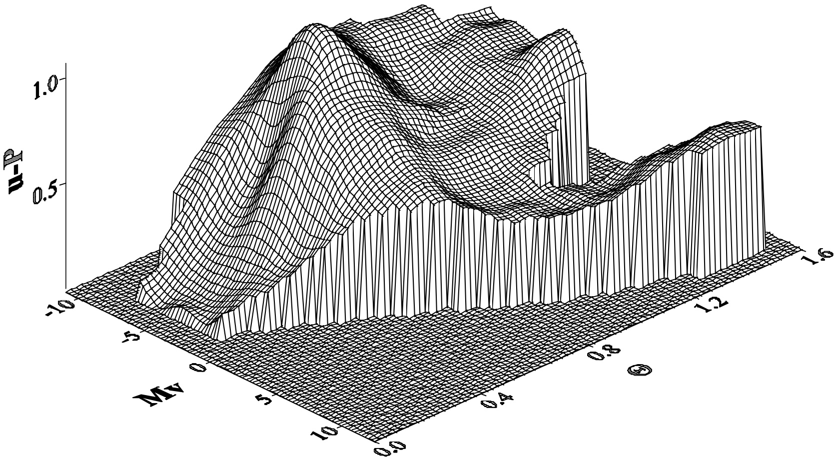

Fig. 3. Calibration of the color index u–P in terms of $\theta = 5040/T_{\rm eff}$ and M_V is plotted.

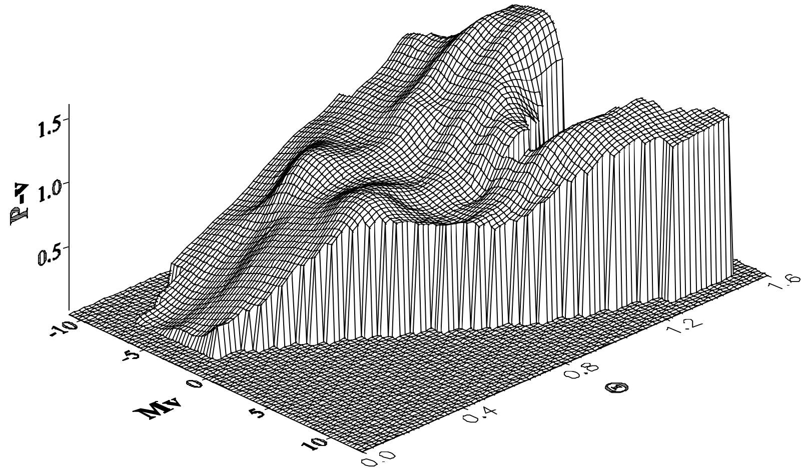

Fig. 4. Calibration of the color index P–v in terms of $\theta = 5040/T_{\rm eff}$ and M_V is plotted.

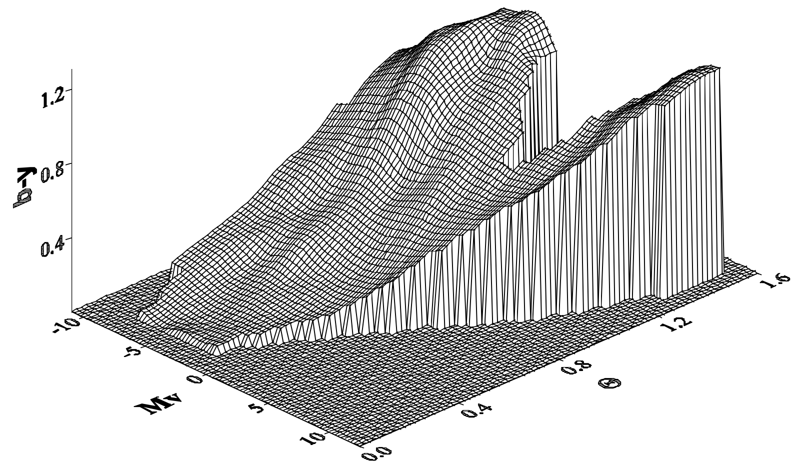

Fig. 5. Calibration of the color index b–y in terms of $\theta = 5040/T_{\rm eff}$ and M_V is plotted.

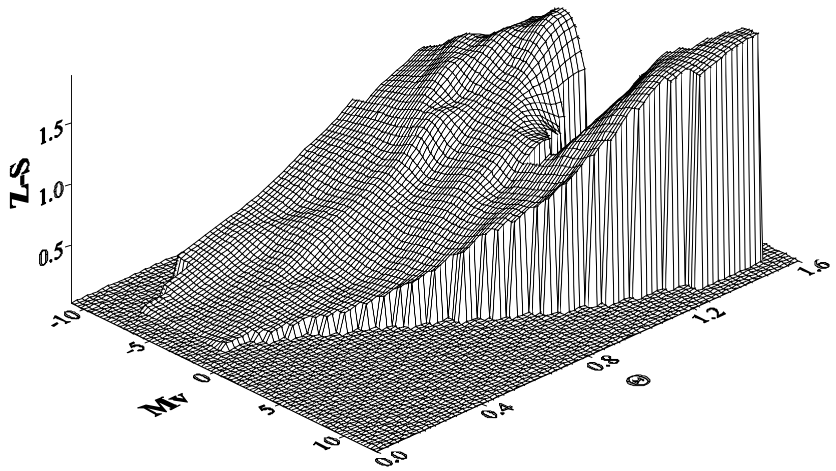

Fig. 6. Calibration of the color index Z–S in terms of $\theta = 5040/T_{\rm eff}$ and M_V is plotted.