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New Photographic Method for the Measurement of Visual Binaries

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Summary. Preliminary results of a new photographic method for the measurement of the visual double stars, are given.

This method, applied to four visual binaries, gives the parameters ϱ, θ, Δm deduced from the measurements taken on two pairs of trails, obtained by photographic observations using the slow motions of the telescope.

Key words: visual double stars – trails

1. Introduction

A new photographic method for observing visual double stars has been carried out with the 41-inch astrometric telescope ($f = 9943$ mm, scale value 20″.744 per mm) of the Observatory of Torino (Armanelli et al., 1978), with the collaboration of the Observatory of Brera for the reduction method.

This new method consists in the determination of the angular separation ϱ and the position angle θ of a double star from the measures taken on two pairs of photographic trails (Fig. 1), obtained by adequate slow motions in α and δ of the telescope.

Table 1, calibrated ... shows ... steps of speed.

With this method, the trails can be considered as an indefinite series of exposures (Pannunzio and Scardia, 1980).

The internal accuracy in ϱ and θ results to be increased by a factor four, and the external accuracy by a factor two (in separations) with good conditions of observation.

Essentially the technique of observation consists in the following points:

1. the slow motions of the telescope are operated so that the trails forming an angle α_0 between themselves (see Fig. 1),
2. each trail is oriented in order to approach the maximum separation of the components,
3. the length of the trails is about 4–5 cm to avoid coma,
4. the East-west direction is obtained stopping the telescope drive.

As comparison 16 multiple exposures of the binary have been taken on the same plate.

Several plates of a binary have been made during the same night, in order to verify the possible influence of different seeing conditions.

All the plates were measured with a two-coordinates measuring machine of the Observatory of Torino and with a microdensitometer PDS 1010 of the Astronomical Observatory of Naples.

With the PDS were measured 250 sections over each pairs of trails, using a slit of 5 × 200 μ with steps of scanning of 2 μ in X and 200 μ in Y. All the measures were reduced by means of the computer Digital PDP 11/34 and PDP 11/10 of the Observatories of Brera and Torino (Santin, 1980).

The first step is to measure the coordinates $X - Y$, by means of a measuring machine, of many points (20) taken on each trail (five trails at all).

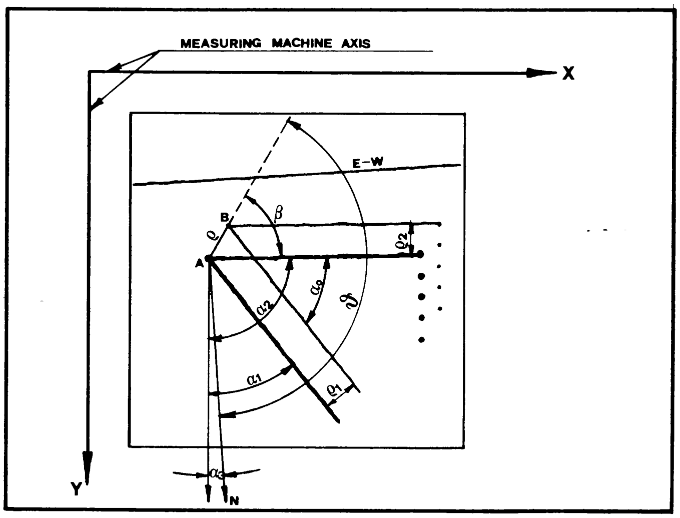

Fig. 1. Schematic representation of a photographic plate made with the method of the trails

Table 1.

Slow motions telescope	Magnitudes
45″/s	4th
30″/s	5th
15″/s	6th
7″.5/s	7th
3″.7/s	8th
1″.8/s	9th
0″.9/s	10th

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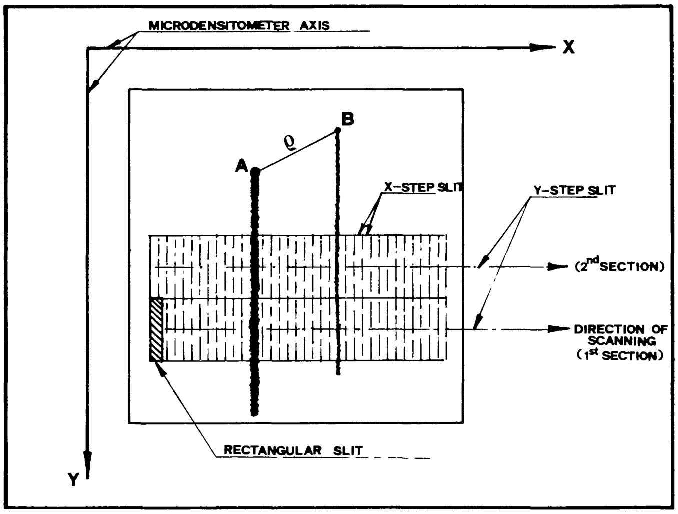

Fig. 2. Procedure of scanning over a pair of trails with the slit of the microdensitometer PDS 1010

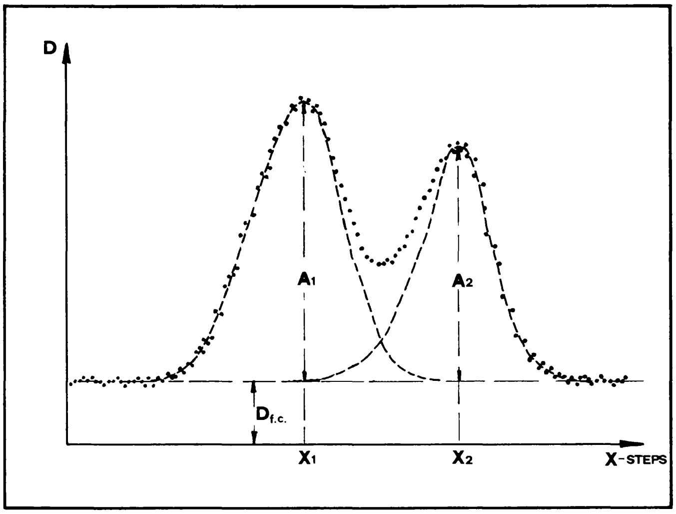

Fig. 3. Densitometric profile of a section of trails scanned with the PDS 1010

Table 2

1	2	3	4	5	6	7	8
			h m	" "	° °	" "	° °
ADS 9979	1	17-JUL-80	20:00			6.617 ± 0.019	232.85 ± 0.16
	2	4-SEP-80	20:00	6.630 ± 0.013	232.94 ± 0.10	6.601 ± 0.025	232.55 ± 0.04
	3	15-SEP-80	20:30	6.646 ± 0.006	232.44 ± 0.09	6.577 ± 0.033	232.68 ± 0.08
ADS 1500	4	1-OCT-80	24:30	3.524 ± 0.002	159.75 ± 0.06	3.546 ± 0.019	159.54 ± 0.19
	5	27-OCT-80	22:35	3.529 ± 0.003	159.87 ± 0.06	3.584 ± 0.019	158.86 ± 0.37
	6	28-OCT-80	22:30	3.480 ± 0.003	160.50 ± 0.07	3.596 ± 0.027	160.26 ± 0.31
	7	28-OCT-80	22:50	3.484 ± 0.003	160.25 ± 0.06	3.540 ± 0.019	159.21 ± 0.37
	8	30-OCT-80	22:30			3.589 ± 0.016	159.48 ± 0.27
	9	30-OCT-80	22:50			3.470 ± 0.035	158.40 ± 0.34
	10	9-DEC-80	20:30	3.427 ± 0.005	159.98 ± 0.13	3.528 ± 0.022	159.94 ± 0.30
	11	9-DEC-80	20:45	3.470 ± 0.005	159.01 ± 0.12	3.596 ± 0.018	160.13 ± 0.21
	12	9-DEC-80	21:10	3.445 ± 0.004	160.61 ± 0.11	3.495 ± 0.034	160.30 ± 0.42
	13	9-DEC-80	21:30	3.419 ± 0.005	156.56 ± 0.13	3.675 ± 0.029	159.38 ± 0.28
	14	17-DEC-80	20:45	3.452 ± 0.006	158.51 ± 0.17	3.492 ± 0.033	159.55 ± 0.38
	15	17-DEC-80	21:05	3.449 ± 0.009	160.25 ± 0.19	3.519 ± 0.034	159.09 ± 0.59
	16	17-DEC-80	21:25			3.479 ± 0.035	159.47 ± 0.55
ADS 3274	17	28-OCT-80	23:15	10.333 ± 0.007	309.10 ± 0.05	10.316 ± 0.020	307.98 ± 0.13
	18	30-OCT-80	23:15	10.331 ± 0.005	308.44 ± 0.04	10.290 ± 0.025	308.35 ± 0.12
	19	30-OCT-80	23:30	10.335 ± 0.005	308.32 ± 0.04	10.297 ± 0.017	308.06 ± 0.08
	20	9-DEC-80	22:00	10.323 ± 0.004	308.40 ± 0.03	10.273 ± 0.015	308.28 ± 0.11
	21	9-DEC-80	22:30	10.326 ± 0.003	308.57 ± 0.02	10.350 ± 0.035	308.17 ± 0.25
	22	9-DEC-80	22:45	10.330 ± 0.004	308.35 ± 0.03	10.313 ± 0.026	307.96 ± 0.10
	23	9-DEC-80	23:05	10.351 ± 0.004	308.59 ± 0.03	10.312 ± 0.014	308.31 ± 0.10
	24	17-DEC-80	21:50	10.307 ± 0.005	308.83 ± 0.04	10.301 ± 0.019	307.95 ± 0.09
	25	17-DEC-80	22:25	10.326 ± 0.004	308.81 ± 0.03	10.327 ± 0.024	307.84 ± 0.14
	26	17-DEC-80	22:06	10.337 ± 0.005	308.62 ± 0.04	10.328 ± 0.016	307.91 ± 0.12
ADS 4068	27	17-DEC-80	22:40	4.721 ± 0.003	207.80 ± 0.05	4.811 ± 0.022	205.62 ± 0.27
	28	17-DEC-80	22:53	4.730 ± 0.003	207.60 ± 0.06	4.799 ± 0.021	205.52 ± 0.24

A least squares method applied to the points measured on each trail (after the correction for the curvature effect depending on the declination of the stars) gives the fundamental angles $\alpha_1, \alpha_2, \alpha_3$ with respect to the instrumental axis of the measuring machine (see Fig. 1).

After this, the plate is measured with a microdensitometer PDS 1010, that scans automatically each pair of the trails by means of a rectangular slit of suitable dimensions.

The scanning is made perpendicularly to the trails with steps of two microns as shown in Fig. 2.

The information obtained from this scanning is a densitometric profile of one section of trails (see Fig. 3).

2. Reduction Method

An automatic procedure allows the registration of a considerable number of contiguous sections for the whole length of the trails (see Fig. 2).

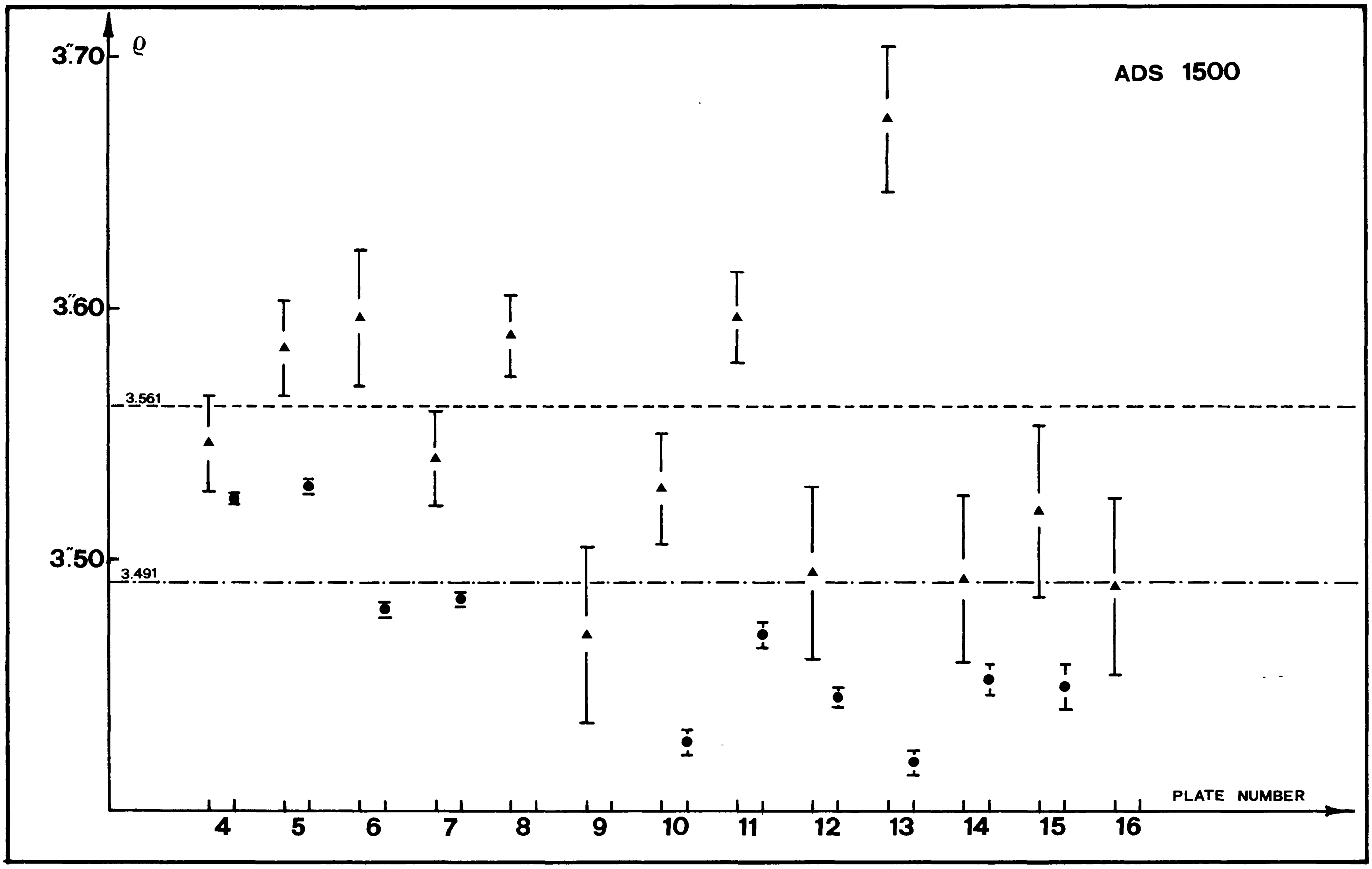

Fig. 4. Dispersion of the ϱ of the ADS 1500 around their weighted mean values for both methods, (▲) multiple exposures method, (●) trails method, (-----) weighted mean ϱ exposures method, (—·—·—) weighted mean ϱ trails method

Since the densitometric profile (Fig. 3) can be considered as the analytic sum of two gaussian functions:

$$D_i=\sum_{J=1}^{2} A_J e^{-H_J^2(X_i-\bar{X}_J)^2}+D_{\mathrm{F.C.}}$$

($i=1,n$; n = numb. of steps for each transverse section)

a least squares solution provides the values of the parameters A_1, A_2, H_1, H_2, $\bar{X}_1$, $\bar{X}_2$, $D_{\mathrm{F.C.}}$ relative to one section.

Repeating this procedure longitudinally, it is possible to find the mean separation of one pair of trails with its mean error by means of the well-known formulae:

$$\bar{\varrho}_1=\frac{\sum_{i=1}^{n}\varrho_{1,i}}{n} \qquad \varepsilon_{\bar{\varrho}1}=\left[\frac{\sum_{i=1}^{n}(\varrho_{1,i}-\bar{\varrho}_1)}{n(n-1)}\right]^{1/2}.$$

For the other pair of trails the technique of measure and reduction is the same as the previous one, obtaining $\bar{\varrho}_2$ and $\varepsilon_{\bar{\varrho}_2}$.

Finally the obtained values of $\bar{\varrho}_1$, $\bar{\varrho}_2$, and α_0 furnish the true separation by means of a generalized Carnot's formula:

$$\bar{\varrho}=\left[\frac{\bar{\varrho}_1^2+\bar{\varrho}_2^2-2\bar{\varrho}_1\bar{\varrho}_2\cos\alpha_0}{\sin^2\alpha_0}\right]^{1/2}.$$

Accordingly, the relative mean error is given by:

$$\varepsilon_{\bar{\varrho}}=\left[\left(\frac{\partial\bar{\varrho}}{\partial\bar{\varrho}_1}\right)^2\varepsilon_{\bar{\varrho}_1}^2+\left(\frac{\partial\bar{\varrho}}{\partial\bar{\varrho}_2}\right)^2\varepsilon_{\bar{\varrho}_2}^2+\left(\frac{\partial\bar{\varrho}}{\partial\alpha_0}\right)^2\varepsilon_{\alpha_0}^2\right]^{1/2}.$$

The position angle is computed from an algebraic combination of the angles α_2, α_3, β where β is given by the following formula (see Fig. 1):

$$\beta=\arcsin\left(\frac{\bar{\varrho}_2}{\bar{\varrho}}\right).$$

The mean error in the position angle is:

$$\varepsilon_\theta=[\varepsilon_{\alpha_2}^2+\varepsilon_{\alpha_3}^2+\varepsilon_\beta^2]^{1/2}.$$

A further improvement can be made taking into account the differential refraction.

3. First Results Obtained

For checking this new photographic method (28 plates) and comparing its results with those obtained by the multiple exposures method, four binary stars have been selected with different separations and magnitudes (Table 2).

The columns of this Table give the following values:

Column 1: ADS number of the double star
Column 2: plate number
Column 3: date of observation
Column 4: time of observation in U.T.
Column 5: $\bar{\varrho}$ and $\varepsilon_{\bar{\varrho}}$ obtained with the trails method
Column 6: $\bar{\theta}$ and $\varepsilon_{\bar{\theta}}$ obtained with the trails method
Column 7: $\bar{\varrho}$ and $\varepsilon_{\bar{\varrho}}$ obtained with the multiple exposures method

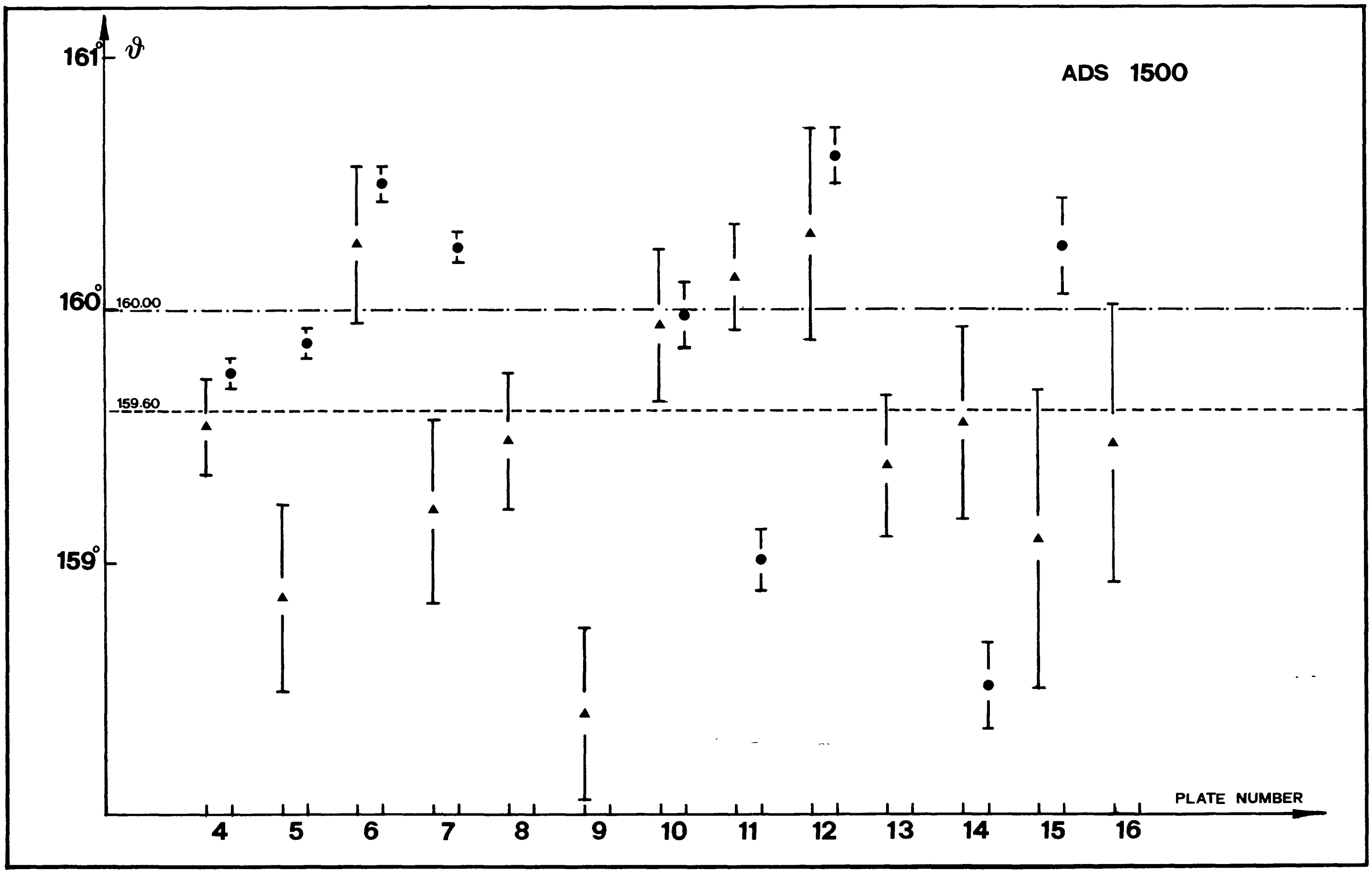

Fig. 5. Dispersion of the θ of the ADS 1500 around their weighted mean values for both methods., (▲) multiple exposures method, (●) trails method, (-----) weighted mean θ exposures method, (—·—·—) weighted mean θ trails method

Column 8: $\bar{\theta}$ and $\varepsilon_{\bar{\theta}}$ obtained with the multiple exposures method

The trails method can also provide the photographic difference of magnitude of the components, when the average curve of calibration of the plates Kodak IIa-O is adopted.

We obtain for ADS 1500 (9 plates):

$\Delta m_{\mathrm{ph.}} = 0.44 \pm 0.01$

and for ADS 3274 (10 plates):

$\Delta m_{\mathrm{ph.}} = 0.73 \pm 0.02$.

The results reported in Table 2 obtained by this method have an internal accuracy four time larger than that obtained with the traditional method.

Concerning the external accuracy, we have plotted for both methods the ϱ and θ values with their mean errors for ADS 1500 and ADS 3274. The dispersion around the weighted values of ϱ is always lower with this new method, particularly when the two components are not too close (Fig. 6).

The external accuracy in θ is of the same order for both methods (see Figs. 5 and 7).

The most important sources of inaccuracy are:

1. different seeing conditions on different nights,
2. differential refraction for each star depending on their colour,
3. photographic effects for very close binaries. In fact, for the ADS 1500 we have obtained a separation systematically smaller than that obtained with the usual method (Fig. 4). Probably, this systematic error depends on the above mentioned photographic effects, because the trails of this binary, in all the plates, were partially superimposed and not well clear,
4. not quite adequate reduction method.

Other possible errors might derive from:

1. plate exposed out of focus,
2. incorrect scale value of the telescope,
3. incorrect orientation of the trails compared with the scanning of PDS slit,
4. trails curvature,
5. differential coma,
6. thermal distorsion of the plate between the observation and reduction.

However, all these last errors are less than 0″.002 and hence negligible, when the separation is less than 10″.

4. Conclusion

For astrometric purposes the method of the trails may be an excellent method for double stars with separations included between 2″ and 10″ and stars not fainter than 10^{m} when the astrometric reflector of the Observatory of Torino is employed.

It appears as a good alternative method with respect the usual photographic one, for the following reasons:

1. the reduction method is automatic and hence the measures are objective,

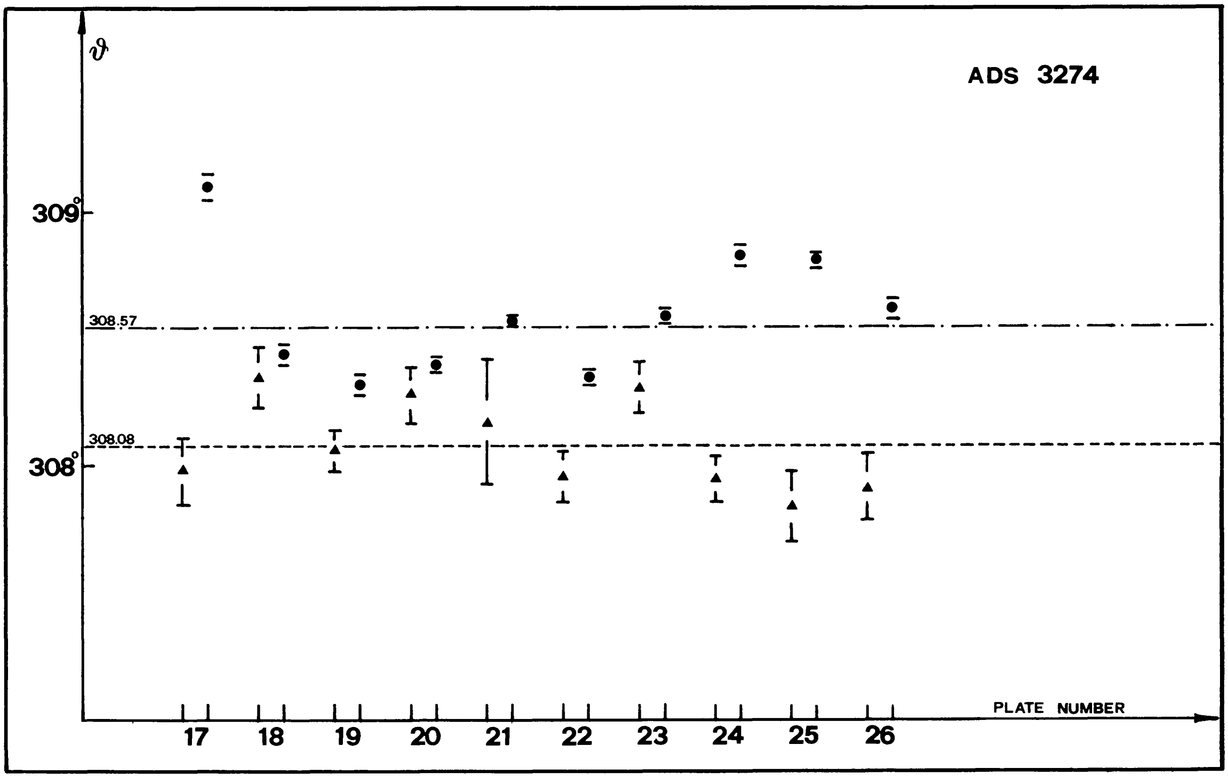

Fig. 6. Dispersion of the ϱ of the ADS 3274 around their weighted mean values for both methods, (▲) multiple exposures method, (●) trails method, (-----) weighted mean ϱ exposures method, (—·—·—) weighted mean ϱ trails method

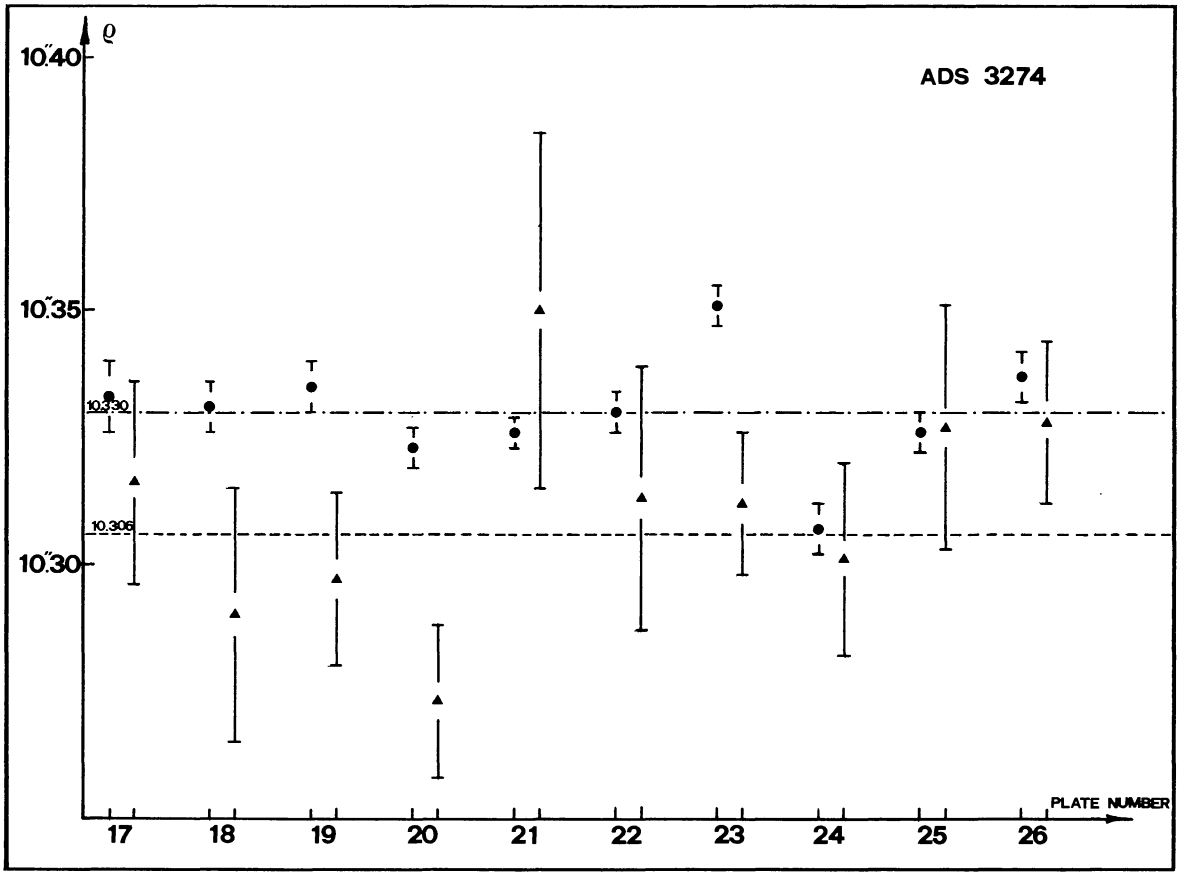

Fig. 7. Dispersion of the θ of the ADS 3274 around their weighted mean values for both methods, (▲) multiple exposures method, (●) trails method, (-----) weighted mean θ exposures method, (—·—·—) weighted mean θ trails method

2. the method gives also informations with not corrected expositions.

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