DET KONGELIGE INDUSTRI-, HÅNDVERK-
OG SKIPSFARTSDEPARTEMENT

NORSK POLARINSTITUTT
(Formerly Norges Svalbard- og Ishavs-undersøkelser)

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Nr. 90

ASTRONOMICAL OBSERVATIONS ON HOPEN

BY

HANS HENIE

OSLO
I KOMMISJON HOS JACOB DYBWAD
1948

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„ 3. WERENSKIOLD, W. and I. OFTEDAL, *A burning Coal Seam at Mt. Pyramide, Spitsbergen.* 1922. Kr. 1,20.
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A. W. BRØGGERS BOKTRYKKERI A/S

Contents.

Introductory.

1. The island Hopen in the Arctic Ocean has been described in "Skrifter om Svalbard og Ishavet" Nr. 10 by Thor Iversen. In this publication the author gives a survey of the various maps which in the course of time have been made of the Arctic Ocean. The position of Hopen changes from one map to the other and all these positions have been collected on a general survey map, showing in all 8 different positions. The latest of these positions has been laid down by Thor Iversen based on two series of observations of the sun's altitude made in August 1924. The observations of altitude have been calculated by B. Caspersen and discussed by W. Werenskiold in a supplementary note. Werenskiold finds a geographical latitude of $76^\circ 34'$ and a geographical longitude of $25^\circ 6',3$ east of Greenwich, and adds that the longitude is well determined, but there is still some uncertainty as to the latitude. These co-ordinates apply to Husdalen in the southern part of the island.

As Norges Svalbard- og Ishavs-undersøkelser have started the surveying of Hopen, and as there is a greater demand for a more accurate position of the island after the establishment of a meteorological station in connection with a wireless station, it became necessary to determine its position once more. On the request of the leader of the Svalbard Office, Dr. Anders K. Orvin, the author of the present treatise, Dr. Hans Henie, undertook to make the necessary observations and calculations in order to carry out a sufficiently exact determination of a point on which the survey of the island could be based, and which could be used for laying down the exact position of the island on the map.

2. The astronomical station. On July 10th, 1947 the M/S "Minna", chartered by Norges Svalbard- og Ishavs-undersøkelser, landed a party of topographers on the east coast of Hopen under the leadership of T. Askheim as well as H. Henie with his instruments for astronomical observations. The expedition stayed on the island until the 12th September. When selecting the site for the astronomical station one had to consider the visibility to Koefoedodden on the south coast, where a concrete foundation for a trigonometrical signal had been built previously. This foundation should now serve as a meridian mark.

One also had to consider that the station was situated so that it could be directly connected to the geodetic net, and finally it had to be in the vicinity of the wireless station at Husdalen, where the chronometer and the instruments were kept, and were a room had been placed at the disposal of the observer.

A point abt. 55 m to the south of the southernmost building of the wireless station was selected. The point is on the same marine terrace as the meteorological station, and here, where the ground was firm and dry, we dug down into the frozen ground where the foundation for the observation pillar was erected. The pillar is of concrete, abt. 80 cm above the surface of the ground, square 50 by 50 cm and provided with a copper bolt fastened in the centre of the pillar. Three steel plates with groves for the foot screws of the instrument were also placed in the concrete on the top of the pillar. Around the pillar we built a hut propped up by drift wood. At a distance of 18 m west of the pillar a copper bolt was imbedded in a concrete block at the ground level for greater safety. The area was surveyed by the topographer Askheim.

3. Instruments. The instruments used were lent by Norges Geografiske Oppmåling, Oslo. They consisted of an old universal instrument, the so-called Olsen small microscope-theodolite, a magnetic declinometer and a sidereal time chronometer. The universal instrument has a horizontal circle with microscopes and is read by estimation to one second. Its vertical circle, fitted with verniers, is read to 10″. The telescope has a broken axis and by means of simple mechanism it can be reversed in the bearings. It has a filament, specially designed for trigonometrical observations. There is only one horizontal thread, whereas the vertical thread in the centre is double, and has on each side two threads, so that the filament consists of 6 threads in all for the observation of transits. The instrument has no ocular-micrometer. It is provided with a striding level to be mounted on the horizontal axis, and another level attached to the verniers of the vertical circle. The value of one division of the striding level is 4″.

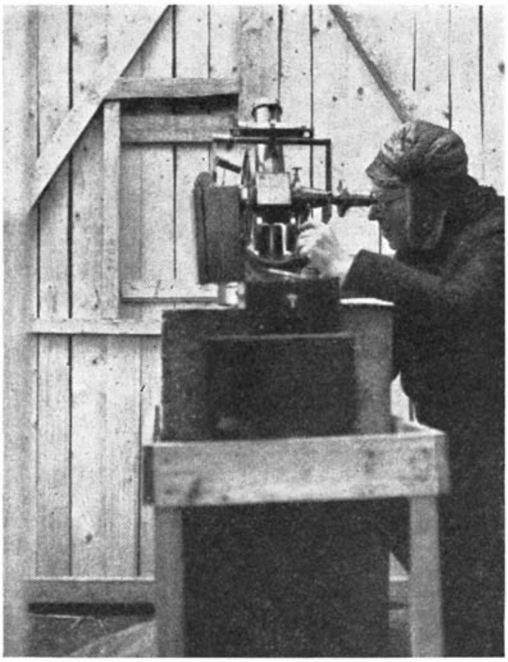
The chronometer which is adjusted for sidereal time is an ordinary chronometer of the type used on board ships. It has been made by Aug. Michelet, Oslo.

A description of the declinometer will be given in the chapter: Magnetic Declination.

4. The programme for the observations. The four problems we had to solve were:

1. Determination of the geographical longitude by means of star transits in the meridian and the time signals by wireless.
2. Determination of the latitude by means of star transits in the prime vertical.

The meteorological station in Husdalen, Hopen.
Astronomical station to the right.
Th. Askheim phot. 29/8 1947.



Dr. H. Henie in the astronomical station.
Th. Askheim phot. 29/8 1947.

3. Determination of azimuth of an object near the meridian by observations of the Polar Star.
4. Determination of the magnetic declination by observations of the sun.

In order to carry through this programme on the island Hopen we had, when planning the work, to consider the difficulties which are always connected with the observation of stars in the Arctic as well as the special difficulties we were likely to encounter on Hopen. These difficulties are due to the bright nights and the climate.

Only few stars can be observed at full daylight and with a small instrument. Even when the sun is low, one cannot count on observing stars of smaller magnitude than 2.5 m, and when the sun is near the meridian even the brightest stars will be invisible against the bright sky. Thus there will always be a comparatively long interval between the observations of stars, and it will be almost impossible to carry through a continuous series of observations. Provided one could count on a cloudless sky for some length of time it would, however, be feasible to follow some sort of a plan, but when a cloudless sky is seldom seen, the chances of making satisfactory observations is even further reduced. The only thing to do under such conditions is to keep the instrument in constant readiness, and as soon as the weather allows observations to be made, one must try to observe as many stars a possible.

The prevailing wind on Hopen comes from the northeast and always brings a heavily clouded sky, generally accompanied by fog and drizzle. A clearing of the sky can only be expected when the wind is north or north-west, especially by strong wind, and a wind from these directions never lasts long. On the east coast of the island there is also another obstacle to cope with, viz. the fog in the afternoon on clear days. Currents of air are coming down the slopes in the west, and as soon as the sun is low in the sky, they bring thick fog, which soon covers land and sea. Even on clear days when conditions seemed favourable for observations, the air appeared to be hazy, and the sky, seen through the ocular, presented itself absolutely white to the eye, so that no stars could be discerned. The unfavourable weather conditions in summer on Hopen are illustrated by the fact that during the 8 weeks we stayed on the island we had only eighteen hours allowing us to make our observations, but in the course of this short span of time we carried through the programme for the observations.

When preparing for the observations on Hopen we tried to make such arrangements that everything was ready for making observations at any time of the day. For this purpose pertinent data for stars were compiled in two tables, one pertaining to culminating stars and containing the meridian altitudes for 80 culminations, and one pertaining to stars in the prime vertical and containing the computed time and altitude at transit across the centre thread and the outer side thread of the filament, also for 80 passages. In addition we prepared a table for stars with great transit altitude and a transit time near to β Ursae Minoris. This last table was intended for observations according to the Bessel Method, i. e. observation of the same star in east and west and reversing the instrument between the transits.

Determination of Geographical Longitude.

5. Observations of transits in the meridian were taken between 6.00 p. m. on August 22nd and 1.30 a. m. on August 23rd, G. M. T. At noon on August 22nd there was a northwest breeze, partly clouded with drifting clouds and fog. In the afternoon the sky gradually became clear. A thin veil extinguished the weak stars at daylight. These observations were made in the course of the evening and the night.

Table 1.

Transit Observations in the Meridian 22nd—23rd August.

		I	II	III	Center	IV	V	VI
		m s	m s	m s	h m s	m s	m s	m s
α Lyrae........	E	52 53,5	53 39,0		16 54 21,0		55 2,0	55 43.5
γ Cygni	E	38 2.0	38 48,4		18 39 31,2		40 13,0	40 55,0
α Cygni	E	57 9,5	57 59,6		18 58 46,0		59 31,0	60 17,4
α Cephei	E	33 45,0	35 1,5	36 9,5	19 36 13,0	36 16,5	37 21,4	38 31,4
α U. Maj	E	22 52,6	21 37,6		21 20 26,0		19 18,7	18 10,0
γ Cephei	E	50 5,5	52 46,8	55 12,8	21 55 18,9	55 25,0		
α Andro	W	26 15,1	25 34,2		22 24 56,7		24 20,6	23 43,6
γ Cassi	W	14 46,0	13 34,0		23 12 26,5		11 26	
β Andro	W	27 24,6	26 41,1		23 26 0,2		25 21,5	24 41,7

The observations were made according to the eye- and ear-method. The distance between the two threads — III and IV — of the double centrethread is so small that transits across both threads can only be measured for slow stars. For stars with greater velocity we observed the position of the star in the centre between III and IV. Observing the γ Cephei we reversed the instrument in order to obtain the transit across two threads with the ocular in a different position. However, we missed the star. Observing γ Cassiopeia we did not find the star till it was close upon thread V, so that we are not quite certain about the exact time. Observations were discontinued at 1.30 a. m., when the Polaris became visible in the field, and the azimuth was determined by the aid of this star.

The transit observations were made under fairly favourable conditions. The noise from the breakers was rather disturbing. Both eye- and ear-observations were carried out with precision and composure.

Table 2.

	W	E		b
				s
α Lyrae	33,5	3,2	+36,7	−0,12
	3,9	34,6	−38,5	
γ Cygni	34,3	3,5	+37,8	+0,10
	2,8	33,5	−36,3	
α Cygni	5,0	35,8	−40,8	−0,31
	33,4	2,8	+36,2	
α Cephei	34,8	3,9	+38,7	−0,27
	5,9	36,8	−42,7	
α U. Maj	35,9	4,9	+40,8	−0,01
γ Cephei	5,0	36,0	−41,0	
α Androm	35,9	3,1	+39,0	+0,09
γ Cassio	2,4	35,3	−37,7	
β Androm	36,5	3,9	+40,4	+0,01
	3,8	36,4	−40,2	

The readings of the striding level are shown in table 2.

6. The intervals of the filament. The values of the thread intervals previously used for the Olsen small microscope-theodolite appeared to be of no avail. As it turned out to be infeasible to make special observations in order to determine the intervals, these had to be determined by the transit observations at hand. The values in table 3 have been computed from the differences between the centre of the filament, and the side thread, ϑ, expressed by the equation

$$i = \vartheta \cos \delta$$

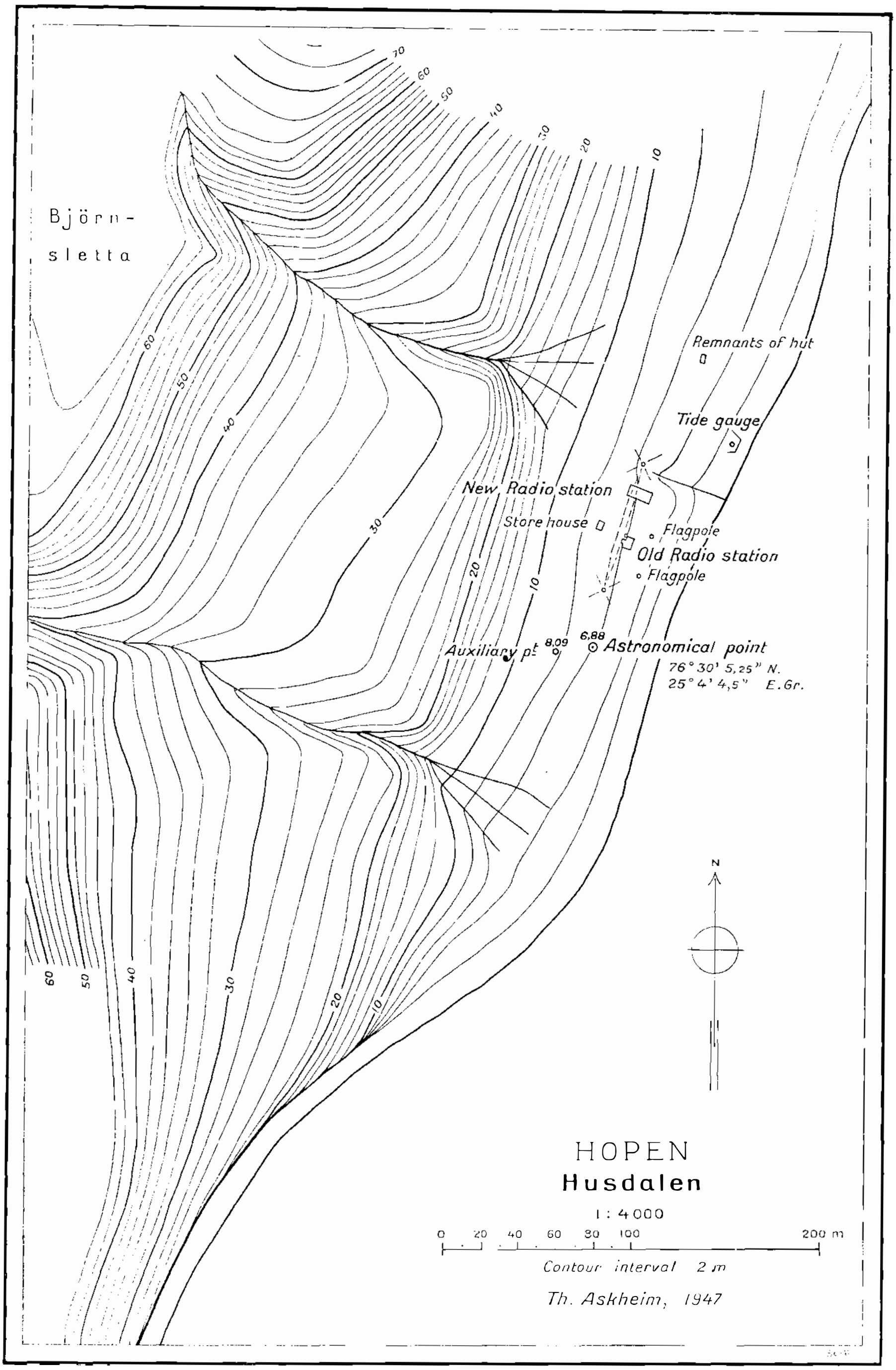
Table 3.

Thread	i	log i
	s	
I	68,53	1,83588
II	33,06	1,51930
V	31,79	1,50229
VI	64,20	1,80754

The values refer to the upper culmination, ocular east.

The two central threads are not shown in this table; we used the mean of the transits of these threads. The values previously used in 1923 are about one half of those which were determined in 1947.

Based on the above values the transit observations have been reduced to the centre of the filament with the result shown in table 4.



Björn-
sletta
Remnants of hut
Tide gauge
New Radio station
Store house
Flagpole
Old Radio station
Flagpole
Auxiliary pt
8,09
6,88
Astronomical point
76° 30' 5,25" N.
25° 4' 4,5" E.Gr.
N
HOPEN
Husdalen
1 : 4000
0 20 40 60 80 100 200 m
Contour interval 2 m
Th. Askheim, 1947

Table 4.

			mag	I	II	M	V	VI	Mean	b	
				h m s	s	s	s	s	h m s	s	
1	α Lyrae	E	0,1	16 54 21,3	21,4	21,0	21,2	21,2	16 54 21,22	−0,12	1
2	γ Cygni	E	2,3	18 39 31,6	31,6	31,2	31,4	31,1	18 39 31,38	+0,10	2
3	α Cygni	E	1,3	18 58 46,6	46,4	46,0	46,0	46,5	18 58 46,30	−0,31	3
4	α Cephei ...	E	2,6	19 36 12,6	12,8	13,0	12,9	13,0	19 36 12,86	−0,27	4
5	α U. Maj ...	E	2,0	21 20 26,5	27,1	26,0	26,8	26,9	21 20 26,66	−0,01	5
6	γ Cephei ...	E	3,4	12 55 18,1	17,6	18,9			21 55 18,20	−0,01	6
7	α Androm...	W	2,2	22 24 56,9	56,5	56,7	56,9	56,9	22 24 56,78	+0,09	7
8	γ Cassio....	W	1,6	23 12 27,1	27,0	26,5			23 12 26,90	+0,09	8
9	β Androm...	W	2,4	23 26 0,6	0,6	0,5	0,4	0,4	23 26 0,54	+0,01	9

Co-ordinates of the stars by culmination Hopen, Nautical Almanac 1947, are shown in table 5.

Table 5.

		RA	Decl.	
		h m s		
1	α Lyrae	18 35 10,38	38° 44′ 10″	
2	γ Cygni	20 20 21,66	40 5 20	
3	α Cygni	20 39 39,68	45 5 34	
4	α Cephei	21 17 21,64	62 21 46	
5	α Urs. Maj.	23 0 27,85	117 57 41	S.P.
6	γ Cephei	23 37 13,62	77 20 12	
7	α Androm	0 5 40,69	28 48 0	
8	γ Cassiop	0 53 31,94	60 25 48	
9	β Androm	1 6 47,39	35 20 30	

7. Correction of chronometer according to Greenwich Sidereal Time (G. S. T.) was determined by means of wireless signals. The intention was to use the signals from Bureau International de l'Heure, at Pontoise. These signals are sent over one long-wave and the short-wave bands, according to the new ONOGO-system and the rhythmic system. We did not bring any receiver sets with us to Hopen. We had in advance made inquiries whether the meteorological station disposed of the necessary wireless sets, and we were told that they had sets for all wave lengths. It appeared, however, that the wireless station on Hopen was out of order. The aggregate had been broken down and there was very little electricity left for the receivers. Not till the new crew arrived at the station with new machinery did the station come into normal operation.

The receiver on the station was unable to take the time signal in the long wave band. The short wave, 40.38 m, gave the best results, but conditions were not favourable for reception. The signals were as a rule disturbed by strong telegraphic signals on a neighbouring frequency.

The rhythmic signals could only seldom be discerned without great disturbances. The registration of the ONOGO-signals was somewhat better, and the correction of the chronometer was, therefore, based on these signals. Before and after the star observations on August 21st and 23rd the correction of the chronometer was based on the entire ONOGO-signals. Before the departure, during the voyage and our stay on the island, the chronometer was continually checked by the time signals from Oslo.

The correction and the rate of the chronometer on the days of observation were checked by series of 10 ONOGO-signals and gave this result:

Aug. 21st	$19^h\ 59^m\ 0^s$	Aug. 23rd	$19^h\ 59^m\ 0^s$ G. M. T.
»	17 56 10.44	»	18 4 3.55 G. S. T.
Chronometer	17 54 39.74	»	18 2 31.29
Correction	+ $1^m\ 30^s.70$		+ $1^m\ 32^s.26$

Chronometer correction Aug. 21st	$17^h\ 56^m\ 10^s$	= $1^m\ 30^s.70$
» 23rd	18 4 3	= 1 32 .26
rate in	$48^h\ 7^m\ 53^s$ =	$1^s.56$
» »	$48^h.1314$	
rate per hour =	$0.^s03241$ (8.51066)	

As the first star transit was observed on Aug. 22nd $16^h\ 54^m$ G. S. T. we have chosen as a starting point for the correction: Aug. 22nd $16^h\ 0^m$ which gives us the following equation for the chronometer on the days of the observations:

$$\text{Correction} = +\ 1^m\ 31^s.42 + (T - 16^h) \times 0^s{,}0324$$

Correction of the meridian observations is shown in table 6.

Table 6.

	T	T—16	Rate	Corr.
	h m s	h	s	m s
1	16 54 21	0,906	0,03	+1 31,45
2	18 39 32	2,659	0,09	51
3	18 58 47	2,979	0,10	52
4	19 36 13	3,604	0,10	52
5	21 20 27	5,341	0,17	59
6	21 55 18	5,922	0,19	61
7	22 24 57	6,416	0,21	63
8	23 12 27	7,208	0,23	65
9	23 26 1	7,450	0,24	66
	16 0 0		1 31,42	

As a verification of the chronometer correction as shown in this time table we may mention the value of the correction derived from the signals from Oslo. As we have been unable to obtain any information as to the accuracy one may ascribe to the Oslo signals, they have been left out of consideration in the following calculations. However, they give us a determination of time entirely independent of the ONOGO-signals, and may, therefore, serve as a verification and a control that no important mistakes have been made in the above computation of the correction.

	Signals from Oslo	Chronometer	Correction
Aug. 21st	$9^h\,55^m\,51.^s75$ G. S. T.	$9^h\,54^m\,21.^s2$	$1^m\,30.^s55$
» 23rd	10 3 44. 86	10 2 12. 6	1 32. 26
	$48^h\;7^m\,53.^s11$	Rate	1. 71

Computed correction Aug. 22nd $16^h\,0^m$ Oslo 1^m 31.60
ONOGO 1^m 31.42
Difference $0.^s18$

The result corresponds to the accuracy with which an isolated signal can be discerned. The accuracy of the chronometer correction has thus been confirmed.

8. The constants of the instrument. The collimation constant was checked by pointing the instrument towards the meridian mark at the Koefoedodden. As the instrument is not fitted with an ocular micrometer the constant could not be determined, but its value was reduced as much as possible. The collective discussion of the observations showed that it was $c = 0^s.537$.

The inclination of the horizontal axis, b, was by each observation determined by means of the striding level. The value of one division of the level is 4″. It was difficult to use the level as it must be absolutely vertical to give a reliable result. The pivots of the axis were examined, but no inequality in the pivots was found.

Our plan was to orientate the instrument in the meridian by corresponding solar altitudes, considering the uncertainty as to the exact position of the island Hopen. But as the sun was visible only at very short intervals the instrument had to be orientated from single observations of the sun. On August 6th and 11th we had glimpses of a clear sky between drifting clouds and we observed a passage of Vega and also made an uncompleted observation of Polaris. They both showed that the instrument had to be turned slightly to the west. The later complete transit observations showed that the instrument was now definitely to the west of the meridian, so that the azimuth constant was rather great. For the reduction of the observations we used a value $a = -74^s.5$ which through the normal equations got a correction of $-0^s.410$. But even if the azimuth is considerable it is well within the allowed limit. This value was later confirmed by a direct azimuth determination by means of Polaris.

9. Calculation of the equations. The calculation of the transit observations are made according to the usual method with corrections for the instrument constants. The transit time, corrected in accordance with the correction and the rate of the chronometer and the aberration which amounts to

$$-0.^{s}0049.\ \sec\delta$$

is dessignated by T.

The reduction equation is:

$$\alpha = T + \Delta T + a\ \sin(\varphi - \delta).\ \sec\delta + b\ \cos(\varphi - \delta).\ \sec\delta + c\ \sec\delta$$

where the last term changes its sign according to ocular east or west.

We give the equation this form

$$\alpha = T + \Delta T + A.a + B.b + C.c$$

where we put

$$\Delta T = \vartheta + \Delta\vartheta$$
$$a = a_0 + \Delta a$$

and obtain

$$\alpha = T + \vartheta + A.a_0 + B.b + \Delta\vartheta + A.\Delta a + C.c$$

We can then calculate

$$T + A.a_0 + B.b = t \text{ whence}$$
$$A.\Delta a + C.c + \vartheta - (\alpha - t) = 0$$
$$\text{Putting } \vartheta - (\alpha - t) = w$$

we get this equation of condition for each passage

$$A.\Delta a + C.c + \Delta\vartheta + w = 0.$$

This forms the basis for the normal equation.

Table 7. *Transits in the Meridian*

		1 α Lyrae e	2 γ Cygni e	3 α Cygni e	4 α Cephei e
Assumed φ 76°30′0″		38° 44′ 10″ 37 45 50	40° 5′ 20″ 36 24 40	45° 5′ 34″ 31 24 26	62° 21′ 46″ 14 9 14
	A	0,785	0,776	0,738	0,527
	B	1,013	1,052	1,209	2,090
	C	1,282	1,307	1,417	2,156
	b	$-0{,}^{s}12$	$+0{,}^{s}10$	$-0{,}^{s}31$	$-0{,}^{s}27$
Observation time		$16^{h}54^{m}21{,}^{s}22$	$18^{h}39^{m}31{,}^{s}38$	$18^{h}58^{m}46{,}^{s}30$	$19^{h}36^{m}12{,}^{s}86$
Chronometer correction		+ 1 31, 45	1 31, 51	1 31, 52	1 31, 52
Aberration		— 1	— 1	— 1	— 1
	T	16 55 52, 66	18 41 2, 88	19 0 17, 81	19 37 44, 37
Assumed a_0 $-74^{s},5$	Aa_0	−58, 49	−57, 80	−54, 99	−39, 27
	Bb	− 0, 12	+ 0, 10	− 0, 37	− 0, 56
	t	16 54 54, 05	18 40 5, 18	18 59 22, 45	19 37 4, 54
	α	18 35 10, 38	20 20 21, 66	20 39 39, 68	21 17 21, 64
	α − t	1 40 16, 33	1 40 16, 48	1 40 17, 23	1 40 17, 10
	ϑ	1 40 16			
	ϑ − (α − t) = w	$-0{,}^{s}33$	$-0{,}^{s}48$	$-1{,}^{s}23$	$-1{,}^{s}10$

Equations of condition

1. $0{,}785\ \Delta a + 1{,}282\ c + \Delta\vartheta - 0{,}^{s}33 = 0$
2. $0{,}776\ \Delta a + 1{,}307\ c + \Delta\vartheta - 0{,}48 = 0$
3. $0{,}738\ \Delta a + 1{,}417\ c + \Delta\vartheta - 1{,}23 = 0$
4. $0{,}527\ \Delta a + 2{,}156\ c + \Delta\vartheta - 1{,}10 = 0$

Table 8.

10. *The normal equations.*

	AA	AC	A	Aw	CC	C	Cw	w
1.	0,616	1,006	0,785	−0,259	1,644	1,282	− 0,423	−0,33
2.	0.602	1,014	0,776	−0.373	1,708	1,307	− 0,627	−0,48
3.	0,545	1,046	0,738	−0,908	2.008	1,417	− 1,743	−1.23
4.	0,207	1,136	0,527	−0,580	4,648	2,156	− 2,372	−1,10
5.	1,994	−3,012	1,412	1,737	4,550	−2,133	− 2,642	+1,23
6.	0,004	−0,306	−0.067	0.196	20,812	4,562	−13,321	−2,92
7.	0,712	−0,963	0,844	0.675	1,302	−1,141	− 0,913	+0,80
8.	0,315	−1,137	0,561	0,550	4,105	−2,026	− 1,986	+0,98
9.	0,651	−0,989	0,807	0,565	1,503	−1,226	− 0,858	+0,70
Sum	5,717	−2,205	6,383	1,603	42,280	4,198	−24,867	−2,35

22nd and 23rd August 1947 Table 7.

5 α Urs.Maj. SP e	6 γ Cephei e	7 α Androm w	8 γ Cassiop w	9 β Androm w
117° 57′ 42″ −41 27 42	77° 20′ 12″ −0 50 12	28° 48′ 0″ 47 42 0	60° 25′ 48″ 16 4 12	35° 20′ 30″ 41 9 30
1,412 −1,598 −2,133	−0,067 4,561 4,562	0,844 0,768 1,141	0,561 1,947 2,026	0,807 0,923 1,226
−0,s01	−0,s01	+0,s09	+0,s09	+0,s01
21h20m26,s66 1 31, 59 + 1	21h55m18,s20 1 31, 61 − 2	22h24m56,s78 1 31, 63 − 1	23h12m26s,90 1 31, 65 − 1	23h26m 0,s54 1 31, 66 − 1
21 21 58, 26	21 56 49, 79	22 26 28, 40	23 13 58, 54	23 27 32, 19
−1 45, 20 + 0, 02	+4, 96 −0, 05	−1 2, 98 + 0, 07	−41, 79 + 0, 17	−1 0, 11 + 0, 01
21 20 13, 08 23 0 27, 85	21 56 54, 70 23 37 13, 62	22 25 25, 49 24 5 40, 69	23 13 16, 92 24 53 31, 94	23 26 32, 09 25 6 47, 39
1 40 14, 77	1 40 18, 92	1 40 15, 20	1 40 15, 02	1 40 15, 30
+1,s23	−2,s92	+0,s80	+0,s98	+0,s70

5. $1{,}412\,\Delta a - 2{,}133\,c + \Delta\vartheta + 1{,}23 = 0$
6. $-0{,}067\,\Delta a + 4{,}562\,c + \Delta\vartheta - 2{,}92 = 0$
7. $0{,}844\,\Delta a - 1{,}141\,c + \Delta\vartheta + 0{,}80 = 0$
8. $0{,}561\,\Delta a - 2{,}026\,c + \Delta\vartheta + 0{,}98 = 0$
9. $0{,}807\,\Delta a - 1{,}226\,c + \Delta\vartheta + 0{,}70 = 0$

The equations are

$$5{,}717\,\Delta a - 2{,}205\,c + 6{,}383\,\Delta\vartheta + 1{,}603 = 0$$
$$-2{,}205\,\Delta a + 42{,}280\,c + 4{,}198\,\Delta\vartheta - 24{,}867 = 0$$
$$6{,}383\,\Delta a + 4{,}198\,c + 9{,}000\,\Delta\vartheta - 2{,}350 = 0$$
$$41{,}430\,c + 6{,}660\,\Delta\vartheta - 24{,}249 = 0$$
$$6{,}660\,c + 1{,}874\,\Delta\vartheta - 4{,}140 = 0$$
$$0{,}803\,\Delta\vartheta - 0{,}242 = 0$$

The values sought are then

$$\Delta\vartheta = \overset{s}{0{,}301}$$
$$c = 0{,}537$$
$$\Delta a = -0{,}410$$

11. The geographical longitude. Substituting the values of a, c, and $\Delta\vartheta$ in the original equations of condition, we find the residuals v as shown in table 9.

Table 9.

	1	2	3	4	5	6	7	8	9
A.a	−0,32	−0,32	−0,30	−0,22	−0,58	+0,03	−0,35	−0,23	−0,33
C.c	+0,69	+0,70	+0,76	+1,16	−1,15	+2,45	−0,61	−1,09	−0,66
Sum	+0,37	+0,38	+0,46	+0,94	−1,73	+2,48	−0,96	−1,32	−0,99
α—t	16,33	16,48	17,23	17,10	14,77	18,92	15,20	15,02	15,30
Diff.	15,96	16,10	16,77	16,16	16,50	16,44	16,16	16,34	16,29
$\vartheta + \Delta\vartheta$	16,30	16,30	16,30	16.30	16,30	16,30	16,30	16,30	16,30
....	+0,34	+0,20	−0,47	+0,14	−0,20	−0,14	+0,14	−0,04	+0,01

Thus we find the probable error as shown in table 10.

Table 10.

v	vv
+0,34	0,1156
+0,20	0,0400
−0,47	0,2209
+0,14	0,0196
−0,20	0,0400
−0,14	0,0196
+0,14	0,0196
−0,04	0,0016
+0,01	0,0001
[vv]	0,4770

As we have 9 equations with 3 unknown quantities, the probable error at the computation of the chronometer correction according to the local sidereal time of Hopen will be:

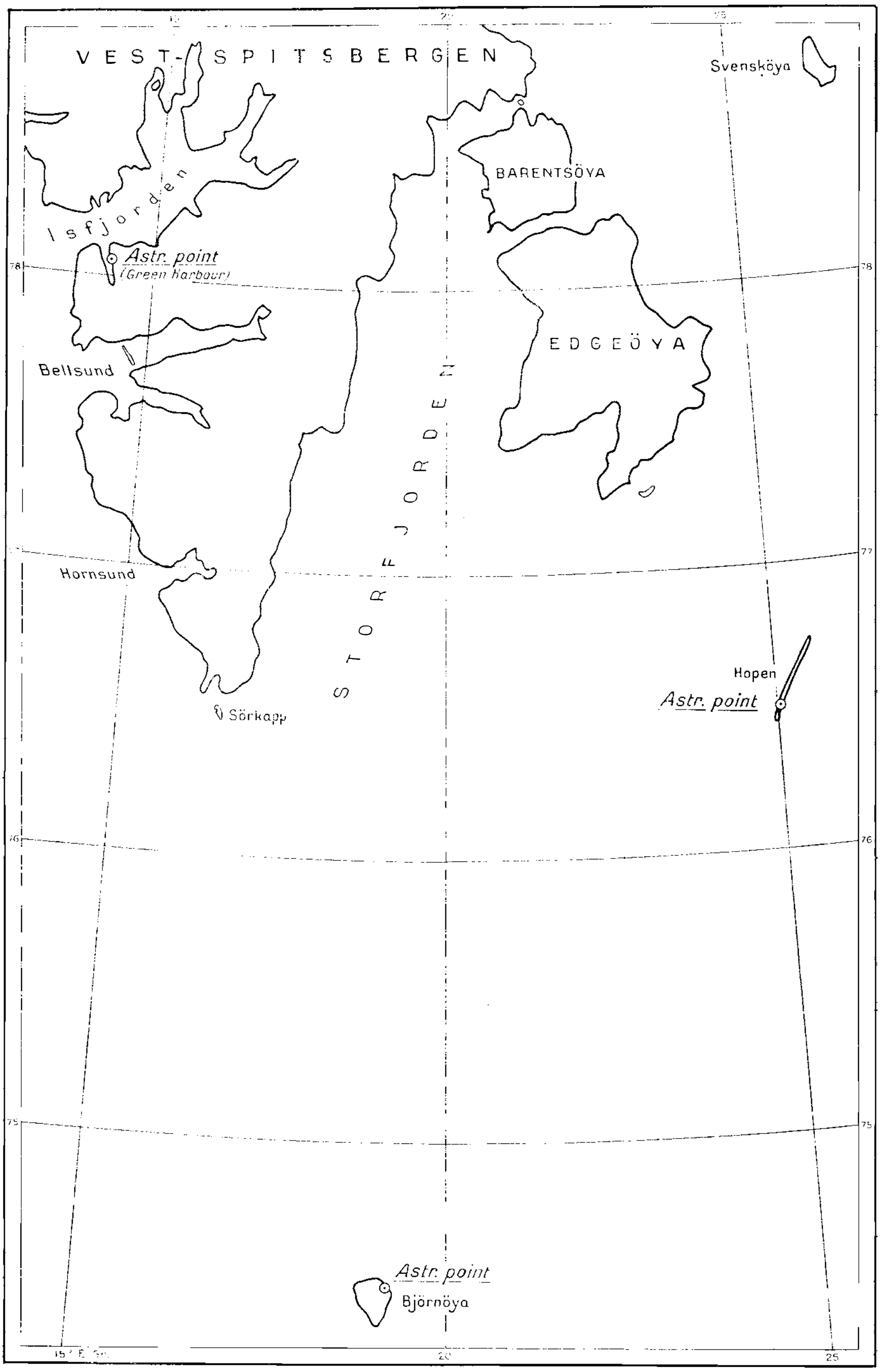
$$\varepsilon = \pm\, 0.67 \sqrt{\frac{[v\,v]}{(9-3)\cdot p}}\; \cos\varphi \quad \text{where } p = 0.803$$

$$\varepsilon = \pm\, 0.^{s}049$$

The factor $\cos\varphi$ has been included to have the probable error of the geographical longitude expressed in seconds of the great circle in the same way as the probable error for the latitude.

The values computed above give this result:

$$\begin{aligned} \vartheta &= 1^{h}\,40^{m}\,16^{s},00 \\ \Delta\vartheta &= \qquad\quad +\,0\;,30 \\ \hline \Delta T &= 1^{h}\,40^{m}\,16^{s},30 \pm 0.^{s}049 \end{aligned}$$


VEST-SPITSBERGEN
Svensköya
Isfjorden
BARENTSÖYA
Astr. point
(Green Harbour)
EDGEÖYA
Bellsund
STORFJORDEN
Hornsund
Hopen
Astr. point
Sörkapp
Astr. point
Björnöya
78
77
76
75
20
25

In the longitudinal difference between Greenwich and Hopen there will also be included an error depending on the accuracy of the registration of the Greenwich sidereal time. We have no exact figures here so it can only be estimated. As all time signals are registered by the ear only without any technical facilities one may, to be on the safe side, reckon with an average error of $0.^s2$. The total probable error in the longitudinal difference will then be:

$$\varepsilon_1 = 0.67\sqrt{\frac{[vv]}{(9-3)\cdot 0.803} + 0.2^2}\ \cos\varphi$$

$$\varepsilon_1 = 0.^s058$$

The final result will then be:

The longitudinal difference Greenwich-Hopen 1947

$1^h\,40^m\,16.^s30 \pm 0.^s058 \qquad (25^\circ\,4'\,4.''5 \pm 0.''87)$

Determination of Geographical Latitude.

12. Observations in the prime vertical were made on August 23rd between 17^h00 and 23^h00 G. M. T., under the same conditions as for the meridian observations. The work had to be discontinued as the sky became more and more cloudy as the night advanced. Gradually the entire sky was covered and we had fog and rain.

The preliminary work for the observations in the prime vertical also planned a special observation of β Ursae Minoris at its passage both east and west with a reversal of the instrument. The declination for β Ursae Minoris is $74^\circ\,22'$ and it is 8° from zenith in the prime vertical, and there is no star of any avail, which comes nearer. The declination for γ Ursae Minoris is 72° and it passes at 12° from zenith, but it was so feeble that it was difficult to discern it. As late in the summer as the end of August, however, it was impossible to make observation of the passage to the east, as the sun was so near that the sky was too bright. The passage to the west was observed. The work, therefore, had to be limited to observations of the stars which we could discern. The transits of four stars were observed, one zenith star to the west and three stars to the east.

Transit observations in the prime vertical on August 23rd between 17^h00 and 23^h00 G. M. T.

Table 11.

Ocular N.	I	II	III	M	IV	V	VI
	m s	m s	m s	h m s	m s	m s	m s
β Urs.Min w	22 5	17 51	13 58	15 13 49	13 40		
γ Androm e		9 25		19 10 11,5		10 56,5	11 43,0
δ Cassiop e........	17 21,0	18 40,8		19 19 55,0		21 7,0	22 20,5
α Persei e.........	43 49,5	44 47,9		20 45 42,5		46 35,4	47 29,2

The co-ordinates of the stars on August 23rd.

Table 12.

Nautical Almanac.

	R. A.	Decl.
1. β Urs. Min ...	$14^h\ 50^m\ 47,^s79$	74° 22′ 30,″3
2. γ Androm	2 0 40, 04	42 4 38, 1
3. δ Cassiop	1 22 22, 16	59 57 37, 3
4. α Persei	3 20 33, 20	49 40 26, 2

In order to examine the influence upon the computed latitude of a possible uncertainty about the declination of the star or about the time observed, the equation referring to the prime vertical is being differentiated

$$\mathrm{tg}\,\varphi = \mathrm{tg}\,\delta \cdot \sec t$$

which gives

$$d\,\varphi = \frac{\cos\varphi}{\cos\delta\cos z}\cdot d\,\delta + \sin\varphi\cdot \mathrm{tg}\,z\cdot dt$$

If this formula is applied to the stars observed we find the following values giving information about the applicability of the observation method:

Table 13.

	An uncertainty of 0,″1 in the declination gives an uncertainty in the latitude of:	An uncertainty of $0,^s1$ in time gives an uncertainty in the latitude of:
β Urs.Min	0,″11	0,″21
γ Androm	0, 22	1, 53
δ Cassiop	0, 19	0, 75
α Persei	0, 22	1, 15

The first part of the differential formula shows two things. Firstly, because of the factor cos φ an uncertainty in the declination of the star will be less appreciable in polar regions than on lower latitudes. The figures show that an error in the declination of a star like γ Androm, despite its distance from zenith of more than 53°, will not be more than doubled. If, therefore, we keep to stars whose exact declination is known, there is no reason to leave out stars passing the prime vertical even at a considerable distance from zenith.

The second part clearly shows the advantage of using zenith stars, but the figures also show that even other stars can be used safely. There is also another fact speaking in favour of using stars at a greater distance from zenith, namely the fact that in polar regions, such as the Svalbard (Spitsbergen) region, zenith stars will always have a great declination. The result of this again will be that zenith stars pass very slowly across the field of the ocular. A star like β Ursae Minoris, passing 8° from zenith, takes more than 17 minutes from the first to the last thread. This slow passage across the threads of the filament makes the time observation less exact. This is especially felt when the threads are not particularly fine, as was the case with the instrument which we used. For stars with a smaller declination and a swifter movement the time observations are more reliable, a fact speaking in favour of using such stars.

Also another circumstance complicates the making of exact time observations in the prime vertical, viz. the oblique passage of the stars through the field. This is especially noticeable for stars with a great declination. A star like β Ursae Minoris falls off as much as 40′ during its passage in the west.

Both these circumstances make it desireable to have a chronograph to hand for observations in the prime vertical.

13. Reduction of the observations in the prime vertical. The chronometer correction was on August 23rd $18{,}^{h}068 + 1^{m}\,32{,}^{s}26$ with a rate $= 0{,}^{s}0324$ per hour.

The correction for passages through the centre of the filament is:

		rate	correction
1, $15^{h}\,13{,}^{m}8 = 18{,}^{h}07$	$-\,2{,}^{h}74$	$-\,0{,}^{s}09$	$1^{m}\,32{,}^{s}17$
2, 19 10, 2	+ 1, 10	+ 0, 04	30
3, 19 19, 9	+ 1, 29	+ 0, 04	30
4, 20 45, 7	+ 2, 69	+ 0, 09	35

As the transit through all threads of the filament was not achieved for all stars, a simplified, summary system of reduction cannot be applied. We shall, therefore, have to reduce each individual transit to the centre of the filament. The transit is reduced according to the formula:

$$\vartheta = \frac{i}{\sin\varphi \cos\delta \sin(\vartheta - \frac{1}{2}\vartheta)}$$

i is the distance of each thread from the centre, for ϑ we use the hour angle for the transit through the centre of the filament (M).

ϑ on the right side is approximately like the difference between the transit time through centre and side thread.

Table 14.

Observations			Red.	Red. time	Mean values
		h m s	m s	h m s	h m s
β Urs.Min.	IV	15 13 40		15 13 49,0	
	III	13 58		13 49,0	
	II	17 51	4 0,2	13 50,8	
	I	22 5	8 10,2	13 54,8	15 13 50,90
γ Androm	II	19 9 25,0	47,0	19 10 12,0	
	M	10 11,5		10 11,5	
	V	10 56,5	45,1	10 11,5	
	VI	11 43,0	1 31,3	10 11,7	19 10 11,68
δ Cassiop	I	19 17 21,0	2 34,7	19 19 55,7	
	II	18 40,8	1 14,8	19 55,6	
	M	19 55,0		19 55,0	
	V	21 7,0	1 12,1	19 54,9	
	VI	22 20,5	2 25,7	19 54,8	19 19 55,20
α Persei	I	20 43 49,5	1 53,7	20 45 43,2	
	II	44 47,9	54,8	45 42,7	
	M	45 42,5		45 42,5	
	V	46 35,4	52,9	45 42,5	
	VI	47 29,2	1 46,7	45 42,5	20 45 42,68

Table 15.

Readings of the level. Inclination b.

	North	South		b
1.	30,1	9,8	+39,9	−0,″6
	10,1	30,5	−40,5	
2. and	7,3	38,2	−45,5	+0, 2
3.	38,3	7,4	+45,7	
4.	36,2	5,3	+41,5	+1, 8
	4,4	35,3	−39,7	

The azimuth of the instrument was at the meridian observations a = —74.^{s}91. Turning the instrument 90° to arrive at the prime vertical, we find the same value for azimuth in this position, but with the opposite sign, in accordance with the usual definition for this constant of the instrument. The value, which should be corrected by means of the normal equations, is rather great, but inside the allowed limit for the application of the usual equations of reduction. The collimation constant of the instrument remains the same as before:

$$c = -0{,}^{s}537 \text{ for ocular north.}$$

14. Equations of condition for the latitude. The computation is made by the aid of the equations for the prime vertical. The approximate value of the latitude, φ_1 and the corresponding zenith distance, z, are found by the formulae:

$$\operatorname{tg} \varphi_1 = \operatorname{tg} \delta \sec t$$
$$\operatorname{tg} z = \operatorname{tg}' t \cos \varphi_1$$

With the correction of the instrument constants the improved latitude will be:

$$\varphi = \varphi_1 + b + c \sec z - a \operatorname{tg} z$$

where tg z has the same sign as tg t.

Table 16.

	1	2	3	4
Observ. time ...	15^h 13^m 50,^{s}90	19^h 10^m 11,^{s}68	19^h 19^m 55,^{s}20	20^h 45^m 42,^{s}68
Cronom. corr. ..	+ 1 32, 17	1 32, 30	1 32, 30	1 32, 35
G. S. T.	15 15 23, 07	19 11 43, 98	19 21 27, 50	20 47 15, 03
Long E Gr.	1 40 16, 30			
Local S.T. Hopen	16 56 39, 37	20 52 0, 28	21 1 43, 80	22 27 31, 33
R. A.	14 50 48, 79	2 0 40, 04	1 22 22, 16	3 20 33, 20
Hour angle	2^h 4^m 49,^{s}58	− 5^h 8^m 39,^{s}76	− 4^h 20^m 38,^{s}36	− 4^h 53^m 1,^{s}87
» in degrees	31° 12′ 23,″70	−77° 9′ 56,″40	−65° 9′ 35,″40	−73° 15′ 28,″05
Decl.	74 22 30, 3	42 4 38, 1	59 57 37, 3	49 40 26, 2
b	− 0,″60	+ 0,″20	+ 0,″20	+ 1,″80
$-a_0$ tg z	− 158, 36	+ 1178, 33	+ 573, 00	+ 887, 24
c sec z	− 8, 13	− 11, 67	− 9, 04	− 10, 26
Sum	− 167,″09	+ 1166,″86	+ 564,″16	+ 878,″78
	− 2′ 47,″09	+ 19′ 26,″86	+ 9′ 24,″16	+ 14′ 38,″78
φ_1	76 32 50, 16	76 10 39, 86	76 20 45, 12	76 15 34, 07
	76 30 3, 07	76 30 6, 72	76 30 9, 28	76 30 12, 85
$-\varphi_0$	76 30 8, 00			
....	−4,″93	−1,″28	+1,″28	+4,″85

Equations of condition

$$-0{,}1409\, \Delta a - \Delta \varphi - 4{,}''93 = 0$$
$$1{,}0487\, \Delta a - \Delta \varphi - 1{,}\ 28 = 0$$
$$0{,}5099\, \Delta a - \Delta \varphi + 1{,}\ 28 = 0$$
$$0{,}7896\, \Delta a - \Delta \varphi + 4{,}\ 85 = 0$$

We introduce:

$$\varphi = \varphi_0 + \Delta\varphi$$
$$a = a_0 + \Delta a$$

where the values $\Delta\varphi$ and Δa are found by a joint computation according to the method of the least squares.

The equation will then be

$$\varphi_0 + \Delta\varphi = \varphi_1 + b + c\sec z - a_0 \operatorname{tg} z - \Delta a \operatorname{tg} z$$
$$-\Delta a \operatorname{tg} z - \Delta\varphi + b - a_0 \operatorname{tg} z + c \sec z + \varphi_1 - \varphi_0 = 0$$

we make

$$+ b - a_0 \operatorname{tg} z + c \sec z + \varphi_1 - \varphi_0 = f$$

and we shall have this equations of condition for all transits:

$$-\Delta a \operatorname{tg} z - \Delta\varphi + f = 0$$

15. The normal equations.

Table 17.

$\operatorname{tg}^2 z$	$-\operatorname{tg} z$	$f \operatorname{tg} z$	$-f$
0,0199	+0,1409	+0,6946	+4,93
1,0998	−1,0487	−1,3423	+1,28
0,2600	−0,5099	+0,6527	−1,28
0,6235	−0,7896	+3,8295	−4,85
2,0032	−2,2073	+3,8345	+0,0800

$$2{,}0032\,\Delta a - 2{,}2073\,\Delta\varphi + 3{,}8345 = 0$$
$$-2{,}2073\,\Delta a + 4{,}0000\,\Delta\varphi + 0{,}0800 = 0$$
$$1{,}5678\,\Delta\varphi + 4{,}3052 = 0$$
$$\Delta\varphi = -2{,}''746 \text{ with the weight } p = 1{,}5678$$
$$\Delta a = -4{,}''94$$

The insertion of the value for Δa in the correction equation gives the final residuals:

Table 18.

	1	2	3	4
$-\Delta a \operatorname{tg} z$	+0,70	−5,18	−2,51	−3,90
76° 30′	3,07	6,72	9,28	12,85
76 30	3,77	1,54	6,77	8,95
v	−1,48	−3,71	+1,52	+3,70

The corrected latitude will then be:

$$\begin{aligned} \varphi_0 &= 76^\circ\,30'\,8,''00 \\ \Delta\varphi &= -\qquad 2,\ 75 \\ \hline \varphi &= 76\ \ 30\ \ 5,\ 25 \end{aligned}$$

16. The geographical latitude. The final residuals will give us this probable error:

Table 19.

v	vv
−1,48	2,1904
−3,71	13,7641
+1,52	2,3104
+3,70	13,6900
[vv]	31,9549

$$\text{The probable error} = 0{,}67\sqrt{\frac{[vv]}{(4-2)\cdot p}} = \pm\,2,''15$$

As a definite result we get:

The geographical latitude for Hopen 1947

$76^\circ\,30'\,5,''25 \pm 2,''15$

Determination of Azimuth.

17. Determination of Azimuth by Polaris. On August 23rd at about 1.30 G. M. T. in the morning the meridian observations were discontinued, because Polaris approached the meridian and we made a series of observations in order to determine the direction to the signal on Koefoedodden. This signal, which below is referred to as the Mire, is situated slightly to the west of the meridian, abt. 9°. It is constructed as a permanent trigonometrical signal, consisting of a concrete pillar with an ordinare wooden signal with wings. It is placed on the same marine terrace as the astronomical station some 6200 m to the south of this. The line of sight is, therefore, almost horizontal. When the air is not too foggy, the signal is clearly seen against the open horizon. But as the line of sight is just above the sea-level the signal is often hidden by mist and fog.

The observations for the determination of azimuth were made by observation of Polaris, then the instrument was turned around its horizontal axis till it was in a horizontal position with the objective pointing southward towards the Mire. The instrument was then reversed and again directed against the Mire with the instrument in this position. A second observation of Polaris was also made with the instrument in this position. Two such sets of observations were made. By this method of observation we eliminate the influence of the collimation constant. It is enough to turn the instrument some few degrees around the vertical axis.

The sunshine increased as the observations were made, and gradually the sky became so bright that at the last observation of Polaris it was very difficult to discern the star in the ocular. As the sky became brighter and brighter we had to discontinue the observations till the sun was well over on the western side of the meridian. We then made observations to determine the latitude.

Table 20.

Observations of Polaris-Mire Aug. 23rd. $1^h30—4^h00$ G.M.T.

Position of the instrument by meridian observations:			Horizontal circle 9° 0′ 26″	
	Chronometer			
	h m s			
Ocular west	0 6 0	Polaris	8 41 5	
			41 4	
		Mire	17 54 3	
			54 6	
Ocular east		Mire	17 54 3	
			54 2	
	0 55 26	Polaris	7 42 4	Level b
			42 4	35,8 3,1 38,9
				1,5 34,0 −35,5 3,4
Ocular east	1 8 49	Polaris	7 26 35	
			26 32	
		Mire	17 54 10	
			54 10	
Ocular west		Mire	17 54 2	
			54 8	
	1 53 25	Polaris	6 39 1	36,5 3,0 39,5
			39 3	2,9 36,4 −39,3 0,2

The azimuth for Polaris is computed by the formula

$$\operatorname{tg} a_n = -\frac{\operatorname{cotg}\delta \sec\varphi \sin t}{1 - \operatorname{cotg}\delta \operatorname{tg}\varphi \cos t}$$

Reading of the horizontal circle by observations of:

Polaris H
Mire H_0

When the inclination of the axis $= b$ we must correct the reading of the circle by $b \operatorname{cotg} z$. As Polaris is situated very near the meridian we use the value $z = \delta - \varphi$ for the correction.

The collimation error is eliminated by taking the average from the readings of ocular west and ocular east. Pointing at the Mire we have $z = 90^\circ$ and the correction for inclination is 0.

The azimuth searched for will then be:

$$a = a_n + H_0 - H - b \operatorname{cotg} z$$

We then find the azimuth reckoned from south towards the west. By adding 180° we find the azimuth from north towards the east.

18. Azimuth of Polaris.

Table 21.

Computation of the chronometer correction:

T	T − 16h	Rate	1m 31,s42	G. S. T.	
h	h	s	m s	h m s	
Aug. 23. 24,100	8 100	+0,26	1 31,68	0 7 31,68	1.
24,924	8,924	29	71	0 56 57,71	2.
25,147	9,147	30	72	1 10 20,72	3.
25,890	9,890	32	74	1 54 56,74	4.

Co-ordinates of Polaris by the upper culmination Gr. Aug. 23rd 1h 47m 26s G.S.T.

RA. = 1h 47m 26,s16 Var. 24h = + 1,s24

Decl. = 89° 0′ 42,″6 = + 0,″03

Δ RA	RA	
−0,″09	1h 47m 26,s07	1.
− 4	12	2.
− 3	13	3.
0	16	4.

Table 22.

	1	2	3	4
Observ. G. S. T.	0h 7m 31,s68	0h 56m 57,s71	1h 10m 20,s72	1h 54m 56,s74
Long. Hopen . . .	1 40 16, 30			
Local S. T.	1 47 47, 98	2 37 14, 01	2 50 37, 02	3 35 13, 04
RA. Polaris . . .	1 47 26, 07	1 47 26, 12	1 47 26, 13	1 47 26, 16
Hour angle	0h 0m 21,s91	0h 49m 47,s89	1h 3m 10,s89	1h 47m 46,s88
» in degrees	0° 5′ 28,″6	12° 26′ 58,″3	15° 47′ 43,″3	26° 56′ 43,″2
a_n	−0 0 26, 2	−0 58 53, 4	−1 14 16, 6	−2 2 56, 2

19. Azimuth of Mire Koefoedodden.

Table 23.

	1 West	2 East	3 East	4 West
$a_n + 0,''3$	$-0°\ 0'\ 25,''9$	$-0°58'\ 53,''1$	$-1°14'\ 16,''3$	$-2°\ 2'\ 55,''9$
H_0	17 54 4, 5	17 54 2, 5	17 54 10, 0	17 54 5, 0
$-H$	−8 41 4, 5	−7 42 4, 0	−7 26 33, 5	−6 39 2, 0
$-b$ cotg	− 15, 3	− 15, 3	− 15, 3	− 0, 8
a	9 12 18, 8 9 12 50, 1	9 12 50, 1	9 13 4, 9 9 12 6, 3	9 12 6, 3
Mean 1 and 2...	9 12 34, 5	Mean 3 and 4	9 12 35, 6	

Azimuth: astronomical station — Mire Koefoedodden from north towards the east:

$$189°\ 12'\ 34,''5$$
$$189°\ 12'\ 35,''6$$

The azimuth for this direction has also been determined by another, entirely independent method, i. e. by means of the meridian transits. These transits give a determination of the azimuth of the instrument and as the Mire was pointed this instrument constant can be transferred to the terrestrial object.

The azimuth of the instrument	a_0	$= -74,^s50$
	Δa	$= -\ \ 0,\ 41$
	$a_0 + \Delta a$	$= -74,^s91$
		$= -0°\ 18'\ 43,''6$
The horizontal circle		$=\ \ 9\ \ 0\ 26,\ 0$
The meridian point		$=\ \ 8°\ 41'\ 42,''\ 4$

Pointing the Mire:

Ocular west	17° 54′ 0″	
	54 0	
» east	54 8	
	54 6	
» east	54 10	
	54 6	
» west	54 5	
	54 5	17 54 5,0
Azimuth Mire from south		9 12 22,6
» » » north towards east		189 12 22,6

A double weight is attached to this value when combined with the two values found by means of Polaris.

Table 24.

	v	vv
Azimuth Mire = 189° 12′ 34,″5	+5,″7	32,49
35, 6	+6, 8	46,24
22, 6	−6, 2	38,44
22, 6	−6, 2	38,44
Average value = 189 12 28, 8	[vv]	155,61

$$\text{the probable error} = 0{,}67 \sqrt{\frac{vv}{4 \cdot 3}} = \pm\, 2{,}''4$$

Definite value for azimuth:

Astronomical station — Mire Koefoedodden from north towards east

$$189^\circ\ 12'\ 28'',8 \pm 2,''4$$

We find a confirmation of this value for the azimuth in two azimuth determinations by means of the sun. These determations were made on July 26th in order to determine the meridian for setting up the instrument. The new co-ordinates for the station give this value of. the azimuth:

$$\text{azimuth} = 189^\circ\ 12'\ 44,''7$$

This value is not combined with the other values, and it is to be considered as a verification. The signal on Koefoedodden had not been built at that time, so it was not the signal, but only the concrete pillar which was sighted.

Determination of the Magnetic Declination.

Instrument and station. To determine the magnetic declination on Hopen we had borrowed a magnetic declinatorium, known as the "Bamberg 9631". The instrument which is of an extremely simple design, is the property of the University Observatory. It has a double magnetic needle with mirror. The two parallel needles are connected and repose on a pivot. The reading of the position of the needle is made by means of a small telescope, fitted with a vertical thread. By means of a simple arrangement the zenith light is thrown through the telescope against the mirror between the needles. The observation consists in turning the instrument around the vertical axis until the filament thread coincides with its reflcetion in the mirror. The horizontal circle is read in this position by means of verniers with an exactitude of 30 seconds. The needle as well as the telescope can be reversed, enabling us to make observations in 4 combinations. The direction of the meridian is determined by aid of the sun.

As we could only count on seeing the sun at short intervals, all observations of the magnetic needle were referred to one direction. The instrument was placed over the security bolt west of the astronomical station, and the direction to the Mire at Koefoedodden was used as direction of reference. The azimuth for this direction was specially determined.

The observations demand a comparatively calm weather to allow the needle to remain quiet. Nor can observations be made at rain and fog, as the needle, through the reversion, is exposed to moisture which will prevent the needle from turning.

Observations were made on the 21st, 22nd, 23rd, and 24th July while the observatory hut was in course of construction. The observations on July 23rd had to be interrupted because of rain and wind. On July 24th weather conditions were exceptionally favourable and we made a complete set of observations.

To find the azimuth of the sun we use the same formula as above.

21. Azimuth of the magnetic station-Mire was determined by aid of the declinometer pointing the sun. We used a mean time watch.

Table 25.

	July 21	July 23	July 23
Sun right	11h 28m 28s	11h 1m 21s	11h 4m 21s
» left	30 42	3 37	6 35
» centre	11 29 35	11 2 29	11 5 27
Watch correction	– 55, 5	– 1 38, 5	– 1 38, 5
Norw. Mean Time	11 28 39, 5	11 0 50, 5	11 3 48, 5
G. M. T.	10 28 39, 5	10 0 50, 5	10 3 48, 5
Equation of time	– 6 14, 3	– 6 19, 9	– 6 19, 9
G. app. T.	10 22 25, 2	9 54 30, 6	9 57 28, 6
Longitude Hopen	1 40 16, 3		
Local app. t.	12 2 41, 5	11 34 46, 9	11 37 44, 9
Hour angle	0 2 41, 5	–0 25 13, 1	–0 22 15, 1
» » in degrees	0° 40′ 22,″5	–6° 18′ 16,″5	–5° 33′ 46,″5
Sun's declination	20 36,2	20 13, 1	20 13,1
Sun's azimuth	0 45,6	–7 6, 5	–6 16,4
Circle Mire	355 5,0 5,0 8,5 8,0	53 52, 0 52, 0	53 52,0 52,0
H	355 6,6	53 52, 0	53 52,0
Sun	346 50,0	37 43, 0	38 33,0
H—sun	8 16,6	16 9, 0	15 19,0
Sun azimuth	0 45,6	–7 6, 5	–6 16,4
Az. Mire from S	9 2,2	9 2, 5	9 2,6
» »	Mean	9° 2,′4	

22. The magnetic declination. The following readings of the position of the magnetic needle were made in the 4 combinations of the position of the needle and the telescope.

Table 26.

Horizontal circle	July 24	July 21	July 22
Magnetic needle	52° 23,'1 52 25, 5 52 20, 8 52 6, 8	350° 18,'0 350 14, 0 350 38, 0 350 24, 0	170° 58,'8 171 35, 2 171 24, 0 171 20, 8
	52 19, 0	350 23, 5	171 19, 7
Mire	56 54, 7	355 6, 6	176 0, 0
Difference	4 35, 7	4 43, 1	4 40, 3
Azimuth Mire	9 2, 4	9 2, 4	8 2, 4
Magnetic declination ..	4° 26,'7	4° 19,'3	4° 22,'1

On July 24th 40 readings of the magnetic needle were made, and 8 readings on each of the other two days. When working out the average value the first value counts double, and we find

Table 27.

		v	vv
Magnetic declination	4° 19,'3 4 22, 1 4 26, 7 4 26, 7	— 4,'4 — 1, 6 + 3, 0 + 3, 0	19,36 2,56 9,00 9,00
Mean	4 23, 7		[vv] 39,22

$$\text{Probable error} = 0.67 \sqrt{\frac{[vv]}{3 \cdot 4}} = \pm 1,'2$$

Magnetic declination Hopen August 1947

4° 23,'7 ± 1,'2 east.

The magnetic declination for Hopen has not been determined previously. The comparatively great value for the magnetic declination agrees with experiences of the navigators in the eastern parts of Arctic Ocean.

On Iversen's map for Hopen the value 1° west is given, applicable for the year 1923. It is doubtful which importance we may attribute to this value. If we take this value as our starting point, we can find an expression for the annual change in the magnetic declination. The change will be 5,°5 in 24 years or 14′ per year. This annual change is of the same order and has the same sign as the corresponding value for Bjørnøya. With some reservation we may give this equation for the magnetic declination on Hopen:

$$4^\circ\,23{,}'7 \text{ east} + (T - 1947) .\, 14'$$

Summary. The astronomical observations obtained in the summer 1947 on Hopen give the following values for the observation pillar at Husdalen:

Geographical longitude	1^h	40^m	$16{,}^s30$	E
	(25°	4′	4,″5)	
—»— latitude	76	30	5, 2	
Azimuth Koefoedodden	189	12	28, 8	
Magnetic declination	4	23,7	E	

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A. W. BRØGGERS BOKTRYKKERI A/S

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