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ACCURACY OF THE FIRST CCD DOUBLE STAR MEASUREMENTS MADE AT BELGRADE OBSERVATORY

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Abstract. Internal and external accuracies of our first double star observations made with a CCD ST-6 camera, attached to the Large Zeiss Refractor, are reported. The presentation includes also some notes and suggestions regarding the best use of the frames obtained.

1. INTRODUCTION

From October 1994 to August 1995 observations have been made of double stars using a CCD ST–6 camera, attached to the Large Zeiss Refractor (Popović, Pavlović, Trajkovska). The resolution of the CCD ST–6 camera is 375 × 242 pixels, with a rectangle pixelform. The scales was found to be (Pavlović, Popović, Živkov, 1996):

$$m_x = 0.4525 \pm 0.0021''/\text{pixel}, \qquad m_y = 0.5312 \pm 0.0025''/\text{pixel}.$$

A resolution like this one prevents on one hand the recording of close pairs and, on the other, achieving high quality results. Whereas th former problem could not be circumvented, the latter was overcome by using mean value of several exposures.

More than 100 double or multiple systems were recorded with upwards of 500 frames. The whole of the observational material has been measured by three authors (Popović, Pavlović, Živkov). The possibility was therefore at hand to acquire the first results indicating the accuracy of these measurements and, proceeding from them and the gained experience, to draw conclusions useful concerning the technique and the method of future measurements.

2. INTERNAL AND EXTERNAL ACCURACIES OF MEASUREMENTS

Disposable for analysis were mainly bright Struve's pairs or very faint and wide POP pairs. Both of them turned out to be helpful for deriving of specific conclusions regarding the measuring technique. Trails were made with the most differing exposure times, starting with 0.01 up to over 100 sec. The closest of the observed pairs had a separation of approximately $0''.7$ and the widest one about $100''$ ($120''$ being approximately the upper limit to measuring separation on one recording). Each one of the pairs was captured three times at the least.

Those pairs have been accepted for the evaluation of internal accuracy having at least 21 measurements, performed by three authors, everyone of them having quite independently decided which of the frames he was to measure. The authors chose the best frames and so it came out that one and the same frame was most often measured by three authors. In consequence of the fact that the measurements are not related to one and the same frame (but to a number of them which could, on account of different conditions prevailing at their taking up, be different), and also because the measurements were carried out by three observers, the internal accuracy obtained possesses a specific quality.

The errors have been determined by the relations of standard deviations

$$\sigma_\theta = \sqrt{\frac{\sum_{i=1}^{m}(\theta_{mean} - \theta_i)}{m-1}}, \quad \sigma_\rho = \sqrt{\frac{\sum_{i=1}^{m}(\rho_{mean} - \rho_i)}{m-1}}$$

where θ_{mean}, ρ_{mean} are aritmetical means of m measurements, σ_θ and σ_ρ being the internal error of measurements.

In Fig. 1 the standard deviation σ_θ is plotted as a function of ρ and in Fig. 2 the standard deviation σ_ρ as function of ρ.

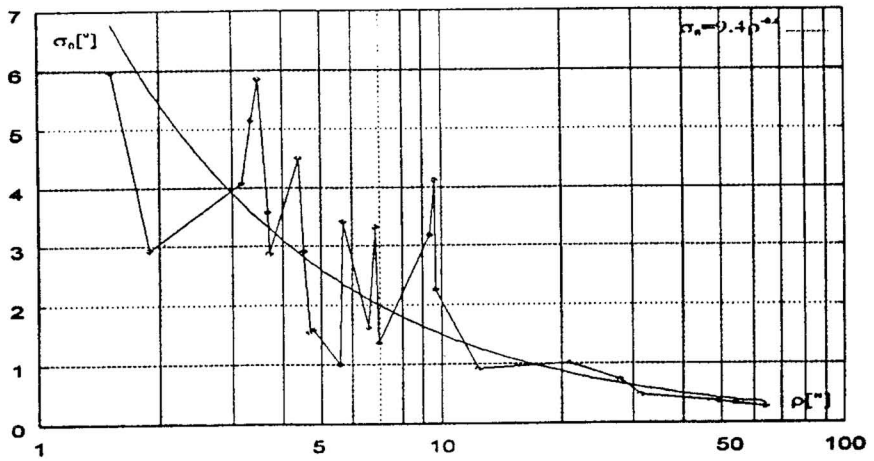

Fig. 1. σ_θ as function of ρ.

Larger deviations in the measurements both in ρ and particularly in θ, are evident in pairs closer than $10''$. The cause of this is to be sought in the first place in the low resolution of the camera used and in the changed mode measuring the position angle.

The setting of the marker on two close components, with the resolution of the camera being low, involves appreciable errors in the position angle. Therefore the mode of the position angle measuring as applied here should be changed for one similar to that employed in the visual measurements.

For the evaluation of the external accuracy we had a modest observational material. Comparison could be effected with 9 pairs only: 4 of them having known elliptical

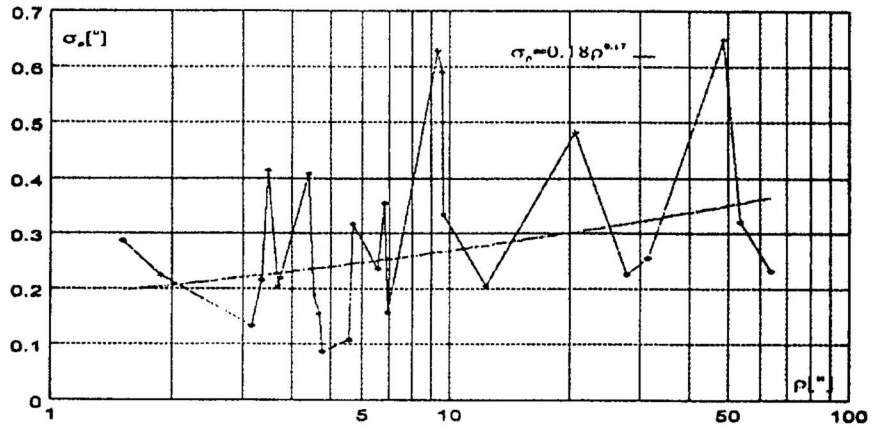

Fig. 2. σ_ρ as function of ρ.

orbits and 5 with rectilinear ones. Owing to this the evaluation of the external accuracy was accomplished by intermediary of direct deviations of our measurements from ephemeris one. Figs. 3 and 4 feature the deviations $(O-C)_\theta$ and $(O-C)_\rho$ from ρ, separately for individual observers and the deviations of the mean values for all three observers from corresponding ephemeris values. It may be perceived from Figures that our measurements are not burdened by systematic errors and that they are within the accuracy of the visual micrometric measurements.

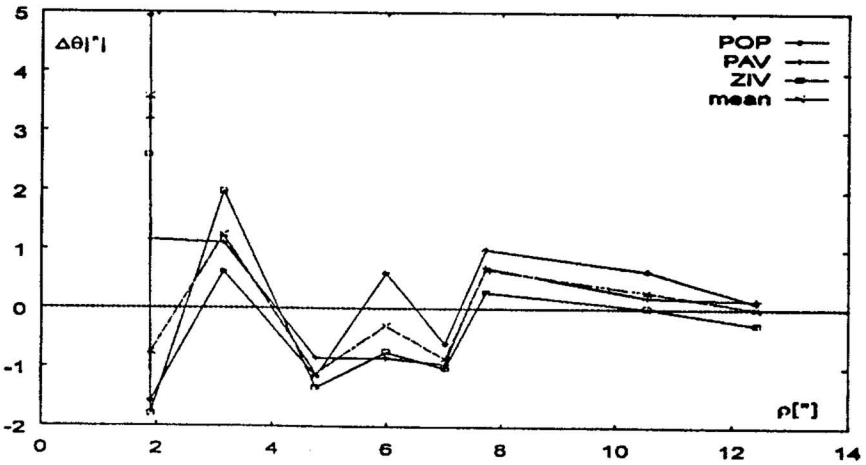

Fig. 3. $(O-C)_\theta$ as function of ρ.

For the pairs with $\rho > 2''$ the differences $(O-C)$ in θ and ρ are

$$(O-C)_\theta \sim \pm 1\overset{\circ}{.}0, \qquad (O-C)_\rho \sim \pm 0\overset{''}{.}1.$$

The measurements of close pairs $\rho \leq 2\overset{''}{.}0$ have considerably higher errors.

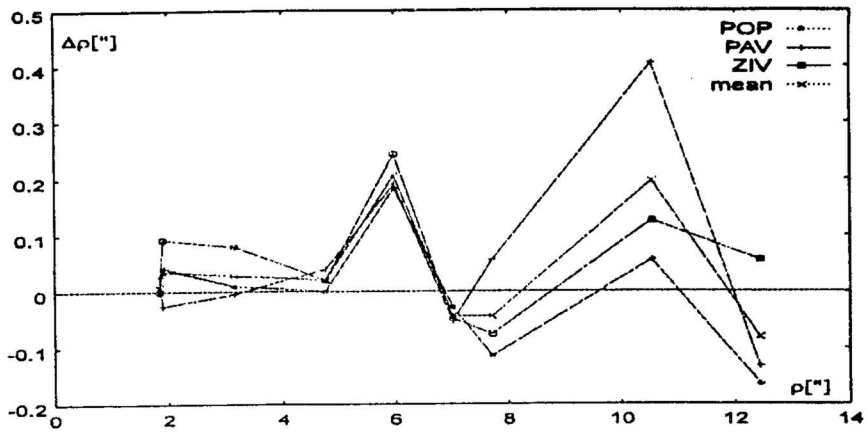

Fig. 4. $(O-C)_\rho$ as function of ρ.

3. CONCLUSIONS SUGGESTING THEMSELVES FROM THE MEASUREMENTS PERFORMED

Upon more than 500 measurements executed the following conclusions are arrived at:

- In wide pairs, in cases of perfect images, the geometric and photometric centers are coinciding. In the closer pairs an overlapping of two images may occur, producing a difference between the photo- and geometric centers. On the whole, the geometric centers yield better results.
- Irrespective of the image quality we deem it necessary to measure several frames, means value being adopted (especially for the pairs with $2'' \leq \rho \leq 10''$).
- The CCD ST-6 is a low resolution camera so that sometimes none of the marker's positions coincides with the star's image center. In such cases the interpolated positions were resorted to, which proved correct.
- Image magnification allows easier measuring and clearer separation of close components, yet not enhancing essentially the measuring accuracy. In our view one should not try more than two magnifications.
- In cases of setting the marker on one and then on the other component large errors in position angles are possible. More reliable seems to set the marker on the endings of the imagine line connecting the component's images.
- In consequence of the instrument's poor daily driving more than one image of the star may appear on frame. Hence it is possible to obtain several measuring from one frame. One should be careful about the exact identification of the components at measuring such frames.
- Occasionally the components images are distorted discordantly – the one in one direction, the other in other direction. This unusual appearance may cause considerable errors.If these images are measured it is better to use the geometric centers, rejecting the clearly outstanding photometric ones.

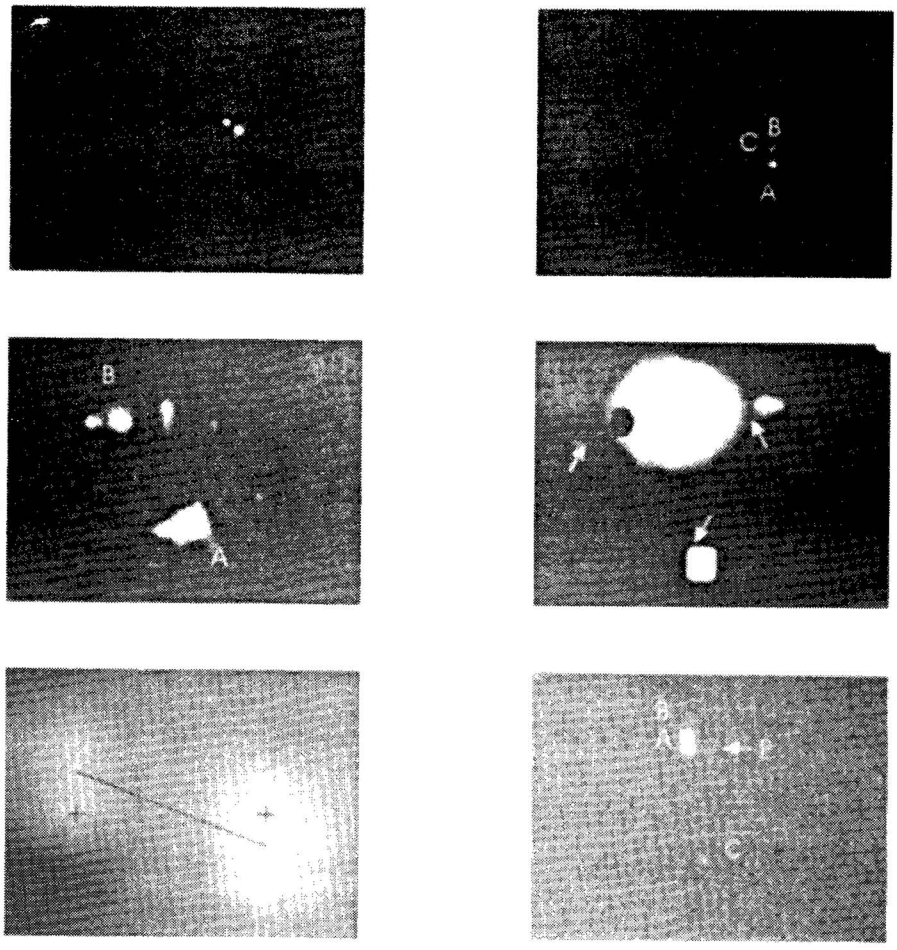

Fig. 5. a) A good image of a double star: ADS9979, $\rho = 7''.0$, $exp = 20^s$; b) The triple star: ADS10725, $\rho_{AB} = 8''.2$, $\rho_{BC} = 2''.2$, $exp = 20^s$; c) The multiple images as a consequence of a bad instrument tracking: POP203, $\rho = 3''.7$, $exp = 20^s$; d) The hot and cold pixels: ADS48A, $exp = 20^s$; e) The difference in positions geo– and photo– (+) center: ADS10460, $\rho \leq 1''.5$, $exp = 2^s$; f) The new component: ADS48P, $\rho_{AP} = 12''.5$, $exp = 20^s$

- A frequent occurrence on the frames are "hot pixels", which might be mistaken for star images. By perusing several frames a possible misidentifications is precluded.
- It is important to exactly identify the pair's position (according to well exposed or overexposed frames), using thereupon underexposed frames, discerning the poor component's images that could not be noticed without previous identification.
- Each component may be marked independently, by choosing optimal camera parameters, i.e. it is not obligatory for both components to be simultaneously visible at measuring.
- By good choice of camera parameters it is often possible to bring the overexposed frames to such a condition as to be acceptable to measuring.

- By good choice of camera parameters it is often possible to bring the overexposed frames to such a condition as to be acceptable to measuring.
- The attention at recording a double star is not to be attached solely to optimal exposure. It is useful to make frames with longer exposures than is required by the given pair, enabling thereby possible faint companions to be registered.

4. CONCLUSIONS

The accuracy obtained with the CCD ST–6 camera is not, in our judgement, higher than that of the visual observations. The advantage of this kind of observation is presented by the cabinet conditions of data handling whereby the work of the observer is substantially facilitated. Additionally, through the use of the camera the number of measured pairs is being increased by an order of magnitude.

Analyzing internal and external accuracies we can conclude as follows:

- ST–6 CCD is not suitable for measurements of the pairs with $\rho \leq 2$ arcsec.
- The pairs with $2 \leq \rho \leq 10$ arcsec can be measured with satisfactory accuracy. Although the internal errors are large the external accuracy is within the limits of micrometric measurements. Practically, the pairs in this field require more exposition and taking the mean values.
- The pairs in field $\rho \geq 10$ arcsec can be measured with high accuracy and it is not necessary to take more than 2 or 3 frames.

References

Santa Barbara Instrument Group: 1992, *Model ST-6 Professional CCD Imaging Camera*, Operating Manual.

Pavlović R., Popović G. M., Živkov V.: 1996, *this publication.*