INVESTIGATION OF THE PHOTOMETRIC SYSTEM OF CCD-PHOTOMETER AND THE AZT-3 TELESCOPE

S.N. Udovichenko

Astronomical observatory, Odessa National University, T.G. Shevchenko Park, Odessa Ukraine, *astro@paco.odessa.ua*

ABSTRACT. The investigation of the photometric system consisting from photometer with CCD detector Sony ICX429ALL, VRI filters and the AZT-3 telescope was carried out. The transformation coefficients from the instrumental values of magnitudes and color indices to the Johnson-Cousins system in the VRI passbands are presented. The instrumental system of telescope and standard system have satisfactory agreement.

Key words: Photometry, transformations coefficients

1. Introduction

The 48 cm reflecting telescope of Astronomical observatory Odessa National University AZT-3 started to operate in astronomical station near Odessa in 1967. The telescope has four changeable operational modes: direct focus, the Cassegrain, Newton and the the Coude focuses. The photometer was mounted in the Newtonian focus (aperture ratio 1: 4.5, field of view 15') in hermetic chamber with thermoelectric (Peltier) cooler, which provide a temperature difference between the CCD detector and the environment of about -30^{o}C – -40^{o}C. The filters turret contains three windows with filters corresponding to the VRI passbands of the Johnson-Cousins system (Bessell, 1990). The filters were made from special sort of domestic glass and the transmission curves of the filters are close to the passbands of the standard system. The photometer had been successfully used for observations of variable stars and other celestial objects. After the addition new filters it was necessary to examine the instrumental photometric system of the telescope. The transmission of standard photometric UBVRI Johnson-Cousins system and CCD detector ICX429ALL (from Sony CCD Instruction Manual) is shown on Fig. 1.

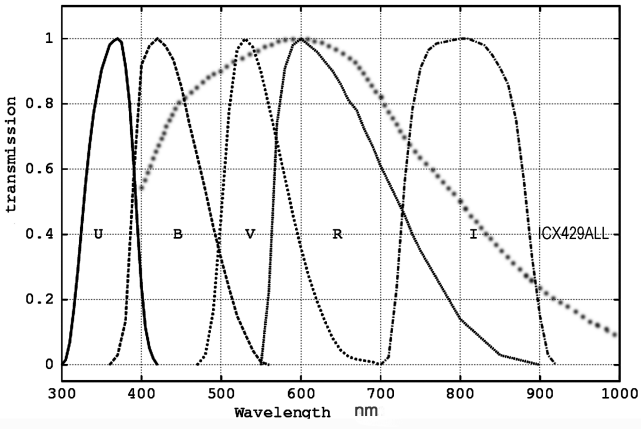

Figure 1: The transmission of standard photometric UBVRI Johnson-Cousins system and CCD detector ICX429ALL.

2. Reduction of images

CCD images contain the both information about sky objects and noise. The noise consists from a sky background, readout noise and thermal noise. Besides, there is a photometric error of a field which appear as a result of not uniform sensitivity of pixels and the various optical effects dispersion of light in a telescope, optical filters and the chamber. The standard procedure was used to correct each image by division on a "flat field", which obtained by measurement of the twilight sky during evening or morning time. The average image "master-flat" has been calculated from 10-15 individual images. Also the average "master-dark" was used for subtraction for each image to compensate thermal noise and readout noise. These corrections images are obtained for the same temperature and time, as images of standard stars. The exposure time was choosing to get the relation a signal/noise 100-300 and accuracy of photometry not worse 0.01 - 0.02^m.

3. Determination of transformation coefficients

The reduction of the CCD frames were carried out using the MUNIPACK software (Motl, 2003-2012). The method of aperture photometry was used. It de-

Table 2: List of standard stars.

Number of Landolt's catalog	RA (J2000)	Dec (J2000)	V	B-V	U-B	V-R	R-I
104 456	12:42:54	-00:32:06	12.362	0.622	0.135	0.357	0.337
104 457	12:42:54	-00:28:49	16.048	0.753	0.522	0.484	0.490
104 460	12:43:03	-00:28:21	12.886	1.287	1.243	0.813	0.693
104 461	12:43:07	-00:32:21	9.705	0.476	-0.030	0.289	0.290
104 350	12:43:15	-00:33:21	13.634	0.673	0.165	0.383	0.353
104 484	12:44:20	-00:30:57	14.406	1.024	0.732	0.514	0.486
104 485	12:44:24	-00:30:16	15.017	0.838	0.493	0.478	0.488
104 490	12:44:33	-00:25:53	12.572	0.535	0.048	0.318	0.312
107 599	15:39:09	-00:14:28	14.675	0.698	0.243	0.433	0.438
107 601	15:39:14	-00:13:26	14.646	1.412	1.265	0.923	0.835
107 602	15:39:19	-00:15:29	12.116	0.991	0.585	0.545	0.531
107 626	15:40:06	-00:17:28	13.468	1.000	0.728	0.600	0.527
107 627	15:40:08	-00:17:22	13.349	0.779	0.226	0.465	0.454
107 484	15:40:17	-00:21:13	11.311	1.237	1.291	0.664	0.577
107 636	15:40:41	-00:14:54	14.873	0.751	0.121	0.432	0.465
107 639	15:40:45	-00:17:11	14.197	0.640	-0.026	0.399	0.404
107 640	15:40:50	-00:16:48	15.050	0.755	0.092	0.511	0.506
HD 89904	10:17:21	+34:24:47	5.878	0.15	-	0.075	-
HD 90040	10:18:24	+34:13:28	5.500	1.18	-	0.602	-

termines a brightness of a stellar object by integrating a signal in a small area on a frame. The point spread function that represents the spatial distribution of the signal from stellar object is rotationally symmetric. The background has been estimated from neighboring pixels as another "aperture" that has a annular shape. The readout from stars with subtracted background convert to instrumental magnitude m_0 using the Pogson's law:

$$m_0 = -2.5 \lg(I/I_0), \qquad (1)$$

where I_0 is a signal from an object of reference flux F_0. The ratio between flux and signal is not known, it is lawful to choose any reference signal I_0, providing a fact that only a difference of magnitude between two objects make sense - the difference is independent of choice of a reference I_0. In the C-Munipack software, the reference flux was set to 10^{10}. As a point of view of the photometer coverage small quantity of the stars, they are practically on equal air mass, and calculation of extinction for difference air mass inside the image not made, but only for a whole of image.

The relation between magnitudes and colors in instrumental and standard systems (Hardie, 1967) is possible to write, as:

$$M = m_0 + \zeta_m + \epsilon C, \qquad C = \zeta_c + \mu c_0, \qquad (2)$$

where M, C – magnitudes and color indices in standard system, m_0, c_0 – magnitudes and color indices in instrumental system, ϵ, μ – transformation coefficients, ζ_m, ζ_c – constants of zero-point.

Stars were measured during several nights and found an average value. For research of photometric system 19 standard stars from catalog was used, which list is presented in Table 2 (Landolt, 1992). The transformation coefficients are calculated by linear least squares method and presented in Table 1.

Table 1: Transformation coefficients.

Passband	ζ_m	ϵ
V_c	-1.293 ± 0.010	0.014 ± 0.039
R_c	-1.951 ± 0.009	0.021 ± 0.055
I_c	-4.628 ± 0.003	0.029 ± 0.019
Color indices	ζ_c	μ
V-R	0.501 ± 0.014	0.956 ± 0.076
R-I	0.472 ± 0.007	0.984 ± 0.048

The dependence of the magnitudes in standard and instrumental systems in filter V and its approximation of the linear function is shown on Fig. 2a. The inclination coefficient equal 1.0085±0.0084, that indicate a good agreement between instrumental and standard systems in the passband V. The same dependencies were obtained in passbands R and I and their values are not presented in this paper.

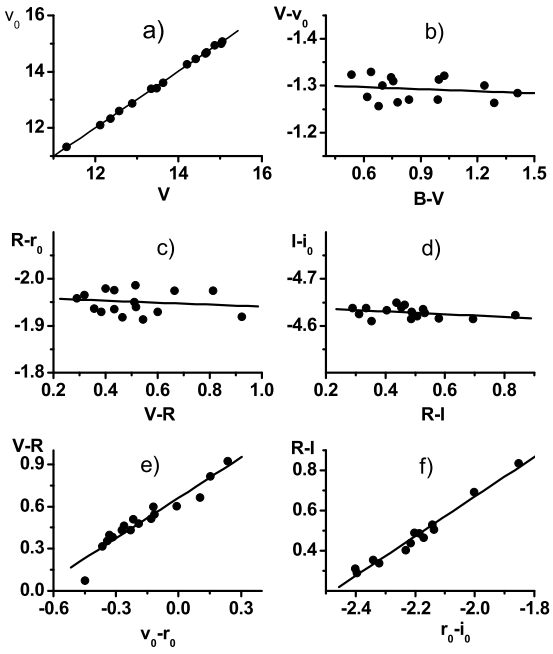

Figure 2: a) Dependence of the magnitudes in standard and instrumental systems in filter V_c; b,c,d) Dependence of the magnitude differences V_c, R_c, I_c on the color indices B-V, V-R, R-I; e,f) Dependence of the color indices V-R, R-I in standard and instrumental systems v-r, r-i

The dependencies of the magnitude differences V, R, I on the color indices B-V, V-R, R-I and their approximations of the linear function are presented in Fig. 2(b,c,d). All dependencies have a small positive slope, and differences do not exceed 0.05^m. The dependencies of the color indices V-R, R-I in standard and instrumental systems v-r, r-i have a positive gradient, and linear coefficients are close to 1. In general, the instrumental system of telescope and standard system have satisfactory agreement. The transformation coefficients for magnitudes and color indices from the instrumental to the standard system of the VRI passbands are determined by measurements of photometric standards.

References

Bessell M.S.: 1979, *PASP*, **91**, 589.
Bessell M.S.: 1990, *PASP*, **102**, 1181
Hardie R.H.: 1967, In book: "Astronomical techniques", Edited by Hiltner, Pablish."Mir".
Landolt A.U.: 1992, *Astron. J.*, **104.**, 340.
Motl D.: 2003-12, *http://c-munipack.souceforge.net*