On the Leiden observations of the right ascension of Polaris (Errata: 9 448)

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COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

On the Leiden observations of the right ascension of Polaris, by *G. van Herk*.

1. After the foundation of the Observatory of Leiden in 1860 in its present state it was decided to observe the transits of Polaris as much as possible. With interruptions this has been maintained until about 1915. A great part of the material thus obtained has been reduced to derive the azimuth of the meridian circle and of the mires which have been used with the different programs in execution. The greatest and by far the most homogeneous part of the observations, viz. from 1877 till 1896, have been thoroughly discussed by Ir. J. WEEDER, who deduced from them the amplitude and epoch of the polar variation[1]). Furthermore, WEEDER derived the right ascension of Polaris and found this quantity to be variable. These latter results, however, have not been published, except for a short note in L. M. KLINKENBERG's Dissertation[2]). Meanwhile W. W. CAMPBELL and J. HARTMANN drew attention to the variability of the radial velocity, which was fully corroborated by others (A. BELOPOLSKY, J. H. MOORE). Other meridian observations were discussed in order to detect any variability in position, chiefly by L. COURVOISIER[3]), E. ESCLANGON[4]), J. XANTHAKIS[5]) and lately by B. P. GERASIMOVIČ[6]). Finally, in 1937, R. H. WILSON detected the duplicity of Polaris with the interferometer[7]).

In 1935 Prof. OORT suggested to me to take up again the regular observations of the transits of Polaris and to determine the right ascension from the old observations in so far as it had not been done already.

The observations since 1864 may best be divided into several groups. It is insuperable that the whole of these different periods is inhomogeneous; the observers have changed and sometimes the mode of observation and the instrument have changed as well. It seems therefore adequate to give for each period a short account of the most necessary data; these may be found in section 2 of the present paper. The periods under review cover the years 1864-1868, 1877–1915, and 1935–1936. Full particulars about the instrument etc. may be found in the various volumes of the *Annalen van de Sterrewacht te Leiden*. In section 3 some details of the reductions are sketched. In section 4 a more detailed discussion is given of the most difficult part of each investigation of this type, viz. the determination of the personal error. It is a pleasure to acknowledge here the kindness with which Ir. WEEDER has shown me the way through several old papers, and his help to understand the reductions from the older computations. His method of reducing was closely followed. I am much indebted to Prof. OORT for many discussions. Messrs B. MEKKING, G. PELS and J. PRINS have assisted in the computations.

2. First period, 1864–1868. For the observers I refer to Table 2. Method of observation: eye and ear. The clock correction was determined from stars reduced to the system of the NFK. The collimation was determined mainly by the aid of the mercury trough and from observations of the mires. The inclination was measured when the tube was horizontal, objective north and objective south. A sufficient number of reflexion observations and of observations of δ U Mi was secured to strengthen the determination of the azimuth. The reductions have been made by Dr. J. E. DE VOS VAN STEENWIJK and were published in *Annalen Leiden* XI, 2, 1918. In deriving the azimuth DE VOS VAN STEENWIJK has reduced all observations to VAN HENNEKELER and has eliminated for this observer that part of the personal error which depends on the time of the day. Page B 9 of the work cited contains the $\Delta\alpha$ (NFK-Obs) deduced from a preliminary azimuth. The α Eph has been rigorously computed, as is explained on page B 44. I have

[1]) Kon. Akad. van Wetenschappen, Amsterdam, *Verslagen*, Deel **8**, p. 656, 1900 (Dutch).
[2]) Die Greenwich Deklinationsbestimmungen von Polaris 1851–1905, Rotterdam 1908.
[3]) *A. N.* **203,** 1917, p. 85. [4]) *C. R. Acad. Sc.* **188,** 1929, p. 857. [5]) *Bull. Astron.* tome VIII, 1933, p. 463.
[6]) *Poulkovo Observ. Circ.* No. 19, 1936. [7]) *P.A.S.P.* **49,** 1937, p. 202.

recomputed these $\Delta\alpha$ by using the final azimuth given on page B 63.

Second period, 1877–1896. Though the second period of extensive observing covers the years 1871–1875 it could not be used for this investigation. The observations have yielded a value of the azimuth which was published in *Annalen Leiden* IV and V. The original papers, however, are no longer in Leiden. I am indebted to all those who have made a search for those papers though this has been in vain. The next period commenced in 1877. The observers are given in Table 2. Method of observation: eye and ear. The clock correction was determined from stars of the FK. For the collimation and the inclination see the previous section. The pivots of the instrument were renewed in 1876; the new form differed very little from the ideal shape and no corrections had to be applied. Until 1886 the number of reflexion observations has been sufficient to yield a correction of the inclination. The objective-end and the eye-end were interchanged in 1882 and again in 1890. The reductions have been made entirely by J. WEEDER.

Third period, 1899–1915. The observers are given in Table 2. Method of observation: eye and ear, for E. BAKHUYZEN; with the signal key for all others. PANNEKOEK has observed with both methods and has determined his personal difference between the two methods. I have left out WEEDER's observations with the eye and ear method as I could not come to a well determined difference between this method and that of the signal key. The reversing prism at the ocular end has been generally used and where differences depending on direction of motion were found they have been applied as corrections. As regards the inclination and collimation no change with the former periods is to be reported.

Fourth period, 1936. Observers: the present author and, a few times J. ZEEMAN and L. PLAUT. It had been my aim to observe Polaris at least two years but unfortunately, owing to illness, I had to give it up after about one year and a half. I wish to thank Messrs ZEEMAN and PLAUT for their kindness in helping me. Their observations helped in deriving the instrumental errors, though their total number of observations is too small to permit an independent determination of the right ascension. The clock error was deduced from the Rugby signals. The collimation was determined only with the aid of reversals of the instrument with pointings on the marks or on Polaris. The inclination was measured when the instrument was directed towards the star, and special investigations were made to derive the corrections due to inequalities of the pivots. The reversing prism has frequently been used. To get as much information as possible I observed alternately with either eye. The method of registering with the signal key was used throughout.

3. The general line in the reductions has been to find out the behaviour of the instrumental constants, and then to investigate the stability of the meridian marks. The formula used is that of MAYER. In the following N and S stand for the azimuth of the marks, k for that of the instrument, i for the inclination and c for the collimation. For the different connections between these quantities I refer to *Annalen Leiden* XI, 2. The instrumental constants did not give rise to serious difficulties.

The question of the stability of the whole instrument and of the azimuth marks requires a more detailed account. As is usually done we adopt the principle that the marks have the greatest stability of the parts involved. This does not change the fact that we have to accept the possibilities: movements of either mark or of the instrument. A movement of the latter is reflected in the former. We have, however, an independent check, viz. the behaviour of the inclination. The instrument may turn, changing k, or i, but it may show a parallel displacement in east-west direction as well, and it is likely that these movements, if they exist, will not act independently. An east-west shift yields a clue to explain some special phenomena. In Leiden it has always been the practice to determine half the sum of the azimuths of the marks, $\frac{1}{2}(N + S)$, together with half the difference, $\frac{1}{2}(N-S)$. The latter quantity is independent of the polar variation and no observations of stars are needed to derive its value. Allowance has always been made for the fact that the two marks are below the horizon, so that the inclination has some effect upon the results. The mean azimuth $\frac{1}{2}(N + S)$ proved to be fairly constant; the changes have been gradual, apparently without following any law. From the combined results from upper and lower culminations, which were well intermingled, there has never been found any direct evidence of periodicity, apart from that which arises from the polar variation. There have been times when observations of δ U Mi confirmed this independently. The azimuthal difference, however, has shown from the beginning a marked annual periodicity with an amplitude of about $0^s{\cdot}04$. Investigators of the first period passed a single harmonic through the points. From the second period on it was shown that the curve is slightly asymmetrical, but in all cases the curves showed nearly the same phase and nearly the same amplitude at the same date of the year. These facts are now easily understood by admitting an east-west movement of the meridian instrument. The northern mark is situated at a distance of about 108 metres, the southern at 87 metres from the instrument. An annual motion of the instrument in the east-west direction with an amplitude of 0·28 mm would explain the observed change in $\frac{1}{2}$ $(N—S)$. The amplitude in $\frac{1}{2}$ $(N + S)$ is then computed as 0^s·004, a quantity too small to be detected. It goes without saying that the change in k arising from the change in longitude caused by this displacement is too small to have any effect on the computed $\frac{1}{2}$ $(N + S)$.

As regards a daily period in $\frac{1}{2}$ $(N—S)$ DE VOS VAN STEENWIJK (l.c. page 60) reports that he could find no trace of it. In his papers WEEDER hinted at the possibility of such a daily periodicity but wished to wait for more observations, specially for those made in the early morning. From the material of 1886 till 1894 of which the numbers were at hand I computed the following expression for $\frac{1}{2}$ $(N—S)$ derived from two-hourly means: $+ 0^s$·0076 sin $(\theta + 61°·5)$; θ denotes the mean time counted from noon and is expressed in degrees. Furthermore I investigated the data from the periods 1899–1907 and 1935–1936 with the following results, derived from hourly means: $+ 0^s$·0060 sin $(\theta + 45°)$ and $+ 0^s$·0046 sin $(\theta + 52°·5)$ respectively. It is true that for each period the amplitude has a mean error only slightly smaller than its own value, but the agreement of these figures is such that I have enough confidence in these three results to believe that there may exist a daily periodicity. It will be seen later on that the question of a daily period is of great importance. It could have been possible that there exists a daily period only and that the annual period found is a consequence of selection. To find out whether this is true I divided the $\frac{1}{2}$ $(N—S)$ into monthly groups and subdivided these into hourly means. It was at once evident that the annual period is real.

I have tried to find a corroboration of the idea that it is mainly the instrument that is responsible for these movements. If we plot the inclination of the axis during the first period it is at once evident that there existed at that time an annual period and that a secular change was well marked. This secular change gave rise to several re-adjustments of the inclination. The inclinations of the last years show the annual period even more pronounced (amplitude about 5″), the secular change having nearly vanished. The amplitude and the phase of this periodicity of the last years agree well with those of the periodicity in $\frac{1}{2}$ $(N—S)$ in this way that a rise of the western pillar coincides with a movement in eastern direction. No trace of a daily period could, however, be found in the inclinations.

In no period the computed mean azimuth of the marks, $\frac{1}{2}$ $(N + S)$, has been corrected for any of these periodicities. A curve was traced as smoothly as

TABLE 1.

	I	II	III	IV
1864–1868	s	s	s	s
N. M. KAM	+ 0·56 (22)	+ 0·88 (58)	— 1·09 (31)	— 0·40 (32)
A. VAN HENNEKELER	+ 0·58 (35)	+ 0·71 (97)	— 0·97 (44)	— 0·36 (45)
Corrections	— 0·57	— 0·77	+ 1·02	+ 0·38
1878–1882				
T. J. STIELTJES	+ 0·44 (14)	+ 0·22 (17)	— 0·25 (15)	— 0·47 (9)
E. F. VAN DE SANDE BAKHUYZEN	+ 0·80 (11)	+ 0·38 (17)	— 0·54 (14)	+ 0·36 (7)
J. WILTERDINK	+ 0·50 (7)	+ 0·46 (7)	— 0·53 (9)	— 0·43 (4)
Corrections	— 0·58	— 0·33	+ 0·42	+ 0·17
1882–1896				
E. F. VAN DE SANDE BAKHUYZEN	+ 0·38 (52)	+ 0·21 (67)	— 0·32 (46)	— 0·25 (30)
J. WILTERDINK	+ 0·32 (42)	+ 0·08 (74)	— 0·31 (47)	— 0·05 (42)
Corrections	— 0·35	— 0·14	+ 0·31	+ 0·13
1900–1915				
E. F. VAN DE SANDE BAKHUYZEN	+ 0·14 (2)	+ 0·22 (1)	— 0·60 (6)	+ 0·24 (1)
A. PANNEKOEK	+ 0·46 (4)	+ 0·38 (8)	— 1·18 (5)	+ 0·19 (2)
H. J. ZWIERS	+ 0·07 (2)	+ 0·35 (6)	— 0·10 (3)	— 0·31 (1)
J. G. E. G. VOÛTE	+ 0·61 (7)	— 0·29 (3)	— 0·77 (4)	+ 0·44 (1)
J. E. DE VOS VAN STEENWIJK	+ 0·22 (7)	+ 0·06 (8)	— 0·56 (2)	+ 0·30 (4)
J. WOLTJER	+ 0·25 (12)	+ 0·22 (18)	— 1·15 (10)	+ 0·63 (5)
Corrections	— 0·32	— 0·20	+ 0·85	— 0·36
1936				
G. VAN HERK (corr.)	— 0·06 (22)	+ 0·37 (26)	+ 0·10 (23)	— 0·41 (16)

possible through all points, upper and lower culminations being given equal weights. In the years 1864–1868 and in a few years of the period 1877–1915 observations of δ U Mi, ε U Mi or 45 H Ceph have been used as well.

From the adopted $\frac{1}{2}(N+S)$ the right ascension of Polaris was recomputed. For each observer the differences with the right ascension in the NFK were computed and grouped together in periods of three months, for each culmination separately. The results from upper and lower culmination were then averaged with equal weights.

The weights assigned to these means were $2\,\frac{n_1 n_2}{n_1+n_2}$, where n_1 and n_2 are the number of observations of upper and lower culminations respectively. It was evident from these data that an annual variation existed in the results of all observers. Sometimes, especially where the weights are highest, the inequalities of the different observers run very closely together. I believe the origin of this inequality to be mainly of instrumental nature; in fact, a daily term in the azimuth of the mires, for which some evidence was found above, but which has been neglected, would introduce such a feature. I have taken the means of the inequalities for different periods and I have applied them as corrections to all quarterly means. These corrections are given in Table 1.

The mean error of the unit of weight was found to be ± 1^s·02 for KAM, ± 1^s·01 for VAN HENNEKELER, ± 0^s·91 for STIELTJES, ± 1^s·05 (1878–'82) and ± 0^s·96 (1882–'96) for BAKHUYZEN, ± 0^s·85 (1882–'96) for WILTERDINK, ± 0^s·34 for PANNEKOEK and ± 0^s·94 for WOLTJER. (The low value for PANNEKOEK is probably accidental.) These figures will give some idea how far it is allowed to compare the results for the different observers.

The resulting annual means of the differences α Leiden—α NFK are given in Table 2. The number of asterisks indicates the number of quarters in the year concerned for which no observations in both upper and lower culminations were available. In such years the influence of the correction for annual inequality has therefore been appreciable. The numbers between brackets are the final weights.

TABLE 2.

y			
	KAM	VAN HENN.	
	s	s	
1864·5	+ 1·05 (41)	+ 0·60 (51)	
65·5	+ 0·45 (35)	+ 0·25 (58)	
66·5	— 0·05 (46)	— 0·08 (57)	
67·5	— 0·23 (21)	— 0·47 (17)	
68·5	** + 0·17 (28)	— 0·04 (38)	
	E. BAKHUYZEN	WILTERDINK	STIELTJES
	s	s	s
1877·5	** + 0·09 (14)		
78·5	** — 1·18 (27)	** + 0·47 (9)	* + 0·65 (15)
79·5	* — 0·73 (13)	*** + 0·59 (2)	* + 0·17 (19)
80·5	— 0·98 (20)	* — 0·01 (15)	+ 0·58 (32)
81·5	— 1·19 (19)	— 0·09 (27)	+ 0·27 (23)
82·5	* — 0·98 (15)	* — 0·25 (13)	* — 0·35 (9)
83·5	— 1·47 (34)	+ 0·07 (37)	
84·5	— 1·33 (32)	— 0·07 (32)	
85·5	— 1·32 (32)	— 0·47 (21)	
86·5	— 1·15 (17)	— 0·42 (21)	
87·5	* — 1·02 (17)	— 0·12 (16)	
88·5	— 1·13 (15)	— 0·11 (22)	
89·5	** — 1·06 (8)	+ 0·10 (22)	
90·5	** — 0·88 (8)	* — 0·26 (8)	
91·5	— 0·55 (20)	+ 0·35 (11)	
92·5	— 0·60 (16)	* + 0·02 (18)	
93·5	* — 0·45 (12)	** + 0·20 (9)	WEEDER
94·5	** — 0·15 (8)	+ 0·58 (13)	s
95·5	** — 1·47 (4)	** + 0·35 (3)	** — 0·51 (4)
96·5			* + 0·03 (22)
97·5	*** — 0·47 (3)	PANNEKOEK	* 0·00 (9)
98·5		s	*** + 0·06 (3)
99·5		*** + 0·17 (3)	*** — 0·15 (3)
1900·5	*** — 1·78 (2)	+ 0·01 (9)	
01·5	*** — 0·45 (2)	** — 0·28 (4)	
02·5		** — 0·20 (4)	
03·5		*** + 0·24 (3)	
04·5	* — 0·97 (5)	* — 0·10 (11)	
05·5	*** — 1·73 (1)	* — 0·24 (13)	* + 0·31 (7)
06·5	* — 0·24 (6)	+ 0·52 (11)	** + 0·41 (8)
07·5	— 0·88 (11)		
08·5	* — 0·98 (5)		
	ZWIERS	VOÛTE	
	s	s	
07·5	* + 0·42 (15)		
08·5	+ 0·54 (12)	*** — 0·24 (14)	
09·5	* + 0·83 (14)	* + 0·38 (13)	
10·5	* + 0·48 (9)	+ 0·52 (16)	
11·5	* + 0·37 (5)	** 0·00 (11)	*** — 0·16 (3)
12·5	** + 0·11 (5)	* — 0·22 (10)	** + 0·24 (2)
		WOLTJER	
		s	
13·5	*** + 0·62 (1)	* + 0·83 (10)	
14·5	*** + 0·90 (2)	+ 1·24 (26)	
15·5	*** + 0·35 (6)	+ 1·17 (20)	*** + 0·91 (2)
	DE VOS		
	s		
1913·5	** + 0·72 (6)		
14·5	** + 0·54 (15)		
	VAN HERK		
	s		
1935·5	** + 0·19 (24)		
1936·5	+ 0·54 (87)		

4. *The personal error*. The differences of the $\Delta\alpha$ for the different observers are a measure of the differences of the personal errors and may give some answer to the question how far these errors have remained constant. In *Annalen Leiden* VII, 2 a description is given of an instrumental arrangement with which the absolute personal error can be found.

The results of all the observations performed with this instrument for the case of a star resembling Polaris are given below. One series of observations consisted mostly of 10 to 40 transits.

year	observer	correction to transit time	no. of series	weight I	weight II
		s			
1887	E. Bakh.	+ 0·90	18	1	0
	Wilt.	+ 0·23	15	1	0
1907	Pann.	— 0·60	1	1/4	0
1913	Zwiers	— 0·20	2	1/4	0
	Voûte	— 0·42	1	1/4	0
	Woltjer	— 0·34	4	1/4	0
	de Vos	+ 0·10	2	1/4	0
1937	van H.	+ 0·20	11		

In trying this instrument I found it difficult to believe that another systematic error was not introduced, viz. in the determination of the correct position of the movable wire. This wire should bisect the image of the artificial star at the moment the instrument closes the circuit which is connected with the chronograph. Even if this turns out well there is another objection: we have no evidence that the personal error remains the same under all circumstances. I do not believe it does. However, I had to accept several assumptions and the four solutions I finally made were based on the following:

a) the personal errors remained the same through all years and two different sets of weights were assigned to the different equations involving the corrections to the transit time.

b) the period under review here (1877–1915) was divided into two periods, viz. from 1877–1895 and from 1896–1915 while now for each period assumption *a*) was used.

The two different sets of weights consisted of the weights given under I and II while the weights of the differences, found from Table 2 varied from ¼ for Woltjer–Weeder and Weeder–Wilterdink to 10 for Bakhuyzen–Wilterdink.

The corrections to the transit time which were then found by adjustment are given in the following table.

Solution:	*a*, I	*a*, II	*b*, I 1st per.	*b*, I 2nd per.	*b*, II 1st per.	*b*, II 2nd per.
	s	s	s	s	s	s
Δα St	— 0·32	— 0·03	— 0·27		— 0·27	
Ba	+ 1·02	+ 1·33	+ 1·07	+ 0·85	+ 1·08	+ 0·87
Wi	— 0·01	+ 0·27	+ 0·04		+ 0·03	
Pa	+ 0·08	+ 0·51		— 0·07		+ 0·01
Zw	— 0·17	+ 0·17		— 0·31		— 0·33
Vo	+ 0·18	+ 0·56		+ 0·03		+ 0·06
Wo	— 0·58	— 0·28		— 0·69		— 0·79
dV	0·00	+ 0·29		— 0·10		— 0·21
We	+ 0·05	+ 0·41	+ 0·51	— 0·14	+ 0·51	— 0·12

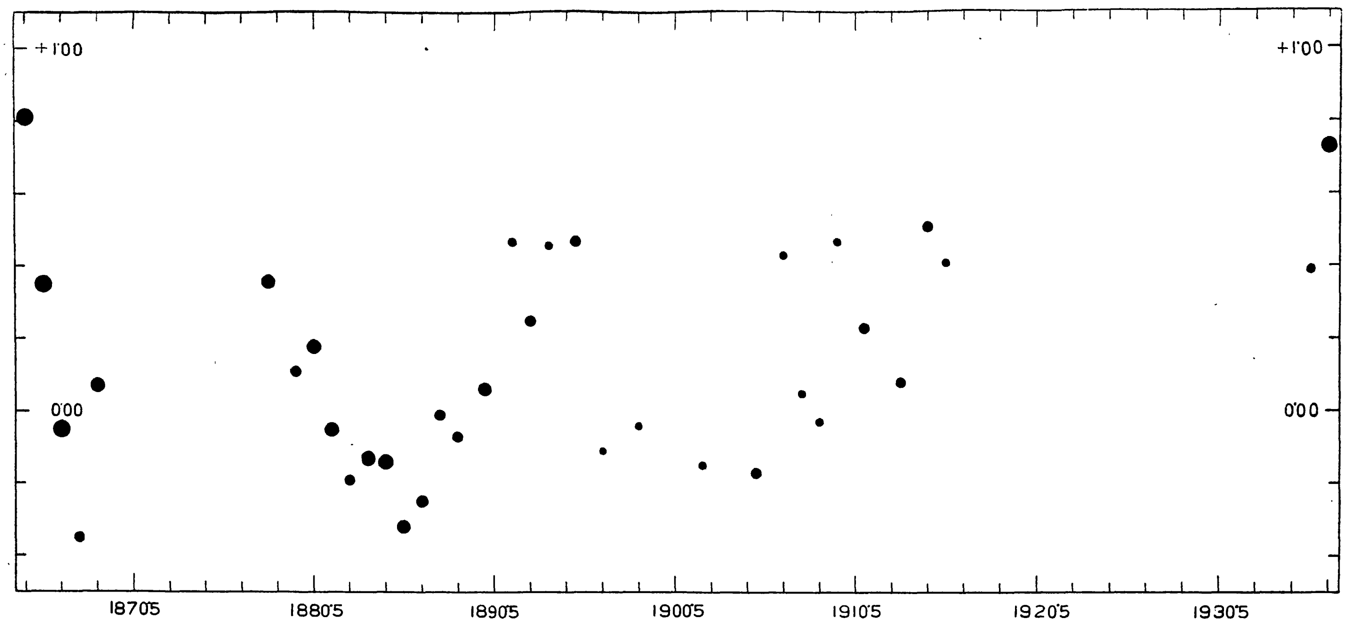
It is a fortunate circumstance that the results are so concordant. The solution *a*, II gives all results about 0s·3 higher than the others, thus the shape of the final curve will in general remain the same. The only results which disagree in the different solutions are Weeder's, but this is not surprising when we look at the very weak connection with the observers of the first period. I have combined the results of the different observers according to their weights after the application of the corrections. The resulting curves are so nearly the same for the four solutions that I give here only the results of solution *b*, I. To the observations of Kam I applied the correction — 0s·11, to those of van Hennekeler + 0s·11 and to my own + 0s·20. There is no way in which these observations can be connected with those of the main period 1877–1915.

The different annual means display a great variety of weights, which makes it difficult to judge the general behaviour. I have therefore combined the results of several consecutive years into one mean so as to make the weight at least twenty. The results are represented in the accompanying figure; the sizes of the dots are proportional to the square roots of their weights. The figure indicates that there appears to be a real variation. Especially the periods 1864–1868 and 1878–1894 appear to show that the variation found is not due to the observers, two different observers giving practically the same curve for each of these periods. It is true that the observers used the same instrumental equipment but it seems very hard to think of anything instrumental that has been overlooked. The rising branch, from 1885 onwards, shows the same trend as Esclangon's figures in his work cited, though the Leiden curve appears to be somewhat steeper. So here two different in-

Δα NFK (solution *b*, I as far as the interval 1877–1915 is concerned)

y	s	y	s	y	s	y	s	y	s
1864·5	+ 0·81 (92)	1881·5	— 0·05 (69)	1891·5	+ 0·47 (31)	1901·5	— 0·10 (6)	1911·5	— 0·01 (19)
65·5	+ 0·35 (93)	82·5	— 0·19 (37)	92·5	+ 0·25 (34)	02·5	— 0·27 (4)	12·5	— 0·16 (17)
66·5	— 0·05 (103)	83·5	— 0·13 (71)	93·5	+ 0·46 (21)	03·5	+ 0·17 (3)	13·5	+ 0·32 (17)
67·5	— 0·35 (39)	84·5	— 0·14 (64)	94·5	+ 0·73 (21)	04·5	— 0·15 (16)	14·5	+ 0·51 (43)
68·5	+ 0·07 (66)	1885·5	— 0·32 (53)	1895·5	— 0·04 (11)	1905·5	— 0·18 (21)	1915·5	+ 0·41 (28)
		86·5	— 0·25 (38)	96·5	— 0·11 (22)	06·5	+ 0·43 (25)		
1877·5	+ 1·16 (14)	87·5	— 0·01 (33)	97·5	— 0·01 (12)	07·5	+ 0·05 (26)	1935·5	+ 0·39 (24)
78·5	+ 0·14 (51)	88·5	— 0·07 (37)	98·5	— 0·08 (3)	08·5	— 0·03 (31)	36·5	+ 0·74 (87)
79·5	+ 0·11 (34)	89·5	+ 0·11 (30)	99·5	— 0·09 (6)	09·5	+ 0·47 (27)		
1880·5	+ 0·18 (67)	1890·5	— 0·02 (16)	1900·5	— 0·22 (11)	1910·5	+ 0·41 (25)		

$\Delta\alpha$ NFK



struments give similar results. This fact especially was a reason why the present investigation was started [1]). The figures given by GERASIMOVIČ seem to indicate that the Poulkovo observations of 1865 do not agree with our results as the general trend of the former is uncertain. The Poulkovo observations of 1885, like ours, are lying on a descending branch.

I am sorry to state that the results which I obtained did not fulfil our hope of finding a regular variation. I would only draw the following conclusions from my figures while I first want to emphasize the fact that the observations after 1894 have a lower intrinsic weight than those before that year, owing to the irregular distribution of the observers.

If there exists a periodical term in the position of Polaris, the period seems nearer to 15 years than to 29·6 years as is demanded by the spectroscopic observations. A period of 15 years could justify the figures of 1935–1936 on a rising branch but I would not go so far as to extrapolate the curve, indicated by the annual means from 1877 till 1895, forward till 1935 or even back to 1868. Even this first period with a very high weight cannot help in this matter. It appears quite unlikely that the results could be changed materially by a correction to the constant of nutation. The observations do not indicate an appreciable error in the proper motion. Finally I believe that some light might be thrown on this question if a small number of plates could be taken with an instrument of long focal length, well divided over the year and during several consecutive years.

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[1]) WEEDER's figures given by KLINKENBERG were based on the observations of E. BAKHUYZEN and WILTERDINK and are slightly different from mine for several reasons apart from the one that I incorporated the results of more observers. I have used the second approximation of the azimuth of the instrument and of the clock error, which had been computed already by WEEDER, but which had not yet been applied. I have counted each culmination only once whereas WEEDER has assigned double weight to the few observations performed with and without reversing prism. Furthermore, WEEDER computed the annual inequality from all quarterly means, neglecting a possible run in the $\Delta\alpha$ while the figures given above are based on those years only where all quarters had given a result.

Finally, WEEDER's annual means extend from July 1 till June 30, while in the present work they extend from January 1 till December 31.

Note added in proof. I have used the material up till 1895 to find out whether some causes, hitherto overlooked, could have been responsible for the variation found. One of the causes could be refraction anomaly, though this seems rather unlikely. The meteorological conditions averaged over one year differ from one year to another far less than the ordinary seasonal differences. The quarterly means not corrected for the annual inequality show convincingly for the 3rd and 4th quarter the same behaviour as the figures given above. For the other quarters, the years 1864–1868 give similar results while those for 1877–1895 are more doubtful. The rather large differences between the different quarter years in this period may well be due to the reduced weights of the individual points.