REALIZATION OF THE VILNIUS PHOTOMETRIC SYSTEM FOR CCD-OBSERVATIONS OF SELECTED SKY AREAS AT THE ANDRUSHIVKA ASTRONOMICAL OBSERVATORY

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We describe a set of glass *UPXYZVS* filters of the Vilnius photometric system of the Andrushivka Astronomical Observatory in Zhytomyr Region (Ukraine) [7]. They are installed at the Zeiss-600 Cassegrain reflector together with the 15-bit 1024×1024 CCD-camera S1C-017. The response curves of instrumental photometric systems are presented and a comparison of them with a standard system are analysed. Test observations in the Vilnius system of the star cluster IC 4665 with the Andrushivka filters were carried out in May–June 2003. The MIDAS/ROMAFOT and ASTROIMAGE software is adapted for digital processing of CCD-images of stellar fields. Comprehensive ground-based observations are being planned to design a catalogue of primary *UPXYZVS* CCD-standards in selected areas of the sky where are with radio sources, globular and open clusters, *etc.*

INTRODUCTION

Regular astronomical observations began in 2001 at the Andrushivka Astronomical Observatory (AAO) in Zhytomyr Region (Ukraine). Its coordinates determined by GPS-methods are: $\phi = 50^\circ\,00'\,02.0''$, $\lambda = 28^\circ\,59'\,50.3''$, $h = 240$ m. The Zeiss-600 Cassegrain reflector ($D/F = 60/750$ cm) with the digital television CCD-camera S1C-017 made by "Electron Optronic" (St.-Petersburg, Russia) is installed at the Observatory. The S1C-017 device can operate over a wide spectral range with a high geometrical accuracy and low reading noise and is destined for the detection of black–white images with low illumination. An image has 1024×1024 pixels, frame size is $7.8'\times7.8'$ and a scale is 1 pixel = $1.34''$ (for the primary focus).

Table 1. Components and optical features of instrumental photometric system filters

Filter	Components	λ_{max} (Å)	Transmission in maximum (%)
U	S21(2.0) + UFS2(1.0) + Quartz(3.0)	3570	24.9
P	SZS21(2.0) + UFS(2.7) + Quartz(10.3)	3760	34.1
X	ZS4(3.2) + ZS7(6.2) + SZS21(1.8) + Quartz(1.8)	4060	20.0
Y	ZS12(5.2) + SZS21(2.6) + SS15(2.0) + K8(5.2)	4630	25.7
Z	ZS17(2.0) + ZS7(3.1) + SZS22(10.0)	5140	36.8
V	OS11(1.5) + SZS22(5.0) + PS7(2.0) + K8(6.5)	5400	32.7
S	KS13(2.0) + SZS23(2.0) + K8(11.0)	6400	31.9

The availability of the high quantum efficiency device for the detection of radiation over a wide spectral range stimulated the realization of that photometric system measurements in which physical properties of celestial bodies can be reflected in an unique manner. Such a system is the seven-colour Vilnius *UPXYZVS* system providing a possibility of a many-dimensional spectral classification of stars when the space reddening exceeds the overall star temperature interval [1]. At AAO, in the first stage of the *UPXYZVS* system realization, observations of a selected list of initial photoelectric standards of the Vilnius system in the north sky will be carried out to form a network of initial CCD-standards. The second stage works will be performed in parallel, namely the formation of a CCD-variant of photometric *UPXYZVS*-standards in selected sky areas, in areas with open and globular clusters, with infrared objects and radio sources for the purpose to perform statistical investigations of the Galaxy and Solar System bodies. The photometric investigations in the Vilnius system in these sky areas will be supplemented with measurements in the Johnson *UBVRI* system. Some results of this program will be as follows: a catalogue of a unified list of stars (objects) in two photometric systems, investigation of interstellar extinction, search maps for sky areas in the form of adapted CCD-images, and investigation of the seeing at Andrushivka settlement (extinction, night airglow brightness). An experience of this kind of investigation was accumulated before [3–5].

A COMPARISON OF FILTERS OF INSTRUMENTAL AND STANDARD *UPXYZVS* SYSTEMS

Three sets of glass filters for seven UPXYZVS bands were made for the Andrushivka Astronomical Observatory in May 2002. The sizes of all the filters are 35 mm×35 mm and their thickness equals 15 mm (to level off optical thickness, quartz or the glass K8 was added by forming the transmission curve of a combination of glasses of different thickness). Industrially prepared standard glass filters were used similar to filters employed by developers of the original *UPXYZVS* system [9, 10]. Spectral transmission coefficients for prototypes of all the filters were measured in the Ukrainian State Research and Production Center for Standardization, Metrology and, Certification (UkrCSM, Kyiv). Absolute errors are within 1.0 percent for transmission coefficient measurements and 1.0 nm for wavelength measurements. For the "telescope+receiver" system, filters play a crucial role in the formation of curves of reaction of the photometric system. Table 1 gives some information on components (a sort of glass and glass thickness in mm in brackets) and optical features (the transmission maximum wavelength λ_{max} (Å), transmission bandwidth (Å), and the transmission maximum value (in percent)) for the filters made for AAO. Atmospheric transparency (the equivalent thickness of the layers O_2 and H_2O are 3 and 10 mm, respectively) and selectivity of mirror reflection [1] were taken into account by calculating final curves of reaction of instrumental system bands.

Figure 1 illustrates the response curves for the instrumental system (the dotted line) and for the standard system [10] (the solid line).

RESULTS OF FIRST OBSERVATIONS

An extensive observational information was accumulated during the spring and summer 2002 period of observations of various sky areas with the use of *UBVR* photometric standards. An analysis of the observations reduced by means of the MIDAS/ROMAFOT software package [5, 6] showed that the limiting magnitude of objects to be recorded (signal accumulation time is equal to 10 min) in integral light is close to 21^m in the R band (these are precisely the magnitudes which are used in ASTROMETRICA, the software package for reducing CCD-observations, that we have applied [`http://www.astrometrica.at`]).

Photometric observations with *UPXYZVS* filters were carried out in June 2003 to check the identity of the instrumental and standard systems. The IC 4665 cluster which is sufficiently compact and rich by stars with *UPXYZVS* values determined reliably (Straizys V., Kazlauskas A., private communication) was selected as an object for observations. The camera was installed in the primary focus ($F = 2400$ mm, the scale is 1 pixel $= 1.34''$). Such mode of the camera installation on at the classical Cassegrain telescope was used to increase the penetrating power of the telescope in the case of observations of extremely faint objects, namely asteroids and comets (a gain of magnitude is almost 1 m at a sacrifice of resolving power). But this mode of the installation is tolerable and allows us to avoid many hazards in the case of photometric observations. The observations were carried out practically in the meridian and the cluster zenith distance did not exceed 30° (plausible corrections for atmospheric extinction can not exceed 0.01^m in this case). The exposure was equal to 60 s for U, P, and X filters and to 120 s for the other filters. The ASTROMETRICA package (version 4.1.2) was used for the initial traditional CCD-frames reducing which included the correction for dark current (dark frame) and flat field (flat field frame). Two software packages, namely MIDAS/ROMAFOT and ASTROIMAGE [`http://www.phasespace.com.au`] packages, were applied in the following stages of reducing, in particular, by determining magnitudes of program stars, since ASTROMETRICA is primarily aimed to calculate star coordinates. The USNO-SA 2.0 catalogue founded on magnitude measurements in B and R filters is used as the basic one in the package, which is developed to solve photometric problems. Compilating and

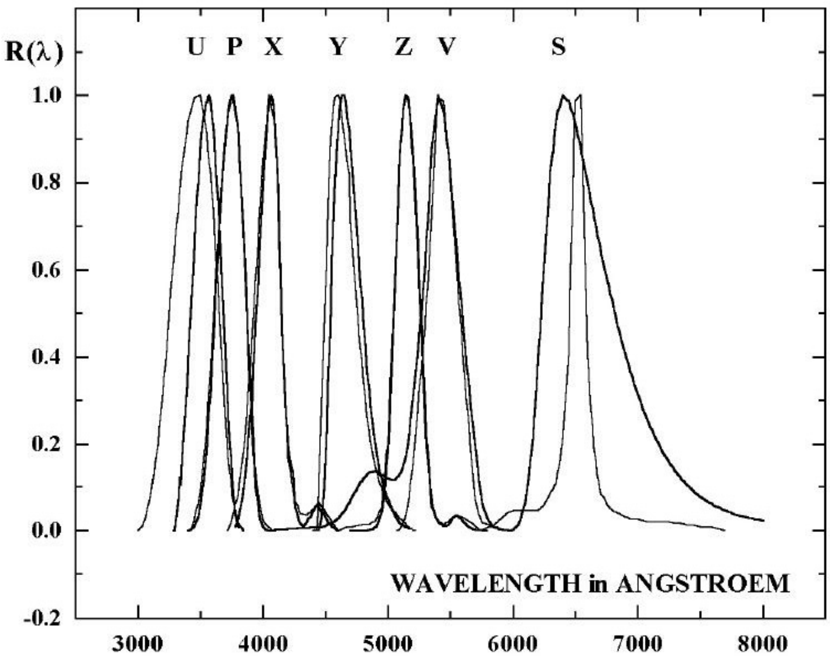

Figure 1. The normalized response curves of the standard Vilnius system (thin line) and the Andrushivka instrumental CCD-system (thick line)

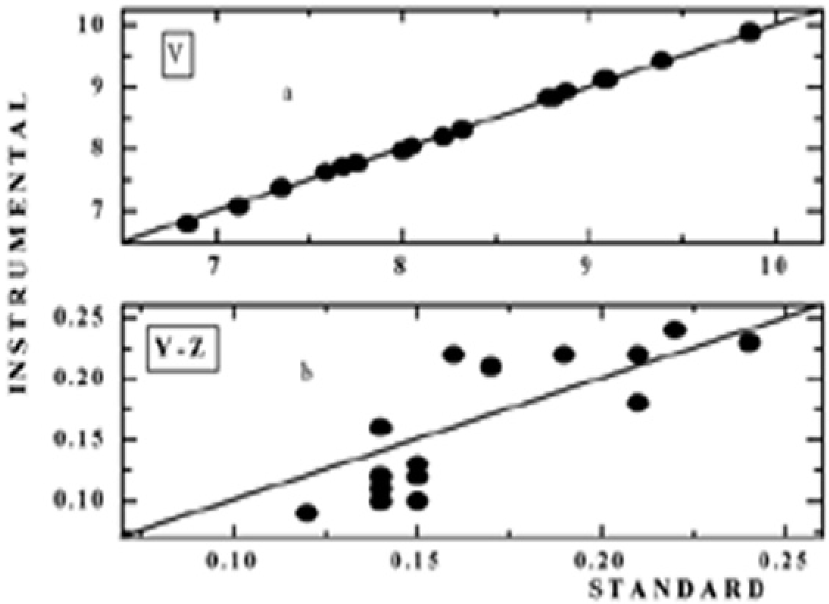

Figure 2. Comparison of observed (axis Y) and standard (axis X) meanings of V-magnitude (panel a) and colour-index Y–Z(panel b) for stars in cluster IC 4665

applying a user's catalogue with magnitudes data in other photometric systems are not provided in the package. Figure 2 illustrates a comparison of *V*-magnitude (panel a) and colour-index *Y–Z* (panel b) of the same stars in the instrumental (the axis *Y*) and standard (the axis *X*) photometric system. It may be preliminary deduced from these graphs that the instrumental *UPXYZVS* photometric system of the Andrushivka Astronomical Observatory is in a reasonably good agreement with the standard system. The research work is planned to be continued using the list of the cluster IC 4665 standards enlarged at the expense of fainter stars.

CONCLUSION

A set of filters for the *UPXYZVS* photometric system was manufactured and their metrological attestation was performed. The response curves for the instrumental system were investigated and compared with ones for the standard system. We carried out series of observations of the cluster IC 4665 stars with magnitudes determined before by the photoelectric method. Our comparison of the instrumental and standard photometric system confirmed an inference which was derived from calculations that these two systems are in good agreement. An extensive observational program is scheduled to be performed to form initial CCD-standards in the *UPXYZVS* system for selected sky areas, in particular, in globular and open clusters, as well as in areas with infrared and radio sources.

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