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WIDE-FIELD STELLAR PHOTOMETRY WITH THE 50/70 cm SCHMIDT TELESCOPE OF NAO ROZHEN

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Abstract. We used observations of Stetson standard photometric field L104 obtained in V-band with the 50/70-cm Schmidt telescope at NAO Rozhen on March 17-18, 2012, in order to check the FWHM, the ellipticity and the position angle of the stellar profile as a function of its position over the studied area of view for different altitude of the telescope pointing. A misalignment between the center of used CCD camera and the optical axis of the telescope is clearly demonstrated via image profile degradation over large area of the detector. Systematic changes of the image profile FWHM and its orientation, probably due to the tension of the telescope tubus before and after the culmination are also seen. Estimated color terms are ~ 0.15 mag while the residual radial dependence is smaller than 0.04 mag within the region of unbiased profiles.

1. INTRODUCTION

Schmidt telescope at NAO Rozhen has 70 cm spherical mirror and 50 cm corrector plate. The focal length is 172 cm. Since 2009 the telescope is equipped with FLI PL 16803 CCD camera with 4096 x 4096 pixels with 9x9 μm size and image scale of 1.08 arcsec/px. This gives field of view 73.6 x 73.6 arcmin^2. The reader is redirected to the manuscript from Markishki (2009) for more detailed information about the telescope design.

Wide field imaging with such a telescope imposes tight requirements to the optics in order to perform accurate photometry. Varying scale factor, misalignment between the detector and the optical axis, tubus tension when telescope is pointing towards different altitudes above the horizon may lead to a significant focus gradient. Thus, the derived stellar magnitudes are subject to spatially dependent systematic errors - a problem already established for images taken with the 2-m telescope of NAO Rozhen (Markov, 2005ab).

In this paper we combine both qualitative and quantitative approach in order to study stellar profile degradation over the detector area.

2. OBSERVATIONS AND DATA REDUCTION

Standard Stetson field L104 with RA(J2000)=12:42:19.4 and DEC(J2000)=-00:34:36 is very suitable target for our study because its size of 88.7 x 58.0 arcmin^2 is comparable to Schmidt field of view and contains 728 stars with known magnitudes in V-band. Observations were carried out on March 17-18 2012 with the 50/70-cm Schmidt telescope at NAO Rozhen.

We took images three times per night: before, during culmination and after that in order to study the effect of telescope position on stellar profiles and photometry. In every run, we took short and long exposure only in V-band. Observing log is presented in Table 1.

Table 1: Observing log

Date yyyy-mm-dd	Hour UT	Exposure sec	Altitude deg	$< FWHM >$ arcsec
2012-03-17	20:48:06	30	37	2.5
2012-03-17	20:58:14	300	37	2.5
2012-03-17	23:21:35	30	47	2.1
2012-03-17	23:22:58	300	47	2.1
2012-03-18	01:41:51	300	37	2.5
2012-03-18	01:48:03	30	37	2.5
2012-03-18	20:03:42	30	30	2.7
2012-03-18	20:14:07	300	30	2.7
2012-03-18	23:21:50	30	47	2.1
2012-03-18	23:36:53	300	47	2.1
2012-03-19	02:18:32	300	30	2.5
2012-03-19	02:25:02	30	30	2.5

The initial reduction was made with standard IRAF routines and includes dark current and flatfield corrections. DAOFIND task found all stellar-like objects in the observed fields and PSFMEASURE was used to determine individual FWHM, ellipticity and orientation of the stellar profile as a function of its position over the detector. In total, we measured 1727, 1996, and 1698 stars on the 300 sec exposures, taken in the three positions of the telescope. We choose to work with images, take on March 18 2012, because the pointings of the telescope are most distant. Aperture photometry was performed for all objects in the three positions of the telescope using PHOT/APPHOT routine. After that, a cross-identification with Stetson standard stars was made and standard V-magnitude was attributed to $\sim$ 450 stars on each image.

3. RESULTS AND DISCUSSION

We started with the spatial variations of image profile width. In Figure 1 (left panels) we plotted FWHM vs. radial distance for all detected stellar-like objects ($\approx$ 2000 in total). Irrespectively to the altitude, the samples can be divided into two subsamples: one - with a normal, and the another - with deviating, bigger FWHM.

We will refer them as sample with normal and biased FWHM. Another striking difference emerges - the mean values of the normal FWHM at culmination are rather smaller (~ 2.1 arcsec) than before (~ 2.7 arcsec) and after (~ 2.5 arcsec) the culmination. In order to distinguish between the samples with normal and biased FWHM we tentatively put a single value discriminator, equal to 3.0, 2.5 and 2.7 arcsec for the telescope pointing before, at, and after the culmination and plotted the sample with biased FWHM on the same figure (right panels). As one can sees immediately, the sample with the biased FWHM has an inhomogeneous spatial distribution over the detector, covering $\approx 30\%$ of total area.

Contrary to that, the sample with normal FWHM, not shown there for clarity, populate the shifted void on each image. The offset is ~ 4 arcmin in R.A. and ~ 15 arcmin in DEC. This spatial distribution is stable in time and we attribute this to a misalignment of the detector center from the optical axis of the telescope. Defocusing of the telescope at lower altitudes can be due to the changes of the seeing quality during the night, which does not seem to be the case, and both to the tension of the telescope tubus and the higher refraction closer to the horizon. It will be check in a forthcoming paper.

Later on, we continue with a study of the sample of cross-identified standard stars with unbiased FWHM and restricted it to stars with standard V magnitudes between 12 and 17.5 magnitudes in order to avoid significant aperture corrections for the brighter stars and to account only for the most accurate standards on the other side.

In Figure 2, the objects position angle is shown at right as a function of image polar angle, and at left - as a function of image profile ellipticity. Here we took the position angles and ellipticities derived within $2 \times FWHM$ in order to be more sensitive to the periphery of the image profile. Neither the position angles, nor ellipticities, which are mostly within 20%, are radially dependent. As expected, the position angle and the ellipticity of the stellar profile are only weakly, if at all, correlated. However, there is an obvious symmetrical change of the position angle of the stellar profile from positive ($\approx 10°$ on average) to negative ($\approx -10°$ on average) values when altitude varies, being $\approx 0°$ during the culmination. It could be explained with a symmetrical tension of the telescope tubus before and after the culmination.

At last, as shown in Figure 3, we performed a comparison between our V-band photometry, after accounting for the color term, and that of Stetson (2012). It was found that zero-point of the photometry varies with altitude, being largest at the culmination due to the lowest atmospheric extinction. Unlike it, the color term coefficient is rather constant (~ -0.1) resulting in a correction of 0.15 mag for the reddest stars. The left panels in the figure demonstrate the lack of color dependence, after accounting for the color term, while the right panels hint a small residual radial trend, less than 0.04 mag, within distances of 1500 px from the center. The possible simultaneous correction of the instrumental magnitudes for the color and the radial terms will be considered in a forthcoming paper.

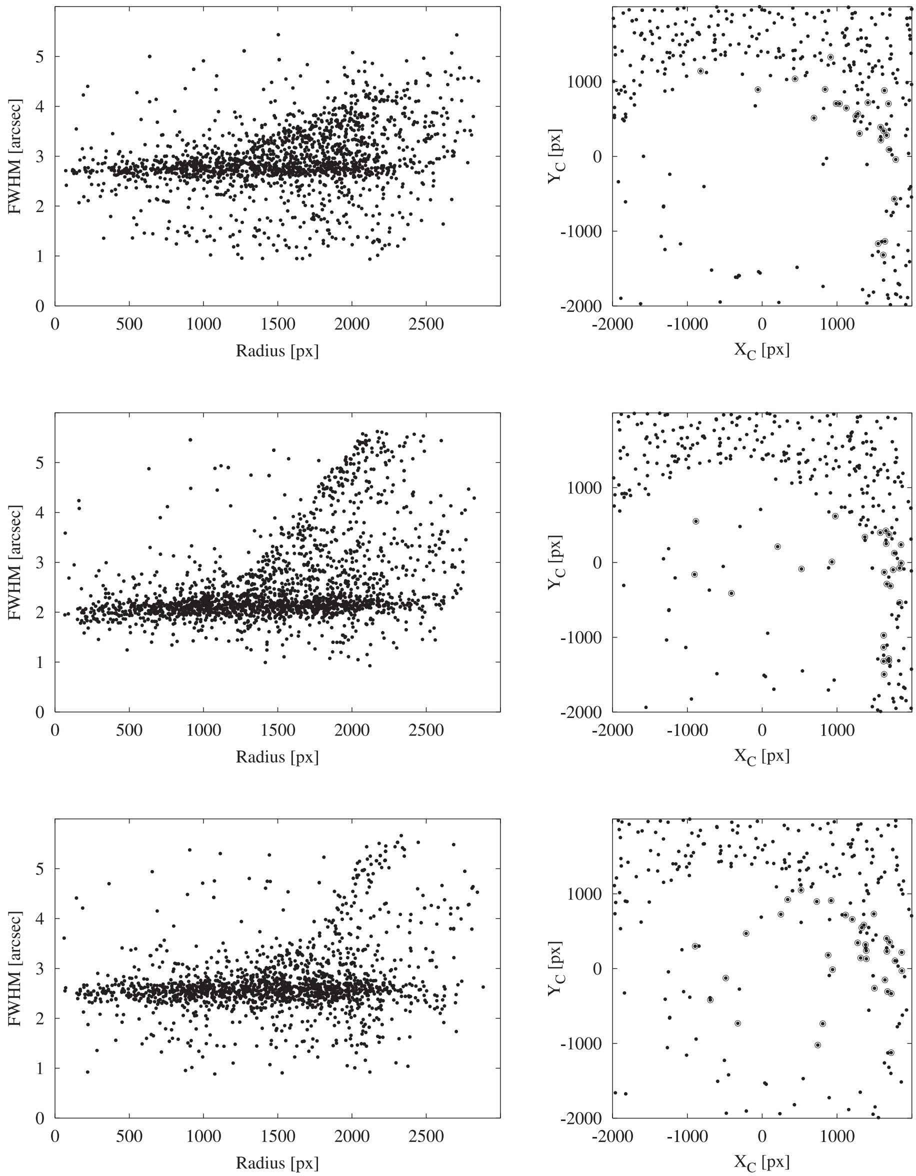

Figure 1: Variations of the FWHM of all detected stellar-like objects as a function of the radial distance (left panels) and the location of the outliers (with FWHM above the main cloud on the left panels) on image plane (right panels) relative to the center for different telescope altitudes 30° before (upper panes), 47° at (middle panels) and 30° after (lower panels) the culmination. Note, the smallest FWHM at the culmination. Only a few cross-identified standard stars, depicted with extra open circles, are outliers. The bulk of rest $\sim$ 400 standard stars with unbiased FWHM populate the shifted void on each image due to an offset of the detector center from the optical axis of the telescope.

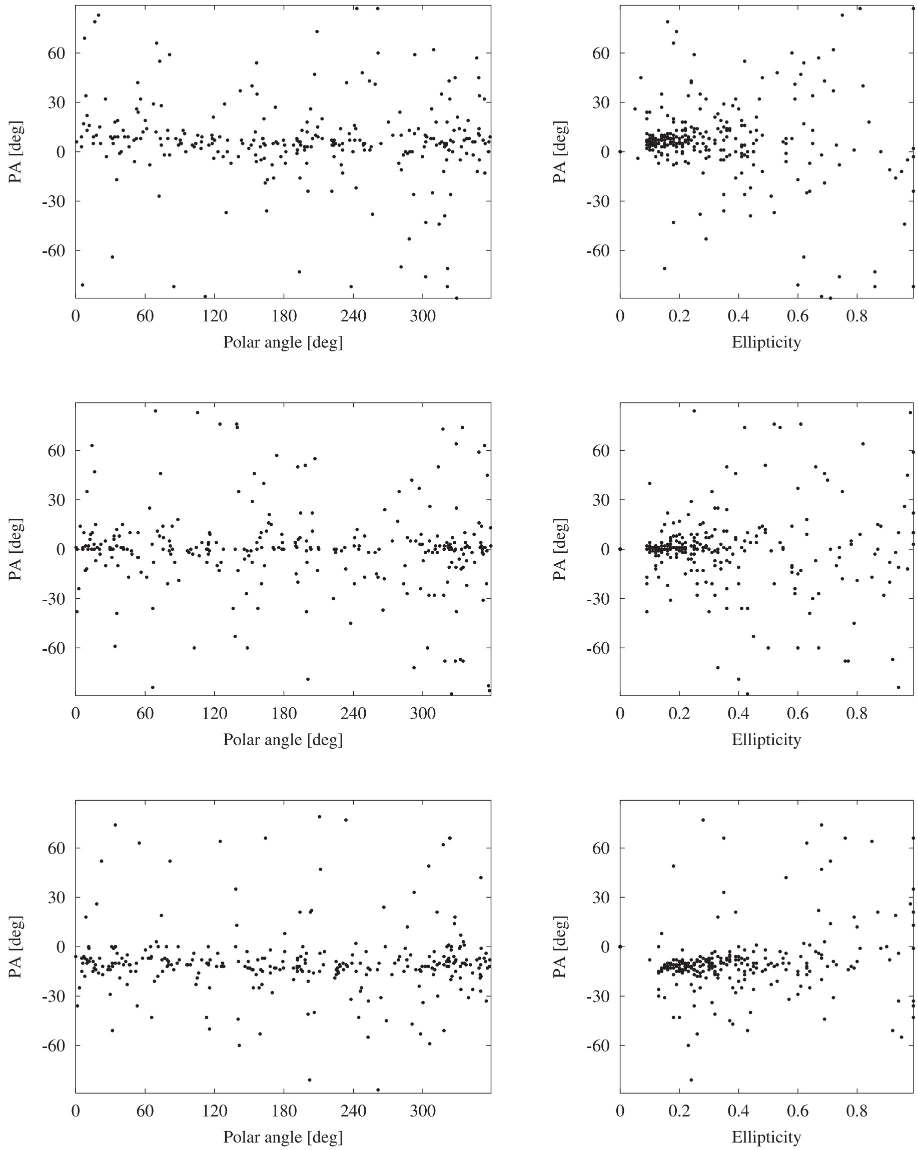

Figure 2: Position angle of the cross-identified standard stars with unbiased FWHM as a function of the object polar angle (left panels) and the stellar profile ellipticity (right panels) for different telescope altitudes: 30° before (upper panes), 47° at (middle panels) and 30° after (lower panels) the culmination. Note the reorientation of the stellar profile from positive ($\sim 10°$ on average) to negative ($\sim -10°$ on average) position angle values when altitude varies. As expected, the position angle and the ellipticity of the stellar profiles are not correlated. In these plots we have restricted the sample to stars with standard V magnitudes between 12 and 17.5.

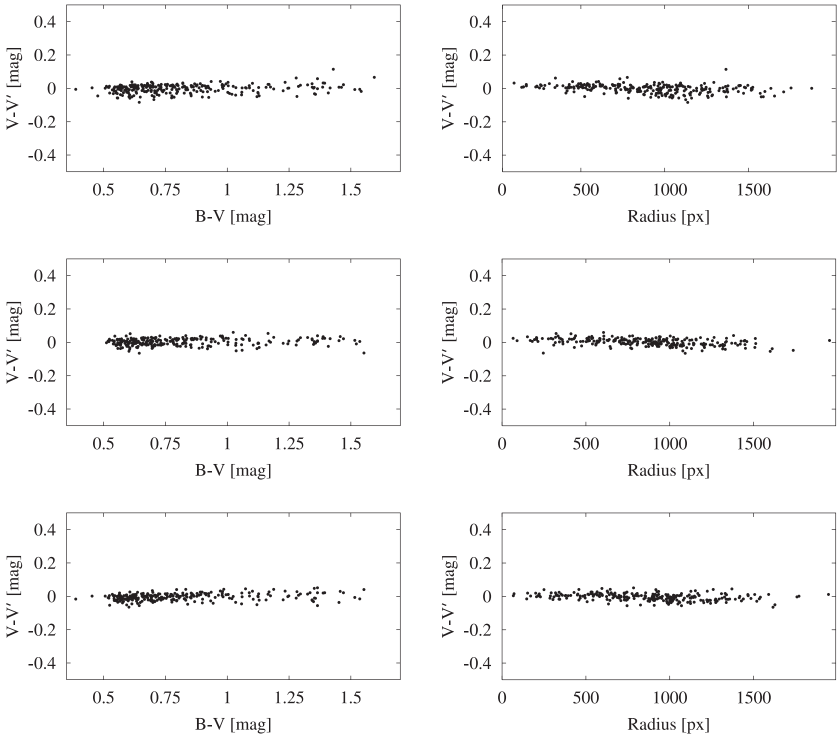

Figure 3: Comparison between our photometry V', after accounting for the color term, and that of Stetson et al. (2012) for the cross-identified standard stars with unbiased FWHM and standard V magnitudes between 12 and 17.5. The left panels demonstrate the lack of color dependence while right panels hint a residual radial trend less than 0.04 mag within distances of 1500 px from the center. Upper panels correspond to the telescope altitude of 30° before the culmination, middle panels – to 47° at culmination, and the lower ones – to 30° after the culmination.

4. CONCLUSIONS

In brief, we may conclude that:

There is yet a lot of mechanical work to be done in order to improve the focusing over the detector. First of all is to remove the offset between the center of CCD camera and the optical axis of the telescope and later - to check once again the perpendicularity between the optical axes and the detector.

Image profile quality (FWHM and PA) is a subject to systematic changes strongly dependent on the telescope pointing being smallest at culmination and increasing at lower altitudes. We attribute this effect to the tension of the telescope tube before and after the culmination.

Nevertheless, the residual radial dependence in magnitudes within the region of unbiased profiles is smaller than 0.04 mag.

Acknowledgements

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