

ON POSSIBLE EXTENSION OF THE VILNIUS PHOTOMETRIC SYSTEM INTO THE ULTRAVIOLET AND THE NEAR INFRARED

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Abstract. The Vilnius seven-color medium band photometric system was chosen as the most effective one for the future Russian astrometric and photometric space project STRUVE (the former name was AIST). The location of telescopes in space allows to add to the Vilnius system three more ultraviolet passbands with medium wavelengths at 282, 247 and 218 nm and with half-widths of 15, 28 and 40 nm, respectively. The main goals of this extension of the system are: better possibilities for classification of stars earlier than F, especially, early B and O-type stars, peculiar stars of types Bp, Ap, Am, Be, etc., and further investigation of features of the interstellar extinction law in the ultraviolet.

It is also suggested to restore the “old” T_2 -passband of the Vilnius system with a medium wavelength of ~ 715 nm and with a half-width of ~ 25 nm for identification and more precise classification of M-type stars.

Key words: methods: observational – techniques: photometric – space vehicles – stars: classification

1. INTRODUCTION

This paper is related with the selection of the optimal photometric system for one of the space projects which are now developed in Russia. Recently we have defined the main tasks and different versions of the space project STRUVE combining the astrometric and photometric observations of stars. The main task of the

project is to create a fundamental catalog of positions, proper motions and parallaxes of stars and other objects over all sky down to $V \sim (17-18)$ mag of the precision of the order of 1–5 milliarcseconds. At the same time, we have studied a possibility to carry out CCD photometry for the same objects. It is obvious, that simultaneous multicolor photometry and precise astrometry of stars and galaxies extends the domains of application of the catalog.

Preliminary estimation of the main photometric possibilities of our project were first reported in October 1993 (Kopylov, Gorshanov & Chubey 1993) and in August 1994 (Kopylov, Gorshanov & Chubey 1995). The project team for the photometric program of the satellite, after detailed comparative analysis of some most frequently used and informative photometric systems, came to a firm decision to choose the Vilnius system, as the most effective one, for the STRUVE space mission.

A detailed scientific and technical description of this project, including the justification of our decision on the photometric system, can be found in the just published book “The STRUVE Space Astrometric System” (Yershov, Kanaev & Kopylov 1995).

The location of telescopes in space and the application of CCDs with high quantum efficiency in the ultraviolet and the near infrared wavelenths give us opportunity to examine a possibility of extending the Vilnius photometric system to the ultraviolet down to 180–200 nm and also to the near infrared up to 800 nm.

In the case of the ground-based photometry, the Vilnius system is very effective in classifying any collection of stars of various spectral classes, luminosities, metallicities and peculiarities, in the presence of interstellar reddening. However, the space ultraviolet radiation of stars with $\lambda \leq 300$ nm contains many strong spectral features connected with composition anomalies and unstable processes in the upper atmosphere layers and envelopes of diverse types of stars, both hot and cold. Moreover, this wavelength range is very important for more accurate study of the interstellar and circumstellar extinction laws. Astrometric coordinate measurements in the ultraviolet are also important being of higher accuracy due to shorter wavelengths (Yershov, Kanaev & Kopylov 1995).

Successful development of CCDs with high QE in the ultraviolet and infrared ranges was reported at the IAU Symposium No. 167 in August 1994 (Philip, Janes & Upgren 1995).

2. A SHORT REVIEW OF THE ULTRAVIOLET SPECTRA OF EARLY-TYPE STARS

We have examined numerous published data on ultraviolet photometry, spectrophotometry and spectroscopy (papers, catalogs, atlases, lists of spectral lines, etc.), obtained with the OAO-2, TD1, ANS, IUE and other space observatories. We also used the catalog published by Sviderskienė (1988) and containing dereddened spectral energy distributions $E(\lambda)$ for 98 representative spectral types of spectral classes from O to M and luminosity classes from V to I. The data cover the wavelength range from 120 to 1050 nm with $\delta\lambda = 5$ nm step. Energy distributions are normalized to 100 at $\lambda = 550$ nm.

Taking into account that the band half-width $\Delta\lambda$ (FWHM) for the “typical” medium band photometric systems is in the range of 15–50 nm, we consider that a step of 5 nm is quite sufficient for our task. However for additional analysis of strong spectral features and their fine structure we have used lists and atlases of spectral atomic lines and molecular bands for different types of stars, especially for peculiar, variable and emission-line stars.

In Fig. 1 we show the samples of $E(\lambda)$ in the wavelength range of 140–370 nm for main sequence stars B8 V – F0 V and for stars of types G2 IV and G8 III. For all stars it was adopted that $E(V) = 100$. In the figure, the vertical broken lines show the positions of main spectral depressions at about 280, 255, 239 nm and the mean position of the interstellar band at 217.5 nm. The position of the strong absorption band near 280 nm is not stable: it changes from 277 to 287 nm, depending on spectral types and luminosities of stars.

The wide double depression around 240–255 nm consists mainly from the resonance lines of Fe II and ions of other metals. The intensity of these bands in different degree depends on the temperature, luminosity and chemical composition of stars and, therefore, these bands are criteria of stellar parameters. The strong and usually very complicated absorption-emission band at 280 nm is a combination of four Mg II resonance lines appearing both in the outer layers of a star (atmosphere, chromosphere, stellar wind, Be-type shell, etc.) and in the extensive circumstellar envelope. The structure and intensity of this band is a rather significant evidence of different unstable processes in wide ranges of temperature and luminosity.

The broad interstellar and partly circumstellar band at 217.5 nm ($212 \leq \lambda \leq 225$ nm) has a total width $\Delta\lambda$ up to 100 nm and half-width $\Delta\lambda$ (FWHM) about 30–40 nm (see, e.g. Bless & Savage 1972).

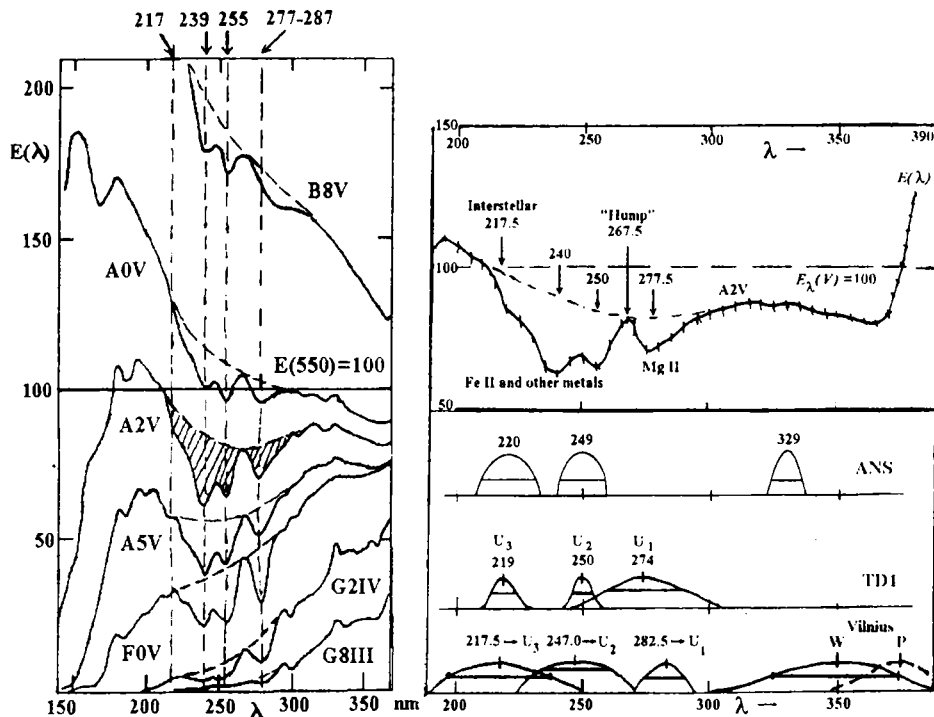


Fig. 1. Energy distribution curves of early-type stars in the ultraviolet with the strongest spectral features shown. The horizontal line at $E(\lambda) = 100$ shows the normalization level of all energy curves to 100 at 550 nm.

Fig. 2. The top panel shows the energy distribution of A2 V type star (solid line), the pseudocontinuum line (broken line) and the positions of the main spectral features. The two medium panels show the positions and widths of passbands of the ANS and TD-1 satellites. The bottom panel shows the positions and widths of the suggested optimum passbands for the STRUVE mission.

3. EVALUATION OF THE UV PASSBAND PARAMETERS

In Fig. 1 by broken lines we draw the continuous (or pseudo-continuous) spectra in the wavelength range of 200–300 nm assuming that the hump at $\lambda = 267.5$ nm is the Balmer continuum point, free of any strong absorption lines. The coarse analysis shows that the relative depths of the main depressions, i.e. the values r_λ/r_0 at $\lambda \approx 280, 255$ and 240 nm for early-type stars (O to G) depend both on spectral and luminosity classes.

Table 1. Parameters of the passbands proposed to supplement the Vilnius photometric system.

Band	λ_0 , nm	$\Delta\Lambda$, nm	$\Delta\lambda$, nm	Remarks
1	2	3	4	5
U_1	282.5	25	14.5	$277 < \lambda_0 < 287$, $21 < \Delta\Lambda < 35$, $12 < \Delta\lambda < 18$
"267"	267.5	25	15	"Hump" (continuum?)
U_2	247	46	28.5	$\lambda_0 = 255$, $40 < \Delta\Lambda < 50$, $237 < \lambda_0 < 240$, $24 < \Delta\lambda < 33$
U_3	217.5	~ 90	40	Interstellar band
T_2	715	42	21	$40 < \Delta\Lambda < 48$, $20 < \Delta\lambda < 22$

The large sample of diagrams $E(\lambda)$, similar to that presented in Fig. 1, allows us to determine provisionally the main parameters of these depressions and, consequently, the main parameters of the future ultraviolet passbands and filters, namely: the mean (effective) wavelength, λ_0 , the total width on the level of the continuum, $\Delta\Lambda$, and the full width at the level of the half-depth, i.e. FWHM or $\Delta\lambda$. These parameters with some additional remarks are presented in Table 1. A preliminary designation of these three ultraviolet passbands is: U_1, U_2 and U_3 . The hump at 267.5 nm is marked as "267". Columns 2–4 contain λ_0 , $\Delta\Lambda$ and $\Delta\lambda$ for these passbands. Column

5 gives some additional remarks, for example, the limits of variation of λ_0 , $\Delta\lambda$ and $\Delta\lambda$ for the passbands U_1 and U_2 dependent on stellar spectral types and luminosity classes. The last line in Table 1 gives the parameters of the red passband T_2 , first proposed by Straižys (1977, 1992). The position of this passband with $\lambda_0 = 715$ nm corresponds to the head of a strong TiO absorption band, and it is most important for identification of M-type stars. About two decades ago, at the beginning of application of the Vilnius system, photomultipliers in this part of spectrum were of low sensitivity. Now there is no problem of this kind, since CCD detectors are very sensitive in this spectral range.

In Fig. 2 we have plotted the following information (starting from the top panel):

- (a) an example of $E(\lambda)$ curve in the wavelength range of 180–390 nm for an A2 V star with indication of the main spectral features,
- (b) the positions and widths of the ANS satellite passbands,
- (c) the positions and widths of the TD-1 passbands,
- (d) the positions and widths of three suggested passbands for the STRUVE project (U_1, U_2, U_3) and the ultraviolet W and P passbands of the Vilnius system.

In Fig. 3 we show the positions of the new proposed passbands U_1, U_2, U_3, T_2 and the seven Vilnius passbands from W to S set up by the interference filters. Approximate transmittance of the filters τ_{max} (%) is shown on the left ordinate scale. The quantum efficiency curve for one of the most sensitive CCD chips is also plotted (the right ordinate scale).

The next steps related with the extension of the Vilnius system into ultraviolet, will be the calculation of synthetic color indices for real stars and model atmospheres, plotting different Q, Q -diagrams, giving the best classification of stars, and the calibration of color indices and Q, Q -diagrams in terms of effective temperatures, surface gravities and other physical parameters.

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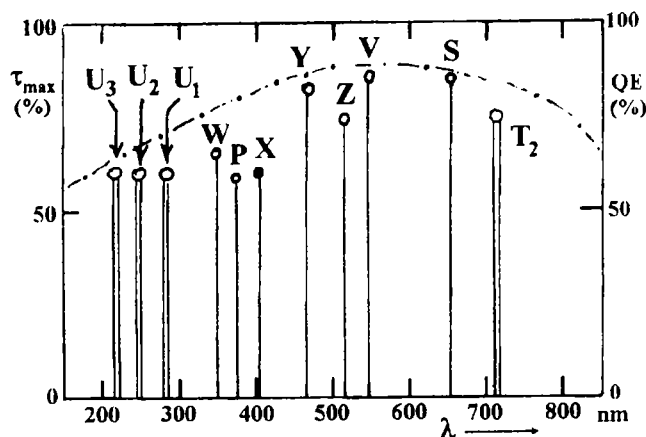


Fig. 3. Positions and maximum transmittances of the filters for the STRUVE space mission. A quantum efficiency curve of one of the most sensitive CCDs is also plotted.

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