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Facility

Photometric performance of UPSO CCD system

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Abstract. The UBVRI photometric calibration of the CCD camera of the U.P. State Observatory, Naini Tal, is given here. This is based on the observations of photometric standards located near equatorial regions as well as in the open cluster M67. The values of transformation coefficients indicate that response functions of all the passbands are in good agreement with those of standard photometric system except in the case of B passbands.

Key words : CCD photometry—calibration—image processing

1. Introduction

The Uttar Pradesh State Observatory has acquired a Photometrics CCD system, which has been installed at the 1-metre telescope of the observatory. The UPSO CCD system configuration is as follows:

(i) A 384 × 576 pixel Thomson chip having 23 μm × 23 μm pixels and metachrome coating for UV sensitivity installed in a Dewar operating at −120C.

(ii) CE 200 camera electronics unit.

(iii) Photometrics 3000 image display system based around a camera controller, image memory, video memory and a 68020 microprocessor.

(iv) An RS170 compatible video display.

(v) A floppy disc drive and a Winchester hard disc of 55 MB capacity.

(vi) A graphic terminal.

(vii) 1/4″ cartridge and 1/2″ streamer tape drives.

(viii) FORTH and UNIX operating systems.

At the f/13 Cassegrain focus of the 1-metre telescope of the Observatory, each CCD pixel corresponds to about 0.36 arcsec thus producing a total field of 140″ × 210″.

The aim of the present work is to calibrate the system and to evaluate its photometric performance. For this, we observed a number of photometric standards given by Landolt (1983) and Schild (1983).

2. Observations and data reduction

Landolt (1983) has observed a number of stars near celestial equator which have precise (better than 0.00 mag) photometric data as well as have a large spread in colour and are therefore ideal for calibrating a photometric system. We have observed a total of 38 stars out of the Landolt's list on four nights 1990 Sep. 23, Sep. 26, Oct. 13 and Dec. 22. The stars observed by us have a large colour range (-0.24 mag $< B - V < 1.51$ mag). A few stars were observed on more than one night while one star (96-406) was observed on all the four nights. On the night of 1990 Dec. 22, we also observed the region of open cluster M67 earlier observed by Schild (1983). Table 1 lists Ladolt's stars observed by us. The

Table 1. Log of stars observed from the list of Landolt (1983).

Star No.	Nights on which observed (yr 1990)
93 101	Sep 23/24
93 103	Sep 23/24
93 241	Sep 23/24
93 317	Sep 23/24
93 326	Sep 23/24
93 332	Sep 23/24
93 333	Sep 23/24
93 424	Sep 23/24
94 242	Sep 26/27, Oct 13/14
94 308	Sep 26/27, Oct 13/14
94 342	Oct 13/14
94 702	Oct 13/14
95 52	Oct 13/14
95 96	Oct 13/14
95 236	Oct 13/14
96 36	Sep 23/24, Sep 26/27, Oct 13/14
96 83	Sep 23/24
96 180	Sep 23/24, Sep 26/27, Oct 13/14
96 235	Sep 23/24
96 393	Sep 23/24, Sep 26/27
96 405	Sep 23/24, Sep 26/27
96 406	Sep 23/24, Sep 26/27, Oct 13/14, Dec 22/23
96 736	Sep 23/24, Sep 26/27
96 737	Sep 23/24, Sep 26/27
102 58	Dec 22/23
102 276	Dec 22/23
102 466	Dec 22/23
102 620	Dec 22/23
102 1081	Dec 22/23
103 302	Dec 22/23
103 462	Dec 22/23
−2 524	Sep 26/27
+5 2468	Dec 22/23
+5 2529	Dec 22/23
11983	Sep 23/24
12021	Sep 23/24
36395	Sep 26/27
100340	Dec 22/23

observations were carried out in U, B, V, R and I filters. The filter combinations for different pass bands used by us are as follows:

U UG1 (2mm) + 100% $CuSO_4$ solution (5mm)
B GG385 (2mm) + BG18 (1mm) + BG12 (1mm) + KG3 (2mm)
V GG495 (2mm) + BG18 (2mm) + KG3 (2mm)
R OG570 (2mm) + KG3 (2mm)
I RG9 (3mm)

A number of bias and dark frames were taken during each night. In each filter at least 5 flat frames were taken by observing the twilight sky. As the average seeing was approximately 2″ on all nights, all the observations have been taken by using a 2×2 binning of the CCD chip resulting in FWHM of approximately 3 pixels. This avoids oversampling of the data while processing the frames.

The data reduction has been carried out on the Micro-VAX II system of the Observatory. For image processing and steller photometry MIDAS and DAOPHOT software packages installed on the computer system have been used. The first step in image processing is to get a clean image. First an average bias frame was prepared. It was found that there was no difference in bias and dark frames of long exposures. Therefore in further analysis we have used only the average bias, neglecting dark frames. Flat frames in each filter corrected for the average bias were normalized and then master flat frame was prepared by averaging them. The program frames were flat fielded after subtracting the average bias. MIDAS package was used to carry out these operations.

After obtaining clean images we proceeded to do photometric measurements using DAOPHOT package. In case of frames having standard stars observations, only aperture photometry for the stars was carried out as these were bright isolated stars. For the frames of M67, the magnitudes have been obtained through profile fitting photometry.

3. Discussion

To determine the transformation coefficients, instrumental magnitudes were plotted against standard magnitudes for each night. The coefficients were then obtained through linear least squares solution. The coefficients thus obtained have been listed in table 2. It

Table 2. Transformation coefficients obtained on different nights

Night	$U-B$	$B-V$	$V-R$	$R-I$	$V-v$
1990 Sep 23/24	0.924 − 1.492	1.197 − 1.110	0.905 − 0.788	1.025 + 0.698	−0.014 + 18.869
	±.019 ±.044	±.012 ±.018	±.014 ±.018	±.017 ±.007	±.010 ±.009
Sep 26/27	0.928 − 1.227	1.196 − 0.941	0.886 − 0.724	1.022 + 0.827	−0.017 + 19.095
	±.009 ±.018	±.010 ±.013	±.018 ±.024	±.015 ±.008	±.004 ±.003
Oct 13/14	0.930 − 1.152	1.190 − 0.950	0.912 − 0.748	1.010 + 0.770	−0.013 + 19.076
	±.017 ±.019	±.013 ±.018	±.014 ±.013	±.019 ±.010	±.011 ±.008
Dec 22/23	0.912 − 1.438	1.205 − 1.026	0.910 − 0.793	1.019 + 0.756	−0.030 + 4.701
	±.007 ±.014	±.010 ±.013	±.009 ±.011	±.011 ±.006	±.005 ±.004

is evident from table 2 that the primary transformation coefficients are almost the same for all the nights. We have observed one star (star no. 96-406) of the Landolt's list on all the four nights. Therefore, we have determined the differential magnitudes for each night with respect to this star. The transformation coefficients have been determined using a linear least squares fit (figure 1). The transformation coefficients thus obtained are:

$$\Delta(U-B) = 0.918 \pm .008 \qquad \Delta(u-b) + 0.026 \pm .006$$

$$\Delta(B-V) = 1.192 \pm .007 \qquad \Delta(b-v) + 0.008 \pm .003$$

$$\Delta(V-R) = 0.898 \pm .007 \qquad \Delta(v-r) - 0.008 \pm .003$$

$$\Delta(R-I) = 1.016 \pm .008 \qquad \Delta(r-i) - 0.007 \pm .003$$

$$\Delta(V-v) = -0.018 \pm .006 \qquad \Delta(B-V) + 0.012 \pm .004$$

We have further checked the validity of these transformation coefficients by making an independent determination of these with our observations of 11 stars in the region of M67 for which the photometric data have also been obtained by Schild (1983). In figure 2, we have plotted these instrumental magnitudes versus magnitudes given by Schild (1983). The ($U|B$) magnitudes have been taken from Eggen (1964). The coefficients have been obtained through a linear least squares fit and the fit obtained has also been plotted in figure 2. The coefficients obtained are:

$$(U-B) = 0.896 \pm .019 \qquad (u-b) - 1.479 \pm .038$$

$$(B-V) = 1.203 \pm .016 \qquad (b-v) - 1.109 \pm .023$$

$$(V-R) = 0.889 \pm .018 \qquad (v-r) - 0.805 \pm .023$$

$$(R-I) = 1.057 \pm .050 \qquad \Delta(r-i) + 0.750 \pm .020$$

$$(V-v) = -0.023 \pm .019 \qquad \Delta(B-V) - 4.696 \pm .013$$

Table 3. Standard deviations obtained for Landolt's and M67 stars

	Landolt stars		M67 stars	
Colour	S.D.	N	S.D.	N
V	0.019	49	0.020	11
$B-V$	0.019	48	0.014	11
$U-B$	0.038	47	0.034	11
$V-R$	0.013	44	0.011	11
$R-I$	0.014	44	0.023	11

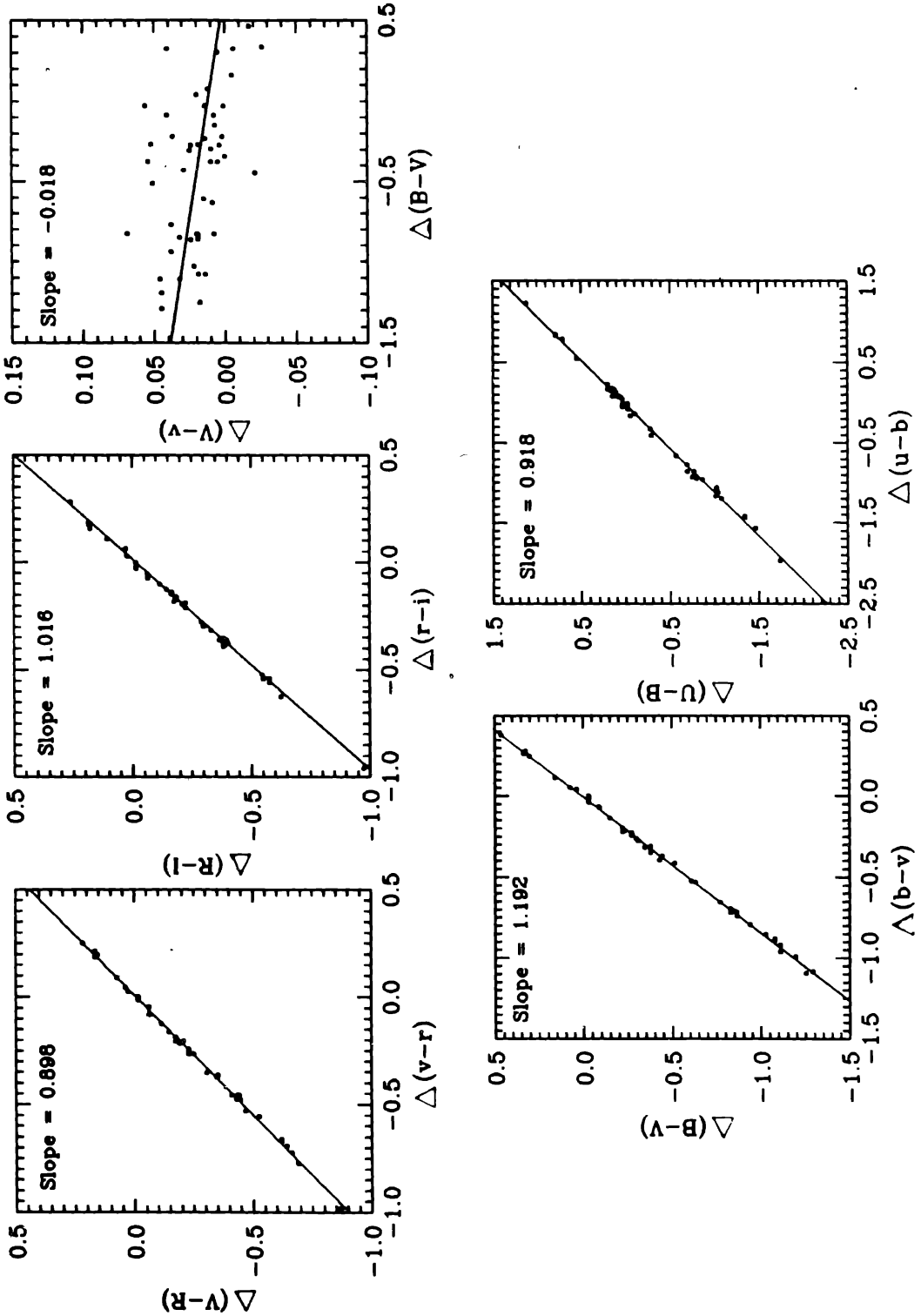

Figure 1. Plot of differential instrumental magnitudes vs. differential standard magnitudes for Landolt's stars.

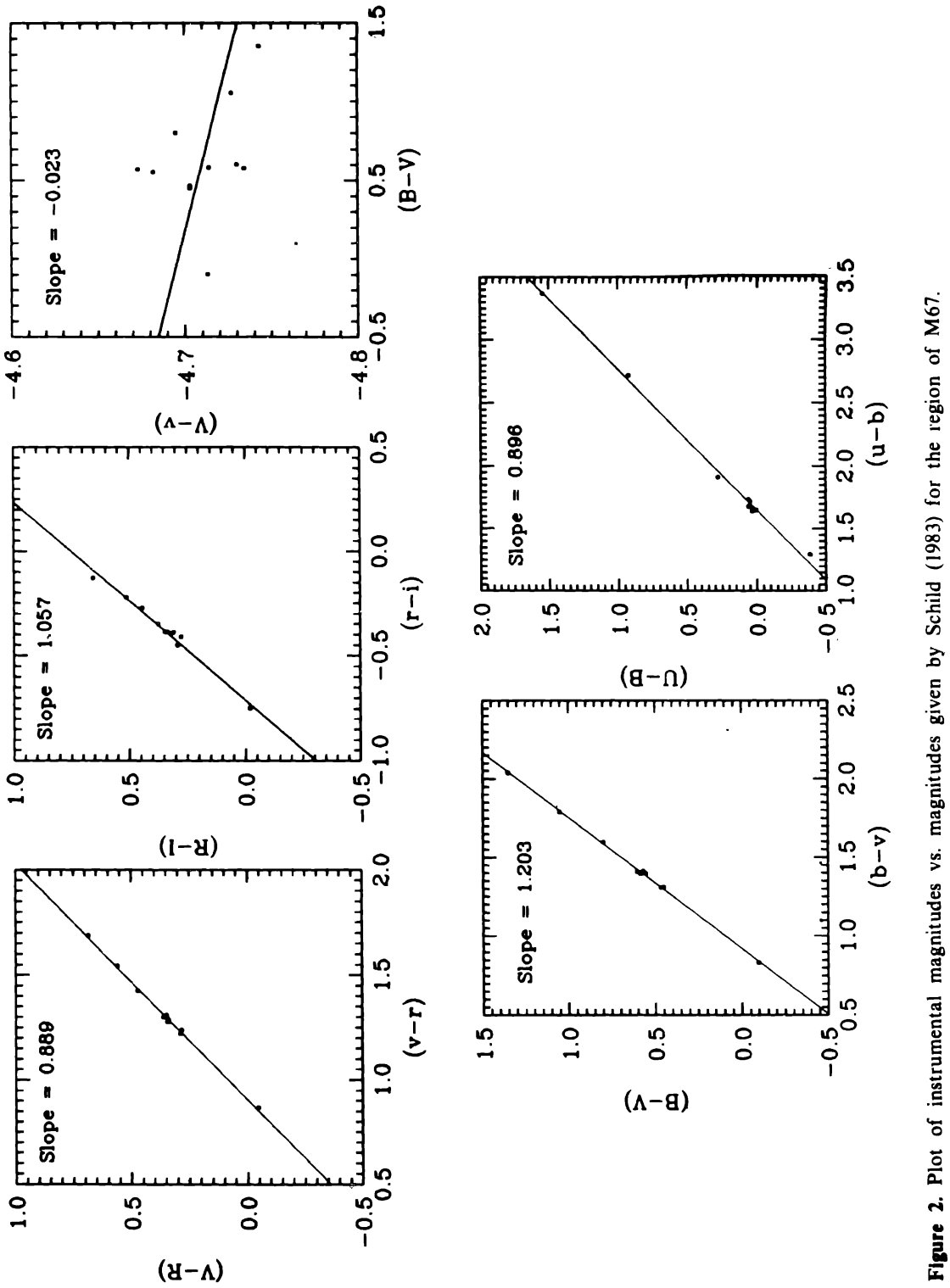

Figure 2. Plot of instrumental magnitudes vs. magnitudes given by Schild (1983) for the region of M67.

A comparison of these coefficients with those obtained through Landolt's stars reveals that the coefficients are in good agreement.

The transformation coefficients thus obtained have been used to determine the magnitudes and colours of Landolt's stars and the stars in the region of M67. The standard deviation of the residuals for different colours are given in table 3.

4. Conclusion

We have obtained photometric transformation coefficients for the UPSO CCD system. The coefficients have been determined by observing a number of standard stars having a large colour range from the list of Landolt (1983) and Schild (1983), on four different nights spread over a period of about three months. The coefficients obtained on all the four nights are in good agreement.

References

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