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On the accuracy of the photographic measures of visual binaries made at Torino

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Summary. — In the present paper we analyse the distribution of the errors of 911 photographic measures of visual double stars made at the Astronomical Observatory of Torino during the period April 1976-June 1982.
By this study, a selection criteria for future programmes of observations can be deduced, in order to decide if the measures of a binary can be retained or rejected.
Futhermore a comparison about the precision of our measures with those obtained by the U.S. Naval Observatory of Washington is given.

Key words : visual binaries.

1. Introduction.

From April 1976, a selected programme of photographic observations of visual binaries, obtained by means of the 1050/9943 mm astrometric reflector (Armanelli *et al.*, 1978), is started at the Astronomical Observatory of Torino.

The main purpose of this research is the accurate determination of the astrometric parameters ρ and θ of wide pairs with separations between 2 and 10 arcsec and magnitude between 4 and 12 mag, in order to find with further observations if dark companions, perturbing the orbital motion of their visible components, exist in some systems.

The technique of observation and the reduction method, as reported in our previous papers (cf. Pannunzio and Siciliano, 1981) can be summarized as follows :

1) Kodak spectroscopic plates with emulsion type IIa-O and format (9 × 12 cm or 16 × 16 cm), are commonly used,

2) about 16-20 exposures followed by an orientation trail, are obtained for each plate,

3) three plates for each binary are usually taken,

4) all the measures of the X-Y coordinates are made with the same Zeiss measuring machine of our Observatory,

5) for each group of observations of the same binary, the seasonal weighted average values of ρ and θ are also found.

The research being still in progress, a study of the accuracy of the above mentioned measures seems advisable.

2. Analysis of the observational data.

The main purpose of this paper is to establish a general criterion of selection about the measures, in order to decide when they are to be retained or rejected. We shall adopt the rule of 3 sigma, related to the error distribution on a considerable sample of data, hypothesizing for them a gaussian representation.

The study of the accuracy of the double star measures is developed on a sample of observations made during the period April 1976-June 1982 (Armanelli *et al.*, 1978 and following).

The sample consists of 911 measures of separations and position angles of several binaries having at least two observations.

This study is conducted only on the separations because, as we have reported in our first paper (Armanelli *et al.*, 1978), the precision of the position angle measures, depends obviously on the separation of the double star, according to the theoretical curve :

$$\varepsilon_\theta = \text{arctg}\,(K/\rho)$$

where K is a constant.

Lower effects derive from other sources (film plate, plate holder, atmosphere, etc.).

Taking therefore into account the separation only, we have plotted in figure 1 the frequency distribution of the deviations of the observed values from its weighted average, for intervals of 0.010 arcsec.

We point out that the distribution of the figure has been obtained for the whole interval of observed separations.

No appreciable systematic effect is evident but, however a preliminary analysis of this diagram shows that the distribution can hardly be considered gaussian because the wings are too steep and the tails too long.

Indeed an analytical representation shows a best-fit gaussian curve completely inadequate for representing the data distribution, as the dashed line of figure demonstrates.

A tentative explanation of this result can be given considering a correlation between deviations and separations in the sense of increasing deviations for decreasing separations.

This would mean that the accuracy of the measures depends strongly on the distances between the binary components.

For this reason we plotted the absolute average values of the deviations against the separations, by steps of 0.020 arcsec (Fig. 2).

A decreasing trend is well evidenced in the range 2-8 arcsec, confirming the suggested hypothesis. The values of $\rho > 8$ arcsec in disagreement with the trend, are probably due to the small number of observations, as the respective large error bars indicate.

Considering this result, in order to eliminate the effect due to the separation, we should divide the sample in sub-samples for which the contribution of the separation is negligible.

In this way we should obtain different gaussian distributions and therefore different relative mean deviations σ_i, for each interval considered. The envelope of all these gaussian curves will give the anomalous distribution shown in figure 1.

Dividing the interval 2-8 arcsec in 6 groups of data (1 arcsec for each) we have seen that indeed the relative distribution trend, fits the gaussian one in a better way.

However we have to note that owing to the small number of data for each interval the influence of very few « bad » observations (due mainly to poor seeing nights) of lower quality, is highly significant for an exact definition of the gaussian parameters.

On the other hand we cannot enlarge the intervals because we have seen that 1 arcsec is just the limit for which the separation effect is still negligible.

We preferred therefore to disregard these few observations which characterize obviously the tails.

The best-fit gaussian curves give the requested values of σ_i, needed for the selection criterion.

These values do not differ significantly, even though a tendency towards lower σ_i values is seen for larger separations, as expected and shown in the table. The same table reports also the determination coefficient r^2, which helped us to establish the best gaussian fit.

For the practical purpose of the present work we can consider σ_i as a constant along the different ranges of separation, at least from 2 to 8 arcsec. Therefore it is reasonable to adopt the mean value $\overline{\sigma} = \frac{\Sigma \sigma_i}{6} = 0.026$ arcsec as a common value satisfying all the observational intervals. On the other hand this value of sigma can be considered as the average external mean error for a single plate.

Another purpose of this paper is to compare the accuracy of our measures with those obtained in other observatories.

For this reason we have completed the statistics finding the most representative internal error for a single image and for a single plate, both in separation and in position angle in order to compare our accuracies with those obtained at the U.S. Naval Observatory of Washington (hereafter we refer to it as U.S.N.O.).

We have chosen this Observatory because it has been strongly involved in this field of research for several years and also because it is engaged in the same programme of observation. It should give therefore an ideal sample of our test.

We remark that the comparison of our results with those of U.S.N.O. have been made adopting their procedure. In fact, in order to give the most representative internal and external errors of the measures, the median value instead of the arithmetical mean is reported. Furthermore in order to compare the precision of the separations with that of the position angles, the following transformation on this last value has been made :

$$\varepsilon_\theta = \varepsilon_{\theta^\circ} \rho'' \cdot \frac{\pi}{180^\circ}$$

where the errors in θ are expressed in arcsec.

On the basis of the previous considerations the study of the internal accuracy of our whole sample of measures gave the following results :

1) the median internal mean error for a single image is $+/- 0''.094$ in separation and $+/- 0''.081$ in position angle,

2) the median internal mean error (of the mean) for a single plate is $+/- 0''.021$ in separation and $+/- 0''.019$ in position angle.

On the other hand the accuracy obtained at the U.S.N.O., as reported in the last paper of Josties *et al.* (1978), can be summarized in the following points :

1) the median internal mean error for a single image is $+/- 0''.068$ for both coordinates,

2) the median internal mean error (of the mean) for a single plate is $+/- 0''.012$ for the separations and $+/- 0''.011$ for the position angle,

3) the median external mean error per plate is $+/- 0''.020$ in both coordinates.

We remember that the values reported in the three previous points are referred to those plates measured manually with the « MANN » Machine in order to compare similar techniques of measurement in both observatories.

3. Conclusions.

From the preceding results and considerations we can outline the following main points :

1) the distribution of the deviations for the whole sample of data cannot be considered gaussian, because of a strong dependence of this parameter on the separation. Marginally also the seeing conditions can affect the expected distributions, giving observations of lower accuracy, independently on the separation,

2) admitting this dependence on the separation, an analysis of several sub-samples of the data, obtained for intervals of 1 arcsec in separation gives σ_i values

comparable to each other, taking into account the practical purpose of the research.

We could therefore establish the following criterion of selection : the observations should be rejected, for each value of the separation, when their deviation from the average is larger than about 0".08. Observations performed on bad seeing nights should give, independently of the separation, low quality results probably outside the adopted limits;

3) comparing the internal accuracies obtained in both observatories we can deduce that the precision obtained at the U.S.N.O. is better than ours; this follows from practical reasons : the number of exposures on each plate and the number of measures on each image are greater than ours. Furthermore we have to note that our observations were made using a non-automatic camera and also the observations made with « bad » seeing conditions, were retained for the computation.

A confirmation of this last conclusion is given from the comparison of the external mean errors obtained in both observatories : the two external errors are similar (0".020 against our 0".026). This is due to the fact that the computation of this error have been obtained rejecting few observations performed in « bad » nights. The remaining small difference among these two errors depends probably either from the practical reasons mentioned at the beginning of point 3) or from the low number of seasonal plates taken for each binary.

However, even though the accuracy of our measures is lower than that obtained at the U.S.N.O., we think that it will be possible to improve the precision of our data, adopting an automatic camera, an automatic plate measuring machine and rejecting all the observations obtained in bad seeing nights.

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TABLE I.

ρ	σ	r^2
2" - 3"	0".026	0.861
3" - 4"	0".030	0.841
4" - 5"	0".030	0.735
5" - 6"	0".026	0.906
6" - 7"	0".022	0.755
7" - 8"	0".021	0.939

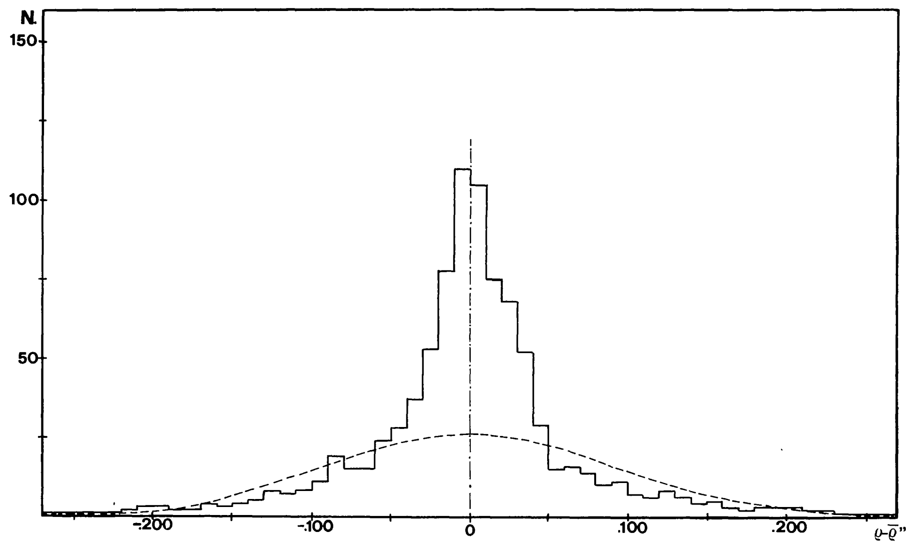

FIGURE 1. — Frequency distribution of the ρ deviations from their weighted mean values, by steps of 0.010 arcsec. The dashed line represents the best-fit gaussian curve.

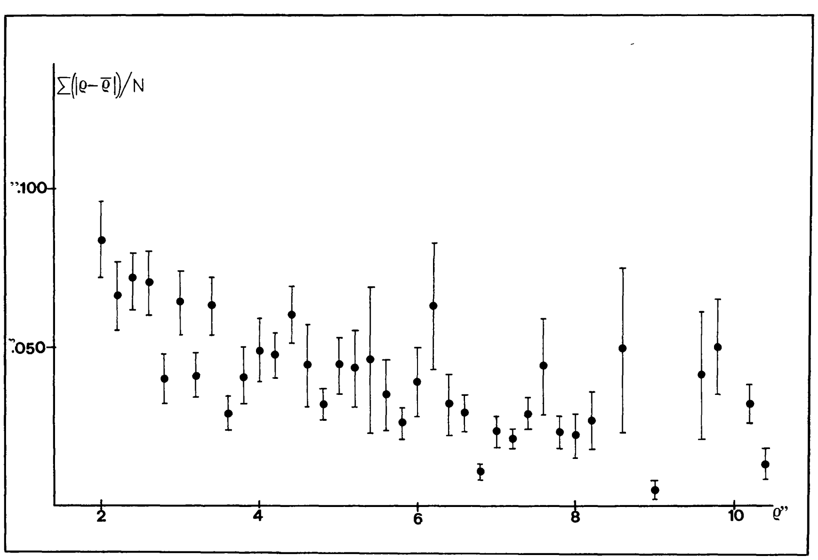

FIGURE 2. — Absolute average values of the ρ deviations against the separations, by steps of 0.020 arcsec.