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COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN.

The latitudes of Jupiter's Satellites derived from photographic plates taken at the Royal Observatory, Greenwich, in the years 1918—19, by *W. de Sitter* and *G. Pels*.

The plates taken at Greenwich at the epoch 1919·0 were intended to be used not only for the determination of the longitudes, but also of the latitudes of the satellites. For this purpose the orientation of the plate must be known very accurately. The standard stars photographed on the plates were observed with the $10\frac{1}{2}$-inch equatorial and Repsold micrometer at Leiden by Mr. VAN DEN BOS on six nights in March 1922. From these measures he found for the difference of declination for 1922·0

$$115''\cdot15 \pm 0''\cdot07$$

The corresponding probable error of the position angle of the standard stars is ± 3″. The difference of declination derived from various sources, and referred to the equinox 1875·0, was found to be:

1858·2	Bonn VI	131″·66
1880·6	A. G. Berlin B	130 ·8
1914·5	Abbadia	131 ·92
1922·2	Leiden (micr.)	131 ·80

It was accordingly assumed that the relative proper motion in declination of the two stars during the interval between the epoch of the observations (1919·0) and that of the micrometrical measures (1922·2) is negligible. The adopted distance and position angle of the stars for 1919·0 have already been given in *B. A. N.* **61**, p. 144.

In addition to the standard stars a second determination of the orientation is derived from interrupted trails or exposures of Jupiter and its satellites. In some of the photographs Jupiter was set about 25′ on the preceding side, the arc was put out and Jupiter trailed. The plate was thus exposed for 10 seconds and then covered. When Jupiter reached 25′ on the other side the plate was again exposed for 10 seconds. On later plates the arc was put out *after* the first 10 seconds exposure and put in again for the second 10 seconds exposure, the short trails being thus replaced by ordinary exposures. The first method was used for the plates 6316, 6317, 6318, 6323, but it was found that the trails of the satellites were invisible, or so faint as to be immeasurable, on these plates.

For the measures of the y-coordinates the reading of the position circle of the measuring apparatus should be $P_0' = P_a' + 90° + K$, where $P_a' + 90°$ is the apparent position angle of the great circle perpendicular to the adopted axis of y, and K is the index-error as determined from the standard stars or from the trails *). If the actual reading of the circle is P_0, then the measured values of y require the correction

$$\delta y = -x\Delta P,$$

where $\Delta P = P_0 - P_0'$

The correction for refraction and aberration is, in this case,

$$\delta y = (A' + C)y$$

as has been explained in *B. A. N.* **50**, p. 63.

This correction was applied by combining it with the correction for scale value, which is of the same form.

The index error K is determined from the standard stars by measuring the difference $A - B$ of the x-coordinates of the two stars, A being the preceding star, when the position circle reads P_{AB}. We then have

$$K_* = P'_* - P_*, \qquad P_*' = P_{AB} + \frac{A-B}{s},$$

P_* being the apparent position angle of the stars. The correction for equatorial adjustment of the telescope can be neglected.

For the trails the difference of the x-coordinates $A - B$ of the two short exposures is measured and we have

$$K_t = P_t' - P_t \qquad P_t' = P_{AB} + \frac{A-B}{\Delta},$$

where P_{AB} now is the reading of the position circle

*) For convenience we continue to speak of "trails", meaning the short exposures for orientation, as explained above.

during the measurement of the difference $A - B$, Δ is the distance between the two exposures A and B, and P_t is the apparent position angle, i. e.

$$P_t = 90^\circ + R + S + C,$$

R being the correction for refraction, S the correction for the motion of the satellite in declination during the interval between the two exposures (i. e. the motion of Jupiter increased by the motion of the satellite relatively to Jupiter) and C is the correction for curvature of the parallel. The angle of measurement P_{AB} is, of course, in both cases so chosen as to make the difference $A—B$ a very small quantity, a few tenths of a revolution of the micrometer screw.

The difference $K_t—K_*$ consists of the errors of measurement, the errors of the images on the plate, the error in the adopted position angle of the stars, which is the same for all plates, and the error in the adopted motion of the satellites, which is entirely negligible. If we call ε the purely accidental error of one pointing on one image and δ the error of the image on the plate, we can, from the interagreement of the different images, derive a combination of the errors ε and δ. For the stars we have two images, each of which is measured twice, for the trails we have four images (on a plate containing four satellites) each of which is measured four times. Consequently the square of the difference of each measure of one image from the mean of all is in the two cases $\frac{3}{2}\varepsilon^2 + \delta_*^2$ and $\frac{3}{8}\varepsilon^2 + \frac{3}{2}\delta_t^2$ respectively. We find, using probable errors, and taking the micron as unit

$$\frac{3}{2}\varepsilon^2 + \delta_*^2 = 4{\cdot}6$$
$$\frac{3}{8}\varepsilon^2 + \frac{3}{2}\delta_t = 5{\cdot}8 \text{ *)}.$$

From the measures of the x-coordinates we find as a general average $\varepsilon = \pm 1^{\mu}{\cdot}7$.

This would give

$$\delta_* = \pm 0^{\mu}{\cdot}5$$
$$\delta_t = \pm 1^{\mu}{\cdot}8.$$

It is possible that the error of pointing ε is larger on the trails than on the stars. In that case δ_t would be found smaller. The square of the probable error of the index correction becomes in the two cases $\frac{1}{2}\varepsilon^2 + \delta_*^2$ and $\frac{1}{8}\varepsilon^2 + \frac{1}{2}\delta_t^2$ respectively, both increased by the error of the reading of the position circle. Putting this latter equal to $\pm 0''{\cdot}7$ for one reading (which is almost certainly too large) we find for the resulting probable errors of the index correction on one plate

from the stars $\pm 3''{\cdot}0$
from the trails $\pm 2{\cdot}6$. **)

The probable error of one difference $K_t - K_*$ thus becomes

$$\pm 4''{\cdot}0.$$

The probable error of the orientation from one trail, derived from the interagreement of the different trails, is $\pm 5''{\cdot}3$. From the Cape plates of 1903, taken with the astrographic refractor, we found for the same error $\pm 5''{\cdot}6$ (see *Cape Annals*, XII, **3**, p. 52). The effect of the longer focal distance is, of course, exactly balanced by the shortening of the time between the extreme ends of the trail, the size of the plates being the same in both cases. In 1903 complete trails were used, which were measured at 11 points, and the best fitting straight line through these 11 points was derived by least squares. In the present case the trail is replaced by two exposures at its two extremities. The accuracy of the latter method comes out a little better than of the former. This must evidently be ascribed to the fact that for an exposure both the errors ε and δ are smaller than for a trail. *) On the other hand evidently the orientation from the trail depends practically on the extreme points, and the ones in the middle were in 1903 only added to investigate the effect of distortion, which was found absent (*l. c.* p. 52).

The values of $K_t - K_*$ actually found for every plate are given in the tables at the end of this paper. From them we find for the probable error of one of them

from all not rejected plates..........	$\pm 11''{\cdot}8$
omitting plate 6367..................	$\pm 10{\cdot}1$
from differences $< \pm 30''$............	$\pm 9{\cdot}3$.

The large excess of these probable errors over the one derived from the comparison of the data on one and the same plate is of the nature of a plate error, or a night error. It is rather disappointing, and I can offer no explanation for it.

It should be mentioned that one exposition of the stars was taken before, and one after the exposures of the satellites. The exposures for orientation (trails) were taken after the last exposure of the stars. The hour angle of the middle point between these exposures is consequently on the average 10 minutes later than that of the central exposures. All hour angles are, however, small.

It will be remembered that also in 1903 we found very large differences between the orientation derived from the trails and from the stars, in fact much

*) No difference in accuracy between the trails of the four satellites is indicated.

**) It should be noted that this latter number is independent of the assumed proportion between ε_t and δ_t.

*) The values found in 1903 for the trails were $\varepsilon = \pm 1^{\mu}{\cdot}9$ $\delta = \pm 2^{\mu}{\cdot}5$.

larger than in the present case. Special plates were then taken to investigate the origin of these discrepancies, which are described in the Appendix to Part 3 of Vol. XII of the *Cape Annals.* The conclusion reached was that the orientation derived from different pairs of stars or from trails can only be depended on to be the same, when the hour angle and declination of the middle point is the same. Now by the motion of Jupiter during the time of the observations (Nov. 1918 to March 1919) $\tan \delta_* - \tan \delta_{♃}$ changed from $-\cdot016$ to $+\cdot004$ and the difference of the hour angles $t_* - t_t$ from $+12^m$ to -34^m, quantities which are considerably smaller than the corresponding differences in 1903. It is not possible to represent the observed differences $K_* - K_t$ by a formula depending on $\tan \delta_* - \tan \delta_{♃}$ and on $t_* - t_t$. If such a dependency exists it is entirely concealed behind the accidental deviations from it on the individual plates. Consequently we must consider the observed discrepancies between the orientation as derived from the stars and the trails as accidental, except in so far as they can contain a small constant term representing a correction to the adopted position angle of the stars. For this constant we find

from all not rejected plates,	mean by	plates	$-\ 8''\cdot7 \pm 2''\cdot5$
» » » »	» , »	» dates	$-10\cdot0 \pm 2\cdot4$
omitting plate 6367	, »	» plates	$-\ 6\cdot5 \pm 2\cdot0$
» » 6367	, »	» dates	$-\ 8\cdot7 \pm 2\cdot2$
from differences $< \pm 30''$,	»	» plates	$-\ 4\cdot9 \pm 1\cdot9$

The mean of the first two determinations, viz:

$$-9''\cdot4 \pm 2''\cdot4$$

appears to be the best to adopt.

For the measures of the y-coordinates the plate is brought in the position angle P_0' as explained above (p. 133). The index correction K_* derived from the stars was used. To derive the values of the coordinates corresponding to the orientation from the trails a correction $\delta y = x\,(K_t - K_*)$ must be applied. The images of the four satellites can then for each of the six exposures be measured with the micrometer screw alone, without using the scale. After rotating the plate by 180° the same measures are repeated in the reversed order. The measured coordinates, which are then referred to an arbitrary origin, are corrected for run, scale value, refraction and aberration and referred to the mean of the four satellites as origin, thus

$$y_i - y_0 = \mathrm{y_i} \qquad \mathrm{y}_{obs} - \mathrm{y}_{tab} = n$$

In the tables at the end of this paper are given the computed tabular values y_i and the values n_* and n_t corresponding to the orientation from the stars and the trails respectively. The tabular values of y_i were computed by the formulas given in *B. A. N.* **50**, p. 62. These values as given in *B. A. N.* **61** are only approximate, a'/Δ having been used in the computations instead of $a'\rho/\Delta'$, but for the purpose of the discussion of the y-coordinates they were corrected, and the y_i given here correspond to the corrected values.

The equations of condition now are, for a plate containing n satellites,

$$\frac{n-1}{n}(b_i\pi_i + c_i\varkappa_i) - \frac{1}{n-1}\sum_{i\neq j}(b_j\pi_j + c_j\varkappa_j) = n_i$$

where

$$b_i = \frac{a_i'\rho_i}{\Delta_i'}k_i \sin 1^\circ \cos B \cos v_i$$

$$c_i = \frac{a_i'o_i}{\Delta_i'}k_i \sin 1^\circ \cos B \sin v_i$$

$$k_1 = 150; \quad k_2 = 100, \quad k_3 = \frac{200}{3}, \quad k_4 = \frac{100}{3}$$

$$\Delta p_i = k_i\pi_i \qquad \Delta q_i = k_i\varkappa_i$$

The weight of this equation is $n/(n-1)$. The normal equations consequently are

$$[b_i^2]\ \pi_i + [b_ic_i]\varkappa_i - \Sigma_j\frac{n}{n-1}([b_ib_j]\pi_j + [b_ic_j]\varkappa_i) = \frac{n}{n-1}[b_in_i]$$

$$[c_ib_i]\pi_i + [c_i^2]\ \varkappa_i - \Sigma_j\frac{n}{n-1}([c_ib_j]\pi_j + [c_ic_j]\varkappa_j) = \frac{n}{n-1}[c_in_i]$$

From these equations, using the n_i corresponding to the orientation derived from the stars, a preliminary solution O was made. In the theoretical expressions for the y_i there are no periodic terms with periods comparable to the interval of time taken by the observations, as in the x-coordinates. Consequently the fact that the observations are spread over five months does not, as in the case of the longitudes (cf. *B. A. N.* **62**, p. 144), affect the accuracy of the resulting values of the unknowns Δp_i and Δq_i, and there was no reason to subdivide the series in two partial ones.

The plates 6325 and 6326 taken on November 21 and 6312 on Oct. 29 were rejected, for the same reason as in the case of the longitudes. Further in the solution depending on the orientation from the stars the plate 6311 was rejected on account of bad quality of the images. In the solution depending on the orientation from the trails the plates 6355 and 6360 were rejected. From the not rejected plates two solutions *IA* and *IB* were made with the orientation from the stars and two solutions *IIA* and *IIB* with the orientation from the trails. In the solutions *A* equal weight was given to every plate and in the solutions *B* to every night. The values of the unknowns resulting from the solutions are given below, the values given under *IA*, *IB*, *IIA*, *IIB* being the corrections to the preliminary solution *O*.

1918—19	*O*	*IA*	*IB*	*IIA*	*IIB*	*I*	*II*
π_1	+ ·000127	+ ·000009	+ ·000009	+ ·000039	+ ·000037	+ ·000136 ± ·000015	+ ·000165 ± ·000017
$\varkappa_1$	+ 77	− 6	− 14	+ 5	+ 23	+ 67 ± 21	+ 91 ± 25
π_2	+ 49	+ 9	+ 13	+ 18	+ 34	+ 60 ± 14	+ 75 ± 17
$\varkappa_2$	+ 173	+ 10	+ 14	+ 52	+ 48	+ 186 ± 17	+ 223 ± 21
π_3	− 51	+ 8	+ 4	+ 58	+ 66	− 45 ± 13	+ 11 ± 15
$\varkappa_3$	− 135	+ 20	+ 34	+ 74	+ 83	− 108 ± 17	− 56 ± 20
π_4	− 99	+ 20	+ 22	+ 32	+ 36	− 78 ± 16	− 65 ± 18
$\varkappa_4$	− 202	− 42	− 3	− 64	− 44	− 225 ± 17	− 256 ± 20
aver. resid.	± ·000050	± ·000044	± ·000038	± ·000049	± ·000036		

The mean of the two solutions *A* and *B* was adopted in both cases. Adding these means to the first approximation *O*, we find the values given under *I* and *II* respectively. The probable errors have been derived in the usual way. The values given are the mean of the two solutions *A* and *B*, which gave nearly the same p. e., both the weights and the p. e. for unit weight being smaller in *B* than in *A*.

In the measures of the *y*-coordinates all the pointings on the images of the four satellites belonging to the same exposure are made in one position of the microscope by the micrometer. Thus the error σ of the pointing on the scale does not enter in the result, as it does in the case of the *x*-coordinates. We have thus here

$$\zeta^2 = \tfrac{1}{4}\,\varepsilon^2$$

instead of $\zeta^2 = \frac{1}{4}\varepsilon^2 + \frac{3}{4}\sigma^2$ as for the *x*-coordinates. Further a possible error due to the displacement of the microscope in its movement from the scale to the plate and back cannot exist here. Taking $\varepsilon = \pm 10$ (in units of a fifth of a micron), as found on the average from the measures of the *x*-coordinates, we would have $\zeta = \pm 5$. The average value $\zeta = \pm 7{\cdot}5$ would, by taking out the error σ, give as an upper limit $\zeta = \pm 7{\cdot}1$. From the comparison of the different pointings we found $\zeta = \pm 4{\cdot}4$ and from the comparison of the measures in the two positions of the plate $\zeta = \pm 6{\cdot}2$. We adopt $\zeta = \pm 6{\cdot}0$.

This gives for the probable error of unit weight for one plate ± ·′00027. For a date with two plates this probable error would become ± ·′00019. Since there are about as many dates with one as with two plates, we adopt for the p. e. of unit weight for one date ± ·′00023.

The probable errors derived from the residuals are larger than these values, which proves the existence of a plate error or a night error. We find:

	orientation from	ρ from residuals	plate / night error
one plate:	stars:	± ·′00036	± ·′00024
	trails:	39	28
one date:	stars:	± ·00031	± ·00021
	trails:	29	18

For the results from the stars the night error is only inappreciably smaller than the plate error, but for the trails the difference is considerable. The plate errors are smaller than in most series of *x*-coordinates (Cf. *B. A. N.* **50**, p. 62; **61**, p. 141; **62**, p. 153; **93**, p. 97).

In *B. A. N.* **62**, p. 154 it was explained that for the series of plates taken at Leiden in 1922 a solution was made of the *y*-coordinates introducing as unknowns corrections ρ_i to the refraction constant, which are assumed to be different for the different satellites. Although in the present series the zenith distances are much smaller than in the Leiden series, a similar solution was made. The coefficients h_y of the corrections ρ_i are given for every plate in the tables at the end of the paper. Two solutions were made, *C*

	IC	*ID*	*IIC*	*IID*
π_1	+ ·000012 + ·371B		+ ·000042	
$\varkappa_1$	− 2 + ·063		0	
π_2	− 6 + ·555		+ 5	
$\varkappa_2$	0 + ·063		+ 50	
π_3	+ 9 + ·853		+ 58	
$\varkappa_3$	+ 40 + ·147		+ 82	
π_4	+ 20 + 1·715		+ 39	
$\varkappa_4$	− 16 + ·280		− 56	
B		− ·000004		
ρ_1	·00000 + ·049B	+ ·00001	+ ·00026	+ ·00027
ρ_2	− 22 − ·045	− 17	− 24	− 24
ρ_3	+ 25 − ·014	+ 17	+ 8	+ 2
ρ_4	− 2 + ·012	0	− 10	− 4
aver. resid.	± ·00045		± ·00048	

introducing as unknowns π_i, $\varkappa_i$ and ρ_i, and D introducing a constant correction B to the adopted orientation as derived from the position angle of the stars, and the corrections ρ_i, but not π_i and $\varkappa_i$. In the case of the trails the solution D contained, of course, only the ρ_i. The solutions were made from the residuals of the preliminary solution O, and are thus directly comparable with the solutions A given above. They were only made with equal weight to every plate.

In the solution $I\,C$ the unknown B was transferred to the right hand members and the unknowns π_i, $\varkappa_i$ and ρ_i were determined as functions of B. The results are given on the preceding page.

It will be seen that the values of π_i and $\varkappa_i$ are practically the same in the solutions C and A. The values of ρ_i are also the same in C and D, but they differ considerably in the solutions derived from the stars and from the trails. In 1922 we found

$$\left.\begin{array}{l} \rho_1 = -\,\cdot 00029 \\ \rho_2 = +\quad\;\, 19 \\ \rho_3 = +\quad\;\, 19 \\ \rho_4 = -\quad\;\;\; 9 \end{array}\right\} \pm \cdot 00011$$

These latter values, only one of which is smaller than its probable error, were found to be of the sign and the order of magnitude to be expected from the fact that the satellites I and IV are red. The values of ρ_i found here show no parallelism with the colour indices. The probable errors in the case $I\,C$ are $\pm\,\cdot 00010$ and in $II\,C$ $\pm\,\cdot 00012$. Thus of the sixteen unknowns eight are smaller and eight are larger than their probable errors, as should be the case if they were purely accidental results. Also the average residuals in the solutions C were exactly the same as in the solutions A, notwithstanding the introduction of three additional unknowns. We therefore conclude that the values found for ρ_i are not real, and we make no further use of the values of π_i and $\varkappa_i$ from the solutions C.

The difference between the solutions I and II, based on the orientation from the stars and from the trails respectively, may be due partly to systematic and partly to accidental errors in the orientation of the individual plates. A systematic error in the orientation from the stars would imply a correction B, the effect of which on the values of π_i and $\varkappa_i$ can be determined from the coefficients of B found in the solution $I\,C$. Although these coefficients have only been derived for the case that every plate has the same weight, they can be used as well for the solution B, with equal weights for every date, since the solutions A and B are nearly identical. We can then determine a value of B by the conditions $II - I = k$B, k being the coefficient of B in the solution $I\,C$. It will be seen from the following table that the differences II—I are roughly proportional to k, except for satellite IV.

	k	II—I	Residuals α	Residuals β
π_1	+ ·371	+·000029	+.000020	+.000004
$\varkappa_1$	+ ·063	+ 24	+ 23	+ 20
π_2	+ ·555	+ 25	+ 12	− 11
$\varkappa_2$	+ ·063	+ 37	+ 36	+ 36
π_3	+ ·853	+ 56	+ 36	0
$\varkappa_3$	+ ·147	+ 52	+ 49	+ 41
π_4	+1·715	+ 13	− 26	
$\varkappa_4$	+ ·280	− 31	− 37	

This is due to the fact that the first 7 plates have no trails, and it so happens that these plates contribute large positive amounts to the right hand members of the normal equations for π_4 and $\varkappa_4$, thereby changing the positive difference II—I of these members resulting from the other plates in a negative one. For the other satellites the effect of the non-coincidence in time of the solutions I and II is not so strongly systematic, owing doubtlessly to the quicker motion of these other satellites, by which the signs of the different coefficients change more rapidly. Two solutions were made for B, with the result

(1) α, from all satellites : B = +·000023 ± ·000017
β, omitting satellite IV : + 69 ± 15

The probable errors were derived from the residuals, which have been given above.

From the differences $K_t - K_*$ we derived a correction to the adopted position angle of the stars of $-9''\!\cdot 4 \pm 2''\!\cdot 4$ (see p. 135), corresponding to

(2) B = + ·000045 ± ·000012.

On the other hand the micrometer observations give, of course,

(3) B = 0 ± ·000015.

It is difficult to determine the relative weight of these different determinations of B. The fact that the hour angle of the trails is systematically different from that of the exposures from which the coordinates y are determined diminishes the weight of the determinations (1) and (2) from the comparison of the stars and trails. On the other hand the determination (3) contains three years of unknown, though probably negligible (see p. 133), proper motion, and of course the hour angle and declination of the stars also differ from those of the y-exposures by small amounts. As a general mean I adopt:

B = + ·000033 ± ·000015.

and corrections $+ \cdot 000033\, k$ must accordingly be applied to the values of π_i and $\varkappa_i$ from the solution *I*.

A further correction is required to both solutions *I* and *II* on account of the corrections to the mean longitudes found from the x-coordinates. The correction on this account to the tabular values of y_i is

$$\delta y_i = -\frac{a_i' \rho_i}{\Delta_i'} \sin B \sin (v_i - L'_i)\, \Delta l_i =$$
$$= (b_i \tan B \sin L' - c_i \tan B \cos L')\, \lambda_i.$$

The correction to $O-C$ has the opposite sign. It therefore is equivalent to corrections

$$\delta \pi_i = - \tan B \sin L' \,.\, \lambda_i$$
$$\delta \varkappa_i = + \tan B \sin L' \,.\, \lambda_i.$$

These corrections have been computed for three different dates, using for the first the values of λ_i from the partial series 1918, for the last those from 1919 and for the middle date the mean of these two, each, of course, with the values of B and L' of the date. The resulting corrections are

	Nov. 10	Jan. 2	Feb. 24	Adopted
$\delta\pi_1$	— ·000010	— ·000011	— ·000012	— ·000011
$\delta\varkappa_1$	— 3	— 2	— 1	— 2
$\delta\pi_2$	— 10	— 11	— 11	— 11
$\delta\varkappa_2$	— 3	— 2	— 1	— 2
$\delta\pi_3$	— 13	— 10	— 7	— 10
$\delta\varkappa_3$	— 3	— 2	— 1	— 2
$\delta\pi_4$	— 10	— 13	— 17	— 13
$\delta\varkappa_4$	— 3	— 3	— 2	— 3

These must be applied to both solutions *I* and *II*. Doing this, applying to *I* also the corrections depending on B as explained above, and returning to the original unknowns, we have

	I	*II*	Adopted mean
Δp_1	+ 0°·0206 ± °·0024	+ 0°·0231 ± °·0026	+ 0°·0218 ± °·0025
Δq_1	+ ·0100 ± 33	+ ·0134 ± 38	+ ·0117 ± 35
Δp_2	+ ·0067 ± 16	+ ·0064 ± 17	+ ·0066 ± 17
Δq_2	+ ·0186 ± 17	+ ·0221 ± 21	+ ·0204 ± 19
Δp_3	— ·0018 ± 12	+ ·0001 ± 10	— ·0008 ± 11
Δq_3	— ·0070 ± 11	— ·0039 ± 13	— ·0054 ± 12
Δp_4	— ·0011 ± 10	— ·0026 ± 6	— ·0018 ± 8
Δq_4	— ·0073 ± 6	— .0086 ± 7	— ·0080 ± 7

The probable errors given for *I* include the uncertainty introduced by B. It is proposed to adopt the mean of the two solutions. The epoch is 1919·06.

The following tables give the date and plate number, the differences $K_t—K_*$ and the coefficients h_y of the empirical corrections ρ_i, the coefficients b_i and c_i of π_i and $\varkappa_i$, the tabular value $\mathrm{y}_i = y_i - y_0$ and the deviations $n = \mathrm{y}_{obs} - \mathrm{y}_{comp}$ for the orientation from the stars and from the trails, and finally the residuals remaining after the substitution of the solution *I* (stars) and *II* (trails) respectively. All other details of the plates have already been given in *B. A. N.* **61**.

Plate N°. Date 1918	Satellite	$K_t—K_*$ h_y	b	c	y	n_*	n_{tr}	Residuals stars	Residuals trails	Remarks
6310 Oct. 22	I		— 4·12	+ 3·26	+ 0′·01462	— 0′·00016		— 0′·00026		no trails
	II		— 0·98	— 5·46	— ·13185	— 48		+ 13		
	III	+ 0·71	— 4·00	— 4·38	— ·12958	+ 144		+ 35		
	IV		— 0·77	+ 5·17	+ ·24680	— 81		— 24		
6311 Oct. 22	I		— 4·31	+ 3·01	+ 0·09667	+ 0·00181		[+ 0·00194]		no trails
	II		— ·82	— 5·49	— ·04957	— 208		[— 129]		images very faint
	III	+ ·65	— 3·94	— 4·44	— .04711	+ 27		[— 65]		
6312 Oct. 29	I		— 3·63	+ 3·96	+ 0·13579	— 0·00059		[— 0·00024]		no trails
	II		— 1·70	— 5·41	— ·00832	— 93		[+ 28]		time uncertain
	III	+ ·58	— 4·55	— 4·01	— ·00084	+ 187		[+ 135]		
	IV		— 1·87	— 4·96	— ·12663	— 34		[— 139]		
6313 Oct. 29	I		— 3·84	+ 3·75	+ 0·13590	— 0·00036		+ 0·00002		no trails
	II		— 1·54	— 5·45	— ·00882	— 58		+ 62		
	III	+ ·56	— 4·49	— 4·07	— ·00094	+ 105		+ 51		
	IV		— 1·84	— 4·97	— ·12613	— 11		— 116		
6315 Nov. 8	I		+ 4·99	+ 2·34	+ 0·00112	+ 0·00037		— 0·00052		no trails
	II	+ ·59	— 5·63	— 1·47	+ ·01476	— 9		+ 45		
	III		+ 6·14	+ 1·00	— ·01587	— 27		+ 6		
6316 Nov. 8	I		+ 4·87	+ 2·57	+ 0·00349	+ 0·00052		— 0·00038		trails not
	II	+ ·61	— 5·59	— 1·60	+ ·01118	— 69		— 13		measurable
	III		+ 6·13	+ 1·07	— ·01467	+ 18		+ 50		

Plate N°. Date 1918	Satellite	$K_t - K_*$ / h_y	b	c	y	n_*	n_{tr}	Residuals stars	Residuals trails	Remarks
6317	I		+ 3·24	— 4·56	+ 0·02458	— 0·00047		— 0·00019		trails not measurable
Nov. 13	II		+ 5·36	— 2·68	— ·01224	— 33		+ 27		
	III	+ 0·54	— 1·48	— 6·15	— ·06218	+ 137		+ 106		
	IV		— 4·68	— 3·01	+ ·04983	— 57		— 114		
6318	I		+ 3·52	— 4·36	+ 0·02588	— 0·00083		— 0·00057		trails not measurable
Nov. 13	II		+ 5·44	— 2·52	— ·01011	— 27		+ 32		
	III	+ ·54	— 1·39	— 6·18	— ·06342	+ 90		+ 62		
	IV		— 4·65	— 3·04	+ ·04764	+ 20		— 35		
6323	I		+ 5·53	— 1·02	+ 0·03172	— 0·00001		— 0·00034		trails not measurable
Nov. 15	II		— 5·96	+ 0·61	+ ·12557	— 52		+ 6		
	III	+ ·54	+ 6·34	— 0·39	+ ·01876	— 55		+ 5		
	IV		— 1·35	— 5·40	— ·17604	+ 108		+ 22		
6324	I	— 18″	+ 5·59	— 0·57	+ 0·03610	+ 0·00001	+ 0·00020	— 0·00037	— 0·00015	
Nov. 15	II		— 5·92	+ 0·36	+ ·12073	— 67	— 93	— 3	— 5	
	III	+ ·54	+ 6·34	— 0·26	+ ·02146	— 84	— 37	— 23	+ 6	
	IV		— 1·31	— 5·41	— ·17828	+ 150	+ 110	+ 64	+ 15	
6325	I	+ 13″	— 3·87	+ 4·24	+ 0·06399	— 0·00225	— 0·00200	[— 0·00191]	[— 0·00162]	
Nov. 21	II		+ 2·82	+ 5·39	+ ·07984	+ 85	+ 89	[— 19]	[— 38]	
	III	+ ·54	+ 3·09	— 5·67	— ·15508	+ 134	+ 145	[+ 98]	[+ 122]	
	IV		+ 5·07	+ 2·57	+ ·01124	+ 7	— 34	[+ 111]	[+ 78]	
6326	I	— 45	— 4·20	+ 3·92	+ 0·06020	— 0·00042	— 0·00133	[— 0·00001]	[— 0·00087]	
Nov. 21	II		+ 2·60	+ 5·50	+ ·08248	+ 60	+ 43	[— 47]	[— 88]	
	III	+ ·54	+ 3·20	— 5·61	— ·15530	+ 86	+ 51	[+ 50]	[+ 27]	
	IV		+ 5·04	+ 2·61	+ ·01262	— 106	+ 37	[— 2]	[+ 149]	
6332	I	— 4	+ 5·25	— 2·28	— 0·06726	+ 0·00063	+ 0·00060	— 0·00014	— 0·00021	
Nov. 22	II		— 5·83	+ 1·56	+ ·05610	+ 20	+ 8	+ 5	+ 2	
	III	+ ·54	+ 6·35	— 1·20	— ·08660	+ 106	+ 109	+ 101	+ 80	
	IV		+ 3·78	+ 4·27	+ ·09777	— 188	— 179	— 92	— 61	
6333	I	0	+ 5·38	— 1·93	— 0·06500	+ 0·00112	+ 0·00112	+ 0·00031	+ 0·00026	
Nov. 22	II		— 5·88	+ 1·37	+ ·05176	+ 4	+ 4	— 7	+ 1	
	III	+ ·55	+ 6·37	— 1·09	— ·08531	+ 78	+ 78	+ 74	+ 49	
	IV		+ 3·75	+ 4·29	+ ·09855	— 195	— 195	— 98	— 77	
6339	I	+ 2	— 3·07	+ 5·08	+ 0·08054	+ 0·00024	+ 0·00028	— 0·00027	— 0·00020	
Dec. 7	II		— 3·80	— 4·98	— ·04733	— 112	— 106	— 57	— 19	
	III	+ ·63	+ 6·36	+ 1·98	+ ·03709	+ 44	+ 41	+ 35	— 7	
	IV		+ 5·78	+ 0·93	— ·07030	+ 43	+ 36	+ 48	+ 44	
6340	I		— 3·47	+ 4·81	+ 0·07879		+ 0·00009		— 0·00033	images of star B invisible
Dec. 7	II		— 3·60	— 5·14	— ·05186		— 141		— 54	
	III	+ ·59	+ 6·32	+ 2·10	+ ·04062		+ 69		+ 19	
	IV		+ 5·78	+ 0·98	— ·06754		+ 62		+ 69	
6343	I	— 19	+ 5·73	+ 1·54	— 0·09037	+ 0·00130	+ 0·00154	+ 0·00028	+ 0·00019	
Dec. 10	II		— 6·25	+ 0·23	— ·03478	— 30	— 58	— 11	— 42	
	III	+ ·58	— 6·60	+ 1·28	— ·03176	+ 27	— 18	— 5	— 30	
	IV		+ 1·64	+ 5·69	+ ·15692	— 126	— 77	— 10	+ 53	
6350	I		+ 5·14	— 3·14	— 0·13989	+ 0·00035		+ 0·00006		no trails
Dec. 31	II		— 5·32	+ 3·49	+ ·01559	— 3		— 15		
	III	+ ·54	— 5·65	+ 3·82	+ ·02414	— 26		+ 9		
	IV		— 5·83	+ 1·48	+ ·10015	— 6		— 1		
1919 6355	I	— 51	— 4·46	+ 4·09	+ 0·11231	— 0·00064	— 0·00090	— 0·00057	[— 0·00093]	
Jan. 8	II		— 4·18	— 4·84	— ·00777	— 102	— 164	— 16	[— 65]	
	III	+ ·59	— 6·81	— 0·43	+ ·06132	+ 123	— 12	+ 59	[— 48]	
	IV		+ 5·51	— 2·28	— ·16588	+ 45	+ 267	+ 15	[+ 205]	
6356	I	— 13	+ 4·36	— 4·08	— 0·04705	+ 0·00084	+ 0·00107	+ 0·00059	+ 0·00058	
Jan. 16	II		+ 4·53	— 4·53	— ·11104	— 67	— 39	— 4	+ 14	
	III	+ ·62	— 4·87	— 4·70	— ·10444	+ 78	+ 62	+ 12	+ 27	
	IV		— 5·07	+ 3·15	+ ·26255	— 97	— 132	— 65	— 98	

Plate N°. Date 1918	Satellite	K_t-K_* / h_y	b	c	y	n_*	n_{tr}	Residuals stars	Residuals trails	Remarks
6357 Jan. 16	I	− 8″	+ 4·63	− 3·77	− 0′·04435	+ 0′·00064	+ 0′·00078	+ 0′·00035	+ 0′·00024	
	II		+ 4·68	− 4·38	− ·10944	− 136	− 118	− 75	− 66	
	III	+ ·58	− 4·80	− 4·78	− ·10701	+ 61	+ 51	− 4	+ 18	
	IV		− 5·09	+ 3·11	+ ·26079	+ 10	− 12	+ 43	+ 24	
6359 Jan. 17	I	− 15	− 5·59	+ 2·20	+ 0·01211	− 0·00007	− 0·00004	+ 0·00092	+ 0·00098	
	II		+ 3·66	+ 5·17	+ ·05133	+ 76	+ 112	− 2	− 1	
	III	+ ·63	+ 0·45	− 6·75	− ·20141	− 45	− 31	− 77	− 40	
	IV		− 5·85	+ 1·10	+ ·13797	− 25	− 78	− 11	− 58	
6360 Jan. 18	I	− 48	+ 5·94	+ 0·47	− 0·00849	+ 0·00028	+ 0·00122	− 0·00012	[+ 0·00070]	
	II		− 5·85	+ 2·31	+ ·08210	− 49	− 81	− 12	[− 38]	
	III	+ ·60	+ 5·50	− 3·90	− ·11582	− 15	+ 123	+ 12	[+ 145]	
	IV		− 5·83	− 1·13	+ ·04219	+ 35	− 162	+ 10	[− 178]	
6361 Jan. 18	I	− 21	+ 5·90	+ 0·83	− 0·00448	+ 0·00052	+ 0·00093	+ 0·00011	+ 0·00040	
	II		− 5·92	+ 2·13	+ ·07868	− 93	− 108	− 53	− 61	
	III	+ ·57	+ 5·56	− 3·81	− ·11404	− 67	− 6	− 38	+ 18	
	IV		− 5·82	− 1·17	+ ·03984	+ 107	+ 20	+ 81	+ 3	
6365 Feb. 7	II	+ ·10	+ 5·59	+ 2·44	+ 0·15500	− 0·00069	− 0·00087	− 0·00054	− 0·00090	
	III		− 2·17	− 6·13	− ·01675	− 23	− 14	− 7	+ 46	
	IV	+ ·54	− 0·73	− 5·63	− ·13825	+ 92	+ 101	+ 62	+ 45	
6366 Feb. 7	I	− 4	− 2·63	+ 5·14	+ 0·15380	− 0·00118	− 0·00118	− 0·00048	− 0·00050	
	II		+ 5·47	+ 2·67	+ ·10816	− 54	− 47	− 65	− 75	
	III	+ ·53	− 2·03	− 6·18	− ·07030	− 1	− 4	− 6	+ 36	
	IV		− 0·68	− 5·64	− ·19166	+ 171	+ 168	+ 119	+ 91	
6367 Feb. 7	I	− 64	− 2·97	+ 4·94	+ 0·15190	− 0·00003	− 0·00015	+ 0·00073	+ 0·00060	
	II		+ 5·38	+ 2·86	+ ·11224	− 54	+ 63	− 69	+ 31	
	III	+ ·54	− 1·93	− 6·21	− ·07143	+ 10	− 43	+ 2	− 6	
	IV		− 0·64	− 5·65	− ·19270	+ 46	− 6	− 7	− 84	
6368 Feb. 8	I	− 21	+ 4·04	− 4·05	+ 0·04475	− 0·00072	− 0·00066	− 0·00039	− 0·00025	
	II		− 3·52	+ 4·90	+ ·21555	+ 93	+ 67	+ 85	+ 54	
	III	+ 0·54	+ 3·30	− 5·56	− ·05159	− 37	− 22	− 20	+ 13	
	IV		+ 1·41	− 5·48	− ·20871	+ 16	+ 21	− 25	− 41	
6369 Feb. 10	I	− 16	+ 5·69	+ 0·25	+ 0·05051	+ 0·00125	+ 0·00108	+ 0·00048	+ 0·00034	
	II		+ 5·17	− 3·24	− ·03999	− 12	− 24	+ 19	+ 32	
	III	+ ·53	+ 4·80	+ 4·28	+ ·16344	− 44	− 42	+ 26	− 1	
	IV		+ 4·79	− 2·97	− ·17396	− 69	− 42	− 91	− 65	
6370 Feb. 11	I	+ 20	− 5·36	− 1·94	+ 0·00545	− 0·00025	+ 0·00024	+ 0·00063	+ 0·00139	
	II		+ 2·39	+ 5·50	+ ·11385	+ 88	+ 100	− 25	− 32	
	IV	+ ·55	+ 5·53	− 1·03	− ·11929	− 63	− 125	− 38	− 107	
6371 Feb. 11	I	− 1	− 5·18	− 2·35	+ 0·00029	− 0·00096	− 0·00099	− 0·00007	+ 0·00016	
	II		+ 2·17	+ 5·59	+ 11684	+ 116	+ 116	+ 2	− 18	
	IV	+ ·53	+ 5·55	− 0·99	− ·11712	− 21	− 18	+ 5	+ 1	
6372 Feb. 12	I	+ 12	+ 3·87	+ 4·16	− 0·00111	+ 0·00148	+ 0·00144	+ 0·00062	+ 0·00039	
	II		− 5·92	+ 0·96	+ ·01036	− 141	− 116	− 130	− 97	
	III	+ ·54	− 5·03	+ 3·97	+ ·06388	− 25	+ 4	− 11	+ 29	
	IV		+ 5·51	+ 1·11	− ·07315	+ 19	− 31	+ 79	+ 30	
6373 Feb. 12	I	+ 1	+ 3·54	+ 4·44	+ 0·00270	+ 0·00123	+ 0·00123	+ 0·00039	+ 0·00020	
	II		− 5·95	+ 0·73	+ ·00629	+ 15	+ 17	+ 30	+ 39	
	III	+ ·53	− 5·10	+ 3·88	+ ·06156	− 98	− 96	− 86	− 73	
	IV		+ 5·50	+ 1·16	− ·07054	− 42	− 46	+ 18	+ 13	
6374 Feb. 13	I	+ 3	− 2·54	− 5·05	− 0·05607	− 0·00017	− 0·00015	+ 0·00009	+ 0·00008	
	III		− 6·30	− 1·13	− 0·02499	+ 8	+ 17	− 75	− 47	
	IV	+ ·56	+ 4·75	+ 3·01	+ ·08105	+ 9	− 3	+ 66	+ 40	
6375 Feb. 25	I	− 49	− 5·47	+ 0·08	+ 0·02234	− 0·00070	− 0·00145	+ 0·00015	− 0·00026	
	II		+ 3·64	+ 4·48	+ ·08008	+ 89	+ 118	− 3	+ 21	
	III	+ ·56	+ 1·31	+ 6·02	+ ·17080	− 88	− 75	− 6	− 12	
	IV		+ 2·00	− 5·02	− ·27322	+ 69	+ 103	− 6	+ 18	