REMARKABLE AURORA-FORMS FROM SOUTHERN NORWAY

III—IX

BY *CARL STØRMER*

(Institute of Theoretical Astrophysics, Oslo University.)

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Introduction.

This series of monographs forms the continuation of two earlier ones, Nos. I and II, published in 1935 and 1937[1]. The monographs have the following titles:

I. Feeble Homogeneous Arcs of Great Altitude (already published).

II. Some Arcs and Bands with Ray Structure (already published).

III. Isolated Pulsating Arcs.

IV. Pulsating Surfaces.

V. Flaming and Flashing Aurorae.

VI. Certain Cloudlike Aurorae.

VII. Some Remarkable Sunlit Rays.

VIII. Divided Rays.

IX. Red Patches and Red Arcs.

At the end of each monograph a summary of the principal results is given.

The pictures discussed in these monographs form a part of an extensive material of many thousand photographs collected at my auroral stations in southern Norway from 1911 to 1941. (See Part X.)

In this paper Middle Time for Central Europe (M E T) is always used (12^h Greenwich Time = 13^h M E T).

[1] Geofysiske publikasjoner, Vol. XI, No. 5 and No. 12.

PART I. ISOLATED PULSATING ARCS (III)

1. Isolated Pulsating Arc on December 19th, 1919.

We first give an account of a case observed on December 19th, 1919, because this is very characteristic of the strange phenomenon. It has been described in French in my paper on aurorae from 1911—1922[1] and here is a translation of my report:

"As I wanted to establish a new aurora station at the house of the astronomer Sigurd Einbu at Dombås (Latitude 62° 5′ 30″, Longitude 1° 37′ 30″ west of Oslo), I took the train to him on December 19th, 1919. I arrived at Dombås in the evening, and he met me at the railway station.

On the way from the station to his house we observed a very strange aurora. Near the horizon in the southwest there was a very feeble bit of an arc which was pulsating. Nowhere in the dark sky could any other aurora be seen, not even near the northern horizon. The arc was quite isolated.

As I had the aurora camera with me I immediately took some pictures of the pulsating arc. But in spite of the long exposures, from 1 to 2 minutes, the impression on the plates was very feeble (plates only sensible to blue and violet). For about 15 seconds it was clearly seen, then it vanished completely for some seconds and came again at the same place, was anew visible for about 15 seconds, disappeared and again appeared, and so on.

When I came back to Oslo I published an article in the newspapers asking for other observations of of this pulsating arc. I got reports from a number of other places; the pulsations had lasted about two hours and the probable position in space must have been over the North Sea west of Stavanger at an altitude between 90 and 120 km.

[1] Geofysiske Publikasjoner, Vol. IV, No. 7, p. 35, 1926.

2. The Pulsating Arc on February 28th, 1929.

It was, however, on February 28th, 1929, that we first got reliable height measurements of this aurora form.

On the two previous nights, in particular on February 27th, fine auroras had been observed in Oslo, and many height measurements had been made. On the date in question, however, no aurora was seen in the northern sky, but at about 19^h I happened to see in the south a most remarkable isolated and pulsating arc. I immediately telephoned to my aurora stations Oscarsborg (*O*) and Kongsberg (K_2) to get them ready, and went myself to the Oslo station (*C*) as soon as possible. When the telephonic connection was in order we began to take simultaneous photographs. At the station Oslo I was first quite alone, but later I was assisted by the astronomer Jelstrup until my assistant Tveter and his wife arrived. At the stations Oscarsborg and Kongsberg my assistants were Mr. Hafnor and Mr. Busengdal senior.

The pulsating arc was quite isolated. No aurora was visible elsewhere, not even near the northern horizon. The sky was quite dark without clouds. For a shorter time, about $20^h\ 30^m$, there was an indication of a broad arc over zenith, but this arc was so feeble and diffuse that the photographs were not good enough for height measurements.

A most surprising fact was the appearance on the plates of some very feeble rays, that we had not observed visually. The measurements showed that these rays lay some hundred kilometers over the pulsating arc in full sunshine, whereas the arc itself lay in shadow.

As we did not see them, their light was probably ultraviolet.

In Table 1 is given a list of the successful photographs. The headings have the following meanings:

No. gives the current number of the photographs.

St. gives the stations from which the pictures were taken. If the set of simultaneous pictures succeeded, the stations are connected by dashes, otherwise separated by commas.

MET is the European mean time at the middle of the exposure.

Ex. is the exposure in seconds.

Ref. Const. means the constellations or stars against which the cameras were pointed. ♃ is Jupiter, ♂ Mars, and ♀ Venus, and the abbreviations for the constellations are those generally adopted.

During the work, the lantern illuminating the watch whose photograph gives the time went out for the pictures 9—16, so no time is given for these pictures.

Table 1.

List of Photographs of Pulsating Auroral Arc on February 28th, 1929.

No.	St.	MET	Ex.	Ref. Const.	Remarks
I	*C*	19.43.30	40	Ari. ♃, ♀	
III	*C*	.47.00	40	—»—	
IV	*C*	.48.30	60	Aur. Tau. ♂	
1	*C—O*	.55.42	90	Ari. Cet. ♃, ♀	
2	*C*	.57.30	60	—»—	
3	*C—O*	.58.42	60	—»—	
4	*C—O*	20.00.12	60	Cet. ♃, ♀	
5	$C—O—K_2$	.02.42	120	Cet. Tau. ♃, ♀	
6	$C—O—K_2$	.05.44	90	Tau.	
7	C, K_2	.08.30	90	Tau. Gem. Ori.	
9	C, O, K_2	-	60	Tau. Ori.	The lantern went out
10	C, O, K_2	-	-	Ari. Cet. ♃, ♀	
11	C, O, K_2	-	-	Cas.	
12	*C, O*	-	-	Gem.	
13	*C, O*	-	-	Cas.	
15	K_2	-	-	Ari. Cet. ♃, ♀	
16	*O*	-	-	—»—	
17	O, K_2	20.58.45	120	—»—	The lantern in order again
18	*C, O*	-	-	Tau. Gem. Ori. ♂	Watch taken out
19	*C, O*	-	-	Gem.	
21	*O*	21.11.45	120	Ari. Cet. ♃, ♀	Everything in order
22	*C—O*	21.22.54	60	Tau. Ori.	
23	*C—O*	.24.24	60	Tau.	
24	*C—O*	.25.24	60	—	
25	*C—O*	.26.42	60	—	
26	*C—O*	.27.24	40	—	
27	*C—O*	22.01.24	120	—	Very fine
28	*C—O*	.07.24	120	—	—»—
29	*C—O*	23.05.00	-	Leo.	—»—
30	*O*	?	-	CMi.	

3. Results of the Height Measurements of the Pulsating Arc on February 28th, 1929.

Some of the plates were first measured and calculated by myself in 1929. Later, in 1931, more systematic work was done by my assistants Anda and Falk, and the results are given in Table 2. One picture, No. 24, has been measured anew by Mr. Egeberg. The measurements of the sunlit rays will be mentioned in the next section.

In the table the headings have the following meanings:

No. and *St.* as in Table 1. The first letter is always the principal station.

P is the chosen point of the aurora.

u_1 is the angle between the direction to the secondary station and the direction to point P, seen from the principal station.

p is the parallax.

h and a are height and azimuth of the point P seen from the principal station.

H is the height of the point P.

D is the distance from the principal station along the surface of the earth to the projection of point P.

Table 2.

Measurements of Pulsating Arc on February 28th, 1929.

No.	St.	MET	P	u_1	p	h	a	H	D
1	C--O	19.55.42	1	50.3	4.7	24.8	57.2	117	238
			2	50.7	4.2	20.6	59.8	114	281
			3	51.6	3.8	17.9	61.9	113	318
			4	52.6	3.5	16.2	63.5	115	354
3	$C-O$	19.58.42	1	50.5	4.8	25.1	58.4	116	234
			2	50.6	4 2	22.0	59.7	120	277
			3	51.2	3.7	19.3	61.4	122	321
			4	54.8	4.5	23.3	64.1	124	269
			5	53.6	5.5	26.3	66.5	113	217
4	$C-O$	20.00.12	1	51.8	3.9	21.6	61.1	130	303
			2	55.9	3.2	16.3	67.0	132	399
5	$C-O$	20.02.42	1	54.6	5.0	24.8	63.5	118	241
			2	55.8	4.5	22.2	65.7	121	276
			3	58.0	4.2	19.2	68.9	117	307
			4	51.0	4.6	23.9	59.8	119	251
			5	51.6	4.5	20.8	61.6	109	266
			6	53.4	4.2	18.1	64.2	107	297
			11	53.6	4.9	27.8	61.1	132	237
			12	51.5	4.9	27.0	58.9	127	234
			13	52.5	4.9	28.0	59.8	131	234
	$C-K_2$	20.02.42	1	24.9	8.2	24.8	63.5	110	227
			2	22.3	6.0	22.2	65.7	118	270
			5	21.2	5.9	20.8	61.6	109	267
			6	18.2	4.2	18.1	64 2	109	305
			11	28.0	9.4	27.8	61.1	117	213
			13	28.5	9.0	28.0	59.8	124	222
6	$C-O$	20.05.44	1	47.3	7.1	37.6	44.2	112	140
			2	47.6	6.9	35.7	47.0	111	148
			3	48.2	6.6	33.8	49.8	111	159
			4	43.9	7.0	35.0	41.4	102	140
			5	44.3	6.3	33.5	44.0	108	157
			6	44.8	5.7	31.7	46.8	114	177
22	$C-O$	21.22.54	1	52.2	9.1	45.3	42.4	110	105
			2	52.6	8.4	43.5	46.1	115	117
			3	53.1	7.6	41.6	49.7	122	132
			4	43.3	6.5	39.4	32.4	120	140
			5	43.4	6.3	38.0	35.4	120	147
			6	43.6	6.0	36.6	38.4	121	157
			7	43.9	5.8	35.1	41.2	122	166
			8	47.8	7.6	41.8	38.6	116	124
			9	48.0	7.2	40.0	42.0	118	135
			10	48.4	6 7	38.3	45.2	121	148

Table 2 (continued).

No.	St.	MET	P	u_1	p	h	a	H	D
23	$C-O$	21.24.24	1	56.3	6.7	42.6	54.0	144	151
			2	55.8	7.0	39.9	56.0	130	149
			3	55.2	7.5	37.7	57.1	116	145
			4	49.6	7.3	38.1	47.4	113	139
			5	50.6	7.0	36.9	50.6	116	148
			6	52.0	6.2	35.7	53.7	127	169
24	$C-O$	21 25.24	1	58.1	6.5	38.0	60.8	136	168
			2	58.0	6.5	31.7	64.4	117	182
			3	49.2	5.7	33.2	51.6	126	184
			4	50.9	5.6	28.8	56.8	116	202
25	$C-O$	21.26.42	1	57.3	8.4	37.2	60.3	105	133
			2	57.7	8.2	34.3	62.6	101	142
			3	57 9	7.9	31.4	64.4	96	152
			4	57.9	7.7	29.8	65.1	94	159
			5	52.4	6.7	33.4	56.0	113	165
			6	53.2	6.1	31.0	58.5	117	185
			7	54.3	5.4	28 5	61.2	124	217
			8	54.8	7.6	35.3	58.1	108	147
			9	55.4	7.3	32.7	60.6	106	158
			10	56.1	6.6	29.9	62.9	108	180
26	$C-O$	21.27.24	1	57.2	7.7	38.7	59.2	118	141
			2	58.2	7.5	36.2	62.2	115	151
			3	59.2	7.2	33.4	65.1	103	164
			4	51.6	6.4	34.3	54.2	117	170
			5	52.9	6.0	32.3	57.4	121	183
			6	54.1	5.9	29.9	60.3	118	197
			7	54.4	7.1	36.5	56.6	118	153
			8	55.5	6.8	34.2	59.7	117	166
			9	56.6	6.5	31.7	62.6	116	180
27	$C-O$	22.01.24	1	54.3	5.4	26.2	62.6	115	221
			2	55.5	5.1	24.7	64.4	117	239
			3	56.7	4.7	22.9	66.4	119	262
			4	59.5	6.2	25.7	68.7	105	205
			5	59.5	5.9	24.1	69.1	103	201
			7	57.7	5.6	25.2	66.7	111	223
			8	58.2	5.2	23.5	67.8	112	243
28	$C-O$	22.07.24	1	53.2	4.8	25.1	61 6	122	245
			2	54.5	4.5	23.1	63.8	123	269
			3	55.5	4.3	21.6	65.5	122	287
			4	56.8	4.1	19.9	67.3	122	308
29	$C-O$	23.05.00	1	48.8	7.8	32.9	—25.1	93	139
			2	46.1	7.1	33.7	—20.4	100	145
			3	46.3	6.8	34.1	—16.0	102	145
			4	41.8	6.4	34.5	—12.0	106	148
			5	40.0	6.3	34.7	— 8.2	104	145
			6	38.6	6.1	34.9	— 4.6	105	145
			7	37.5	6.3	35.1	— 1.3	101	138
			8	36.8	6.3	35.4	1.9	100	137
			9	36.1	6.4	35.6	4.9	99	133

Mean height 115 km.

To the pictures we may add the following remarks:

On account of the small base line of only 27 km and the diffuse outlines of the aurora, the measurements are not as reliable as could be desired. This is evident from the rather great dispersion of the heights around the mean 115 km. The pulsating arc lay in the earth's shadow.

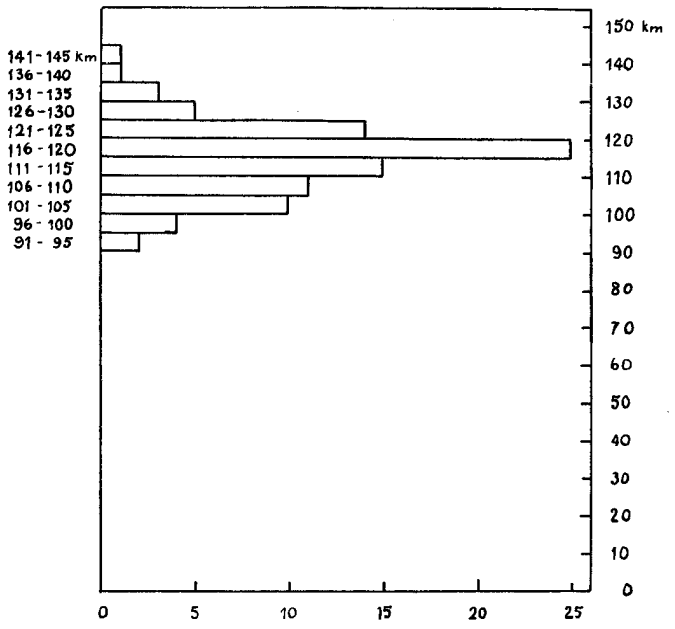

Fig. 1. Statistics of heights of pulsating arc on February 28th, 1929.

Pictures I, II, III, and IV, from $19^h\,43^m$ to $19^h\,49^m$.

These first pictures were all taken of a fragment of an arc under Jupiter. On picture I it is clearly seen, on picture II it has disappeared, on III it has come again at the same place, and on picture IV it is seen more to the east, under Mars.

Pictures C—O, 1, $19^h\,55^m\,42^s$.

Along the left border 4 points, Nos. 1, 2, 3, 4 were chosen. The right part with Venus in the middle did not give any reliable measurements. The sketches are seen on Plate I, the photographs on Plate 14.

Picture C, 2, $19^h\,57^m\,30^s$.

The Oscarsborg picture (*O, 2*) failed. The aurora has not changed since pictures *C—O, 1.*

C—O, 3, $19^h\,58^m\,42^s$.

These pictures are very much like the pictures *C—O, 1,* and the different height may be due to the difficulty in fixing the diffuse outlines exactly. See Plate 1.

C—O, 4, $20^h\,00^m\,12^s$.

Still more difficult to fix the outlines. See Plate I.

C—O—K_2, 5, $20^h\,02^m\,42^s$.

Most interesting pictures. Both base lines *C*—O and *C*—K_2 are used. The heights for the same points 1, 2, 5, 6, 11, and 13 were

Point	1	2	5	6	11	13
C—O	118	121	117	109	132	131
C—K_2	110	118	109	109	117	124

The greatest difference occurs for points at the upper end, where the outlines are very diffuse. Moreover the camera in Kongsberg has moved a little during the exposure. See Plates 1 and 14.

C—O—K_2, 6, $20^h\,05^m\,44^s$.

This set is also most interesting. (See Plates 1 and 14.) We have tried to use the Kongsberg picture for height measures, but as the displacement was near the direction of the largest diameter of the spot, the ends of which were very diffuse, no reliable measurements could be secured. This *K*-picture was, however, so characteristic that it has been reproduced in the Photographic Atlas of Auroral Forms[1]. (See Plate 14.)

During the following hour I had the misfortune that the lamp illuminating the watch in the camera went out so no photograph of the watch was made. For the corresponding pictures the time taken from the photographed watch failed[2].

The next usable picture was *C—O, 22.*

C—O, 22, $21^h\,22^m\,54^s$.

The points 1—7 are chosen along the borders, the points 8, 9, and 10 along the middle line. See Plate 2.

C—O, 23, $21^h\,24^m\,24^s$.

The points 1 and 2 near the upper border, the rest lower down. See Plate 2.

C—O, 24, $21^h\,25^m\,24^s$.

These pictures are very feeble and diffuse, and the first measurements were not so good. Therefore the pictures have been measured anew by my assistant Egeberg in 1940. See Plate 2.

C—O, 25, $21^h\,26^m\,42^s$.

A little better. The points 8, 9, and 10 along the middle line. See Plate 2.

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[1] *Photographic Atlas of Auroral Forms and Scheme for Visual Observations of Aurorae*, published by the International Geodetic and Geophysical Union, Oslo 1930 (A. W. Brøggers Boktrykkeri).

[2] This misfortune was the reason why I later had the time written down by an extra observer.

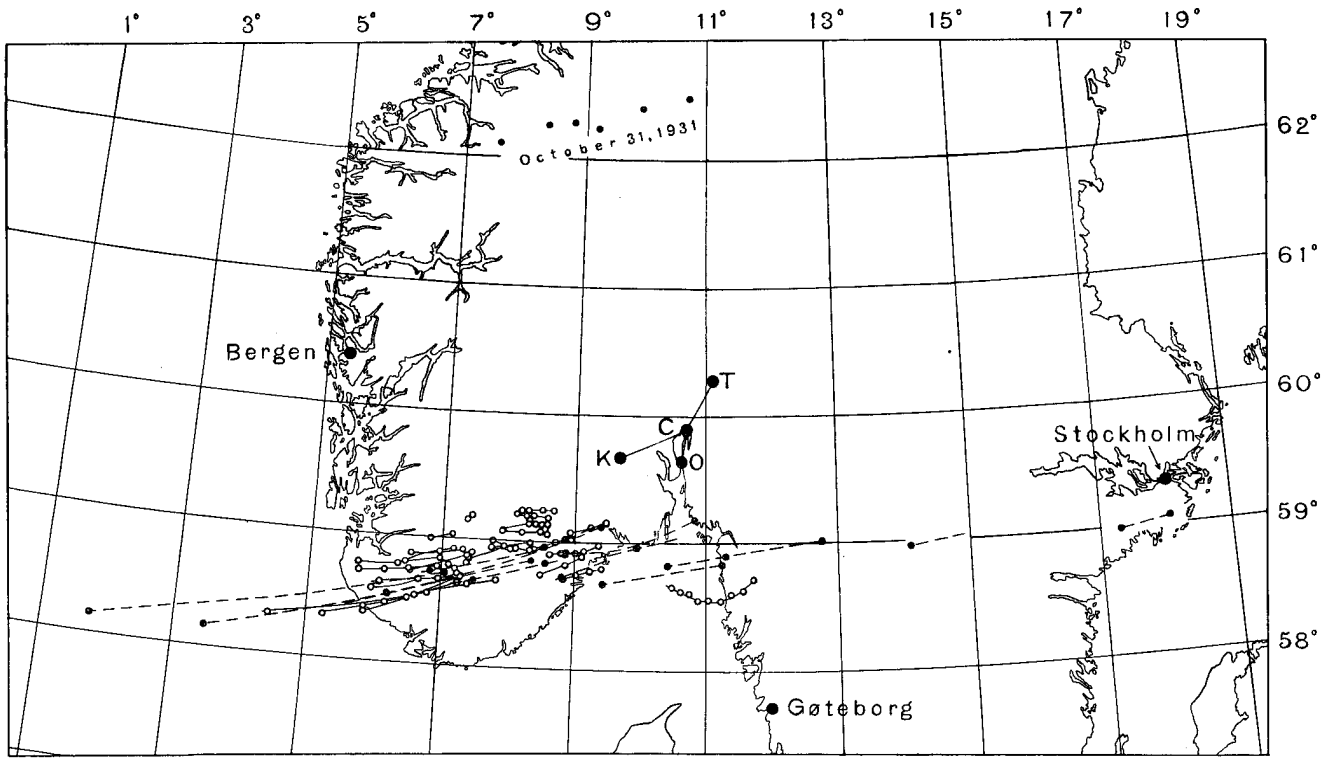

Fig. 2. Geographical situation of the pulsating arc on February 28th, 1929.

C—O, 26, 21h 27m 24s.

Diffuse. Points 7, 8, and 9 along the middle line. See Plate 2.

C—O, 27, 22h 01m 24s.

Much better, due to the longer exposure. The points 1—6 chosen along the lowest part, points 7 and 8 along the middle line. See Plates 2 and 15.

C—O, 28, 22h 07m 24s.

The same in a later stage of pulsation. Very good. Points chosen along lower left border. See Plates 3 and 15.

C—O, 29, 23h 05m 00s.

Also very good. The pulsations since last picture have been few, because the aurora was quiet for a long time, disappeared and reappeared at another place and so on, always like bits of an arc in the south. The lower border, along which the points were chosen, was not as high as before, with mean 101 km. See Plates 3 and 15.

On Fig. 1 is given a diagram with all the heights. As ordinate is the height itself, and as abscissa the number of cases for each interval 91—95, 96—100, ... 136—140, and 141—145.

The mean of all heights is 115 km.

4. Olaf Hassel's Observations. Geographical Situation of the Pulsating Arc.

My valuable assistant Olaf Hassel observed the pulsating arc from the station Krekling not far from Kongsberg. He made sketches with stars and time of observation joined. See Plate 3.

If we assume the mean height found for the aurora, 115 km, these observations can be used together with the measurements of our plates to map the geographical situation of the pulsating arc. This has been done by my assistant Herlofson for the drawings at 19.20, 19.22, 19.32, 19.42, 19.45, 19.47, 20.02, 20.07, and 20.22, and the result is given on the map Fig. 2. The situation from the double photographs is given in full lines and the positions from Hassel's drawings in broken lines. The points used are marked as dark points.

If we compare the situation of the pulsating arc with that of the high homogeneous arc on September 29th, 1930,[1] we see that the position is very nearly the same.

[1] Carl Størmer: Remarkable Aurora-Forms from Southern Norway, I. Geof. Publikasjoner Vol. XI, No. 5, Pl. XIV.

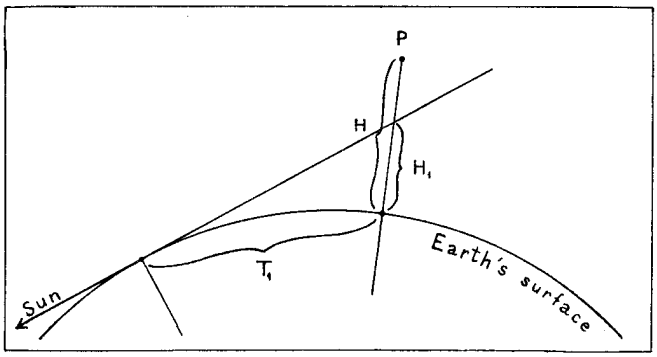

Fig. 3. Section showing the definition of H_1 and T_1.

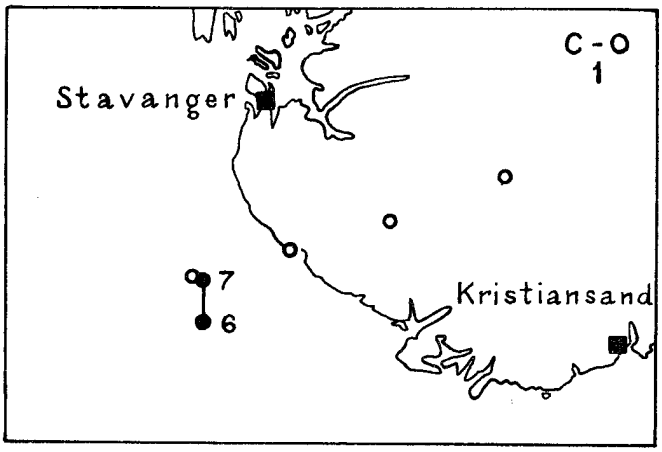

Fig. 4. Geographical situation of the projection of the sunlit rays (full circles) compared with the projection of the pulsating arc (rings) for the picture $C—O$ No. 1.

5. Invisible Sunlit Aurora Rays over the Arc.

It was a most interesting fact that closer inspection of the negatives revealed very feeble traces of rays which none of the observers had seen, and which probably were invisible to the eye because they only radiated ultraviolet light.

The measurements showed that these rays were situated much higher than the pulsating arc, *in the sunlit part of the atmosphere*, in spite of the fact that the arc itself was situated in the earth's shadow.

As the geographical situation was the same, the two aurora forms probably had something to do with each other. On Table 3 the results of the measurements are given.

As to the letters H_1 and T_1 they are defined as follows: (See Fig. 3.)

H_1 is the height of the earth's shadow line (without refraction) in the vertical plane of the point P and vertically under this point.

T_1 is the distance along the surface of the earth from the projection of the point P to the point where this shadow line touches the earth.

Table 3.

Invisible Sunlit Aurora Rays.

No.	St.	Time	P	u_1	p	h	a	H	D	H_1	T_1
1	$C—O$	19.55.42	6	60.5	2.8	40.8	60.9	338	359	241	1728
			7	60.5	3.0	37.6	63.4	295	352	240	1723
3	$C—O$	19.58 42	6	63.1	2.8	39.2	65.2	329	372	245	1743
			7	61.4	2.6	42.3	63.2	379	379	246	1747
5	$C—O$	20.02.44	9	62 0	3.4	46.9	67.4	313	274	284	1871
			10	62.0	3.0	50.1	65.4	371	288	283	1868
	$C—K_2$	20.02 44	9	37.0	4.6	46.9	67.4	336	302	277	1850
			10	40.0	4.6	50.1	65.4	376	293	282	1863

Sketches are seen on Plate 1 and the geographical situation on Figs. 4, 5, and 6, and on Fig. 7 is seen a vertical section showing the situation of the rays and of the pulsating arc together with the shadow line without refraction. This coincidence between sunlit aurora rays and a pulsating arc is quite unique. Never before or after that occasion have I observed anything like it.

6. Isolated Pulsating Arc on October 31st, 1931.

The next time I had occasion to measure an isolated pulsating arc was on October 31th, 1931. This time the aurora had also appeared during the two previous nights, and the pulsating arc was its last appearance.

On that occasion I was at my aurora station Tømte. At $18^h\ 45^m$ I observed an isolated and pulsating auroral arc in the north under the Great Bear and immediately telephoned to my assistant Tveter in Oslo and asked him to get the stations in order. At $19^h\ 8^m$ I got in telephonic connection with my assistant Bakøy at Oscarsborg, but we only got 3 simultaneous pictures before the aurora disappeared. Only one of them, No. 2, taken at $19^h\ 10^m$, could be used. The length of the base line $T—O$ was 73.73 km. The arc was pulsating very slowly. Some single pictures were also taken before the telephone connection was established.

The picture No. 2 was measured anew in 1940 by my assistant Herlofson. For results see Table 4. Here $\varepsilon_1 = 90° — u_1$, where u_1 is the angle between the direction from T to the point P and the direction from T to O.

Table 4.

Pulsating Arc on October 31st, 1931.

No.	St.	MET	P	ε_1	p	h	a	H	D
2	T—O	19.10.00	1			20.4	138.4	111	278
			2	—34.4	10.4	22.0	147.6	114	264
			3	—41.2	10.1	22.9	155.6	108	240
			4			23.3	165.6	111	244
			5			23.0	175.0	111	246
			6	—38.0	10.2	22.5	151.8	111	253

The plates have been measured and calculated by the new improved methods newly published[1]. The three points Nos. 2, 3, and 6 are used for height measuring and the others for geographical positions, supposing the height to be the mean of 114, 108, and 111 km, that is 111 km. See Plate 3. The geographical situation is seen on the map Fig. 2. The arc was lying in the Earth's shadow.

7. Isolated Pulsating Arcs and Spots on September 21st—22nd, 1941.

The most interesting case of pulsating arcs occurred on September 21st—22nd, 1941 and a very extensive material of height determinations and spectra was collected.

As on February 28th, 1929, the phenomenon occurred after some nights of great auroral activity. In fact, on September 18th—19th, a gorgeous aurora was seen over Europe and even so far south as the Azores[2]. In Arosa, Switzerland, the aurora was seen up to 50° over the northern horizon[1]. In southern Norway, cloudy weather prevented continuous work; some of my auroral stations obtained, however, a series of interesting photographs, one of which is mentioned in section 75 and reproduced on Plate 33. The aurora lasted the whole night.

On the next night, September 19th—20th, a fine aurora was seen again, and series of photographs were taken from my aurora stations. It reached far south in the southern sky, but was not as great as on the night before. Most of the aurora had gone at $23^h\ 45^m$ MET and only a glow near the northern horizon persisted. But at about 3^h MET *a remarkable pulsating arc* appeared low down in the south between Orion and Sirius. This persisted until dawn about $4^h\ 30^m$. Some simultaneous pictures were taken with base line 47.3 km, but have not yet been measured.

On the next night, September 20th—21st, I expected pulsating aurora again and asked my assistant

[1] Carl Størmer: Some Results Regarding Heights and Spectra of Aurorae over Southern Norway during 1936. Geof. Publ. Vol. XII, No. 7, p. 6.

[2] According to a letter from Mr. Agostinho, Serviço Meteorologico dos Açores.

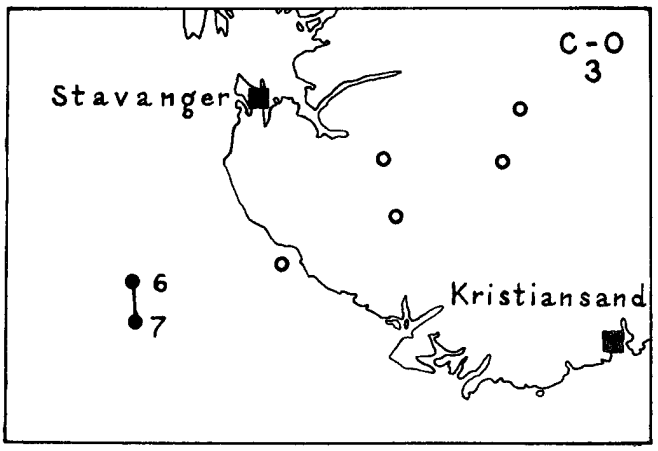

Fig. 5. The same (see Fig. 4) for the picture C—O, No. 3.

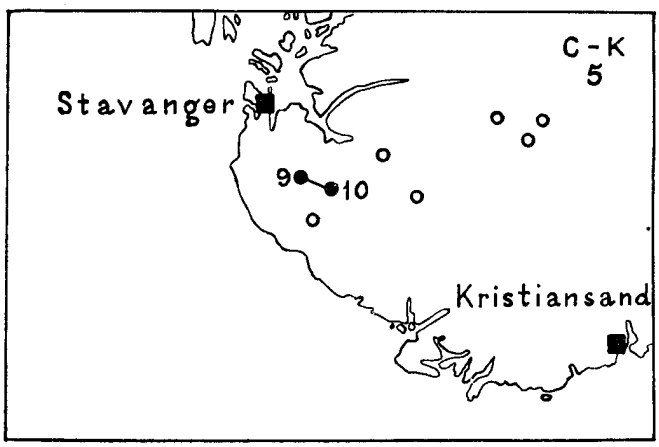

Fig. 6. The same for the picture C—K, No. 5.

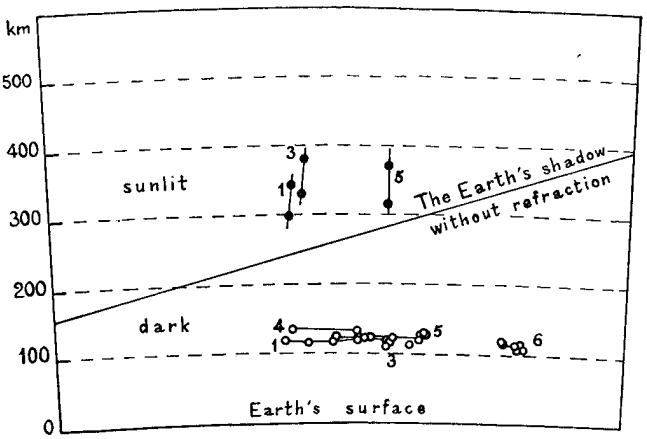

Fig. 7. Position of the same relative to the Earth's shadow.

[1] According to a letter from Professor F. W. Paul Götz, Arosa.

Herlofson to watch the sky. From $18^h\ 45^m$ till $21^h\ 45^m$, however, he did not see any trace of aurora, and then he suspended work. My assistant Hassel who worked independently succeeded, however, in taking some photographs of small pulsating spots in Serpens between $20^h\ 45^m$ and 21^h, but they did not reappear before midnight and he therefore suspended work. Later, however, the pulsating aurora must have begun again. In fact in the journal "Die Sterne", Heft 12, 1941, p. 211, two very fine photographs of a pulsating auroral arc near the northern horizon at $0^h\ 25^m\ 22^s$ M E T and at $1^h\ 1^m$ are reproduced. They were taken by Prof. Hofmeister at the Observatory Sonneberg (Latitude 50° 21′ 24″, Longitude 11° 10′ 45″ E). If we had watched the sky from our stations after midnight this aurora would certainly have been seen.

The aurora on the next night, September 21st—22nd, was most remarkable. From sunset to dawn pulsating bits of arcs appeared in different parts of the sky; *other aurora forms than this were not seen, not even a glow in the north.* As will be seen in the next section, our work continued the whole night and a unique material of photographs and observations was collected.

Among the bits of arcs there are several which also could be characterized as pulsating patches. In fact the different forms of aurora are not sharply defined but merge into one another.

Also on the next night, September 22nd—23rd, an isolated spot in the east was seen and photographed from two stations between 21^h and 22^h M E T. For details see sections 29—30.

Such a series of nights with isolated pulsating arcs and patches after two days of intense aurora is quite unique. It would be of the greatest interest to know if this phenomenon was observed also from other places on the earth where aurora can be seen, in particular in the southern hemisphere.

8. List of Successful Photographs of the Pulsating Arcs and Spots on September 21st—22nd.

I saw the first pulsating arc in Aquila in the south at about 20^h and immediately warned my aurora stations, but only two of them were able to start work, namely the main station *M* on the roof of the Meteorological Institute near Oslo and the station *Ak* in Askim, Østfold. The first photographs with base line *M—Ak* (about 47 km) was taken about $20^h\ 40^m$ M E T and the work lasted till dawn, about $4^h\ 40^m$. At the station *M* my assistants Herlofson, Olsen, Bakken, Nygaard, and myself were working, and most of the pictures were taken by Herlofson. Mr. Bjordal worked at station *Ak*. A great many successive pictures were also taken by Nygaard and myself with a kino camera on Agfa Ultra film. My two assistants Olaf Hassel and Einar Schrøder worked independently, the first at station *M* and the second at Holmestrand (*Hs*) about 55 km south of Oslo.

In Table 5 a list is given of all the successful photographs in chronological order. The headings have the same meaning as in Table 1. As to the abbreviation of the stations, *M*, *Ak*, and *Hs* are explained above; *Mh* means photographs taken at station *M* by Hassel alone.

Between $1^h\ 56^m\ 44^s$ and $3^h\ 04^m\ 36^s$ no photographs were taken because the aurora was so feeble and of so short duration that it could not be photographed.

Among these photographs, 58 sets, marked by x in the last column, have been measured out. We have taken so great a number because the base line *M—Ak* was rather short for such a diffuse and feeble aurora. I am very sorry that the station Lillehammer could not be used that night, for the formidable base lines *M—Li* and *Ak—Li* would have given much more reliable results. It is to be hoped, however, that the many height determinations, in all 283, nevertheless will give fairly reliable means. All the measured aurorae lay in the earth's shadow.

9. The Measured Heights.

As typical cases we first take some of the best sets[1]:

No. 8. Bit of Pulsating Arc b, $20^h\ 41^m\ 54^s$ M E T. Base line *M—Ak*, 47.33 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	— 7.1	11.4	24.8	53.3	212	103
2	— 9.1	8.6	22.7	58.7	283	126
3	—10.5	8.5	20.7	60.2	291	118
4	—11.6	7.9	18.6	61.8	314	114
5	—13.7	7.4	16.6	63.7	338	112

With assumed height of 115 km (mean), 10 more points were chosen along the outline of the arc and their geographical situation marked on a map, Fig. 8.

[1] Here and later on $\varepsilon_2 = \varepsilon_1 - p$ is often given instead of ε_1. We remember that $\varepsilon_1 = 90° - u_1$, $\varepsilon_2 = 90° - u_2$, and $p = u_2 - u_1 = \varepsilon_1 - \varepsilon_2$.

Table 5.

List of Successful Photographs of Pulsating Arcs and Spots on September 21st—22nd, 1941.

No.	St.	M E T	Ex.	Const.	Remarks	Measured	No.	St.	M E T	Ex.	Const.	Remarks	Measured
1.1	*Ak*	20.20.30		Peg.	Patch a		117.2	*Mh*	20.55.23	13	Oph. Her.	b	
1.2	—	.21.00		—	a		26	*M—Ak*	.55.36	35	—	Patch b and a new one b' to the left; b' much	
1.3	—	.22.00		—	a							weaker than b	x
1.5	—	.26.00		Crb. Her.	Patch b								
1.6	—	.27.30		—	b		117.3	*Mh*	.55.52	15	Oph. Her.	Only b visible	
1	*M*	.30.41	27		b		2.6	*Hs*	.56.00	50	—	b	
2	*M*	.36.09	18		b		117.4	*Mh*	.56.22	15	—	b	
6	*M—Ak*	.40.50	10	Oph.	b	x	27	*M—Ak*	.56.34	32	—	Very fine. b' weaker than b	x
7	—	.41.15	10	—	b very fine	x							
1.1	*Hs*	.41.50	30	Oph. Her.	b		3.1	*Hs*	.57.00	40	Oph. Her.	Only b visible	
8	*M—Ak*	.41.53	21	—	b very fine	x	28	*M—Ak*	.57.17	22	Peg.	a fine	x
114.1	*Mh*	.42.20	20	Oph.	b		117.5	*Mh*	.57.22	35	—	a	
114.2	*Mh*	.42.55	20	—	b		3.2	*Hs*	.58.00	30	—	a	
1.2	*Hs*	.42.55	30	Oph. Her.	b		29	*M—Ak*	.58.14	12	—	a fine	x
9	*M—Ak*	.42.58	15	—	b		117.6	*Mh*	.58.22	12	—	a	
114.3	*Mh*	.43.20	20	—	b		3.3	*Hs*	.59.00	40	—	a	
10	*M—Ak*	.43.21	13	—	b		118.1	*Mh*	.59.20	30	—	a	
11	—	.43.49	13	—	b fine	x	30	*Ak*	.59.33	29	—	a	
114.4	*Mh*	.43.50	20	—	b		3.4	*Hs*	21.00.00	30	—	a	
1.3	*Hs*	.43.50	40	—	b		118.2		.00.22	15	Oph.	b very feeble	
12	*M—Ak*	.44.40	10	—	b very fine	x	3.5	*Hs*	.01.00	60	Peg.	Very feeble bit of arc d	
114.6	*Mh*	.44.50	20	—	b								
115.1	—	.45.20	20	—	b		118.3	*Mh*	.01.22	35	Aql.	d	
13	*M—Ak*	.45.38	13	—	b		33	*M—Ak*	.01.30	25	—	d	
1.4	*Hs*	.46.00	40	Peg.	a		35	—	.02.10	24	Oph.	b	
1.5	—	.47.00	40	—	a		118.4	*Mh*	.02.20	30	—	b	
1.6	—	.48.00	50	Aql.	Patch c		3.6	*Hs*	.02.35	70	Peg.	d	
16	*M—Ak*	.48.13	16	Peg.	a		36	*M—Ak*	.03.26	23	Oph.	b and b' equally strong	
17	*M—Ak*	.48.59	22	Aql.	c		118.5	*Mh*	.03.37	35	Aql. Oph.	b' very feeble	
18	*M—Ak*	.49.48	23	Peg.	a		4.1	*Hs*	.04.00	30	Peg.	d	
116.1	*Mh*	.50.20	20	Oph.	b		118.6	*Mh*	.04.20	30	—	d	
2.1	*Hs*	.50.40	60	Peg.	a		37	*M—Ak*	.04.41	22	Oph.	b'	
116.2	*Mh*	.51.20	20	Oph.	b		4.2	*Hs*	.14.45	40	Peg.	d	
20	*M—Ak*	.51.24	12	Her. Oph.	b		119.1	*Mh*	.05.20	40	Oph.	b	
21	—	.51.55	11	—	b		39	*M—Ak*	.06.15	30	—	b' very fine	x
2.2	*Hs*	.52.00	40	—	b		119.2	*Mh*	.06.20	40	—	b	
116.3	*Mh*	.52.20	20	Oph.	b		4.3	*Hs*	.06.45	50	—	b'	
22	*M—Ak*	.52.36	23	Oph. Her.	b fine	x	40	*M—Ak*	.07.06	21	—	b	
116.4	*Mh*	.52.56	16	—	b		119.3	*Mh*	.07.20	20	—	b	
2.3	*Hs*	.53.00	40	—	b		41	*M—Ak*	.07.38	20	—	b and b'	
23	*M—Ak*	.53.09	16	—	b		119.4	*Mh*	.07.52	25	—	b	
116.5	*Mh*	.53.20	20	Oph.	b		4.4	*Hs*	.08.40	60	—	b and b'	
116.6	*Mh*	.53.50	20	—	b		42	*M—Ak*	.08.41	29	—	b and b'	
2.4	*Hs*	.54.00	50	Oph. Her.	b very fine		43	*M*	.09.42	24	—	b'	
24	*M—Ak*	.54.10	16	—	b		4.5	*Hs*	.10.00	55	—	b	
25	—	.54.40	13	—	b very fine		4.6	—	.11.00	55	—	b	
117.1	*Mh*	.54.51	20	—	b		120.4	*Mh*	.12.20	20	—	b	
2.5	*Hs*	.55.00	50	—	b very fine		5.1	*Hs*	.13.00	55	—	b	

Table 5 (continued).

No.	St.	M E T	Ex.	Const.	Remarks	Measured	No.	St.	M E T	Ex.	Const.	Remarks	Measured
120.5	*Mh*	21.13.02	45	Oph.	b		124.2	*Mh*	21.37.20	40	Oph.	b and b'. b very faint	
45	*M—Ak*	.13.41	28	Peg.	a		8.1	*Hs*	.38.00	65	—	b'	
5.2	*Hs*	.14.00	50	Oph.	b		124.3	*Mh*	.38.25	80	—	b' strong, b faint	
5.3	—	.15.00	55	Peg.	a		8.2	*Hs*	.39.00	50	—	b'	
121.1	*Mh*	.15.20	20	Oph.	b		8.3	—	.40 00	50	—	b'	
121.2	—	.16.20	20	—	b		124.4	*Mh*	.40.20	60	—	b' faint, b very faint	
121.3	—	.17.17	20	—	b		124.5	—	.41.22	55	—	b and b', very faint	
121.4	—	.18.20	20	—	b and b' (very feeble)		124.6	—	.42.25	60	—	b and b'	
5.6	*Hs*	.19.00	50	—	b		8.4	—	.43.40	60	—	b'	
121.5	*Mh*	.19.20	60	Oph. Aql.	b and b'		125.1	*Mh*	.44.25	50	—	b much fainter than b'	
6.1	*Hs*	.20.00	40	Oph.	b		62	*M—Ak*	.44.37	35	—	b' pulsating, b now quiet	
121.6	*Mh*	.20.22	15	—	b		8.5	*Hs*	.45.00	55	—	b'	
6.2	*Hs*	.21.00	50	Oph. Her.	b		125.2	*Mh*	.45.32	55	—	b and b'. b very feeble	
6.3	—	.22.00	40	—	b		63	*M—Ak*	.45.53	10	—	b' maximum of intensity	
49	*M—Ak*	.22.05	33	Oph.	b and b' equally strong Very fine	x	64	—	.46.14	8	—	b' next maximum	
							65	—	.46.53	15	—	b' next maximum	
6.4	*Hs*	.23.00	50	Oph.	b'		8.6	*Hs*	.47.20	60	—	b'	
122.2	*Mh*	.23.20	120	Equ.Aqu.Del.	d feeble arc		125.3	*Mh*	.47.20	40	—	b'	
50	*M—Ak*	.23.27	25	—	d feeble arc		66	*M—Ak*	.47.40	23	—	b' very fine	x
51	—	.24.29	39	—	d feeble arc fine		125.4	*Mh*	.48.27	45	—	b'	
6.5	*Hs*	.24.50	60	—	d feeble arc		67	*M—Ak*	.48.32	16	—	b' next maximum since No. 66. Very fine	x
122.3	*Mh*	.25.20	30	Oph.	b								
6.6	*Hs*	.26.00	50	—	b		9.1	*Hs*	.49.00	40	Oph.	b'	
122.4	*Mh*	.26.25	30	—	b and b'		68	*M—Ak*	.49.18	21	—	b' next max. Very fine	x
53	*M—Ak*	.26 49	26	—	b and b' equally strong, very fine	x	125.5	*Mh*	.49.25	30	—	b'	
							9.2	*Hs*	.50.00	55	—	b'	
7.1	*Hs*	.27.00	40	Oph.	b and b' very fine		69	*M—Ak*	.50.06	13	—	b' next max. Very fine	x
122.5	*Mh*	.27.05	30	—	b much stronger than b'		125.6	*Mh*	.50.20	40	—	b'	
7.2	*Hs*	.28.00	50	—	b' very feeble		9.3	*Hs*	.51.00	55	—	b'	
122.6	*Mh*	.28.22	25	—	b only visible		70	*M—Ak*	.51.20	16	—	b' next max. Very fine	x
54	*M—Ak*	.28.59	26	—	b' almost invisible, b very strong. Very fine		9.4	*Hs*	.52.00	50	—	b'	
							126.1	*Mh*	.52.22	65	—	b'	
7.3	*Hs*	.29.00	50	Oph.	Only b visible		71	*M—Ak*	.52.40	31	—	b' next max. Very fine	x
123.1	*Mh*	.29.20	20	—	Only b visible		9.5	*Hs*	.53.00	55	—	b'	
55	*M—Ak*	.29.52	38	—	b and b'. Very fine	x	9.6	*Hs*	.54.00	50	—	b'	
7.4	*Hs*	.30.00	50	—	b' feeble, b divided in two		126.2	*Mh*	.55.15	70	—	b' feeble	
123.2	*Mh*	30.20	80	—	b' feeble, b divided in two		72	*M—Ak*	.55.41	17	—	b' next max. Very fine	x
56	*M—Ak*	.31.13	17	—	b' a little weaker than b, b divided in two		73	*M—Ak*	.56.44	8	—	b' next max.	
							10.1	*Hs*	.57.00	50	—	b'	
123.3	*Mh*	.31.20	30	Oph.	b' almost invisible b divided in two		126.3	*Mh*	.57.20	60	—	b'	
							10.2	*Hs*	.58.00	50	—	b'	
7.5	*Hs*	.32.00	40	Oph.	b only visible		10.3	—	.59.00	50	—	b'	
57	*M—Ak*	.32.12	32	—	b' and the two parts of b equally strong. Very fine		10.4	—	22.00.00	50	—	b'	
							126.4	*Mh*	.00.20	20	—	b'	
							10.5	*Hs*	.01.00	50	—	b'	
123.4	*Mh*	.32.20	80	Oph.	b' only visible		126.5	*Mh*	.02.20	20	—	b'	
58	*M—Ak*	.33.18	15	—	b' only visible		10.6	*Hs*	.03.00	60	—	b'	
123.5	*Mh*	.33.25	30	—	b' and b. b' strongest		126.6	*Mh*	.03.20	60	—	b' disappeared	
59	*M—Ak*	.33.51	22	—	b' and b. b' strongest	x	11.1	*Hs*	.04.15	50	—	b'	
7.6	*Hs*	34.00	60	—	b'		127.1	*Mh*	.05.20	40	—	b' feeble	
123.6	*Mh*	.34.20	40	—	b and b'. b' strongest		74	*M—Ak*	.07.43	23	—	b' and a new spot b" to the left	
60	*M—Ak*	.34.35	22	—	b'. b not visible								
61	—	.35.49	27	—	b'. b not visible		127.2	*Mh*	.09.05	90	Oph.	b'	
124.1	*Mh*	.36.15	70	—	b and b' equally strong		11.2	*Hs*	.11.00	60	Lac.	Pulsating arc e	

Table 5 (continued).

No.	St.	M E T	Ex.	Const.	Remarks	Measured	No.	St.	M E T	Ex.	Const.	Remarks	Measured
76	*M—Ak*	22.11.21	120	Oph.	Feeble remains of b', as a spot b*		105	*M—Ak*	00.18.20	31	Aql.	k	
							106	—	.20.07	12	Equ. Peg.	k	
77	*M—Ak*	.14.42	115	Oph.	b*		107	—	.21.54	26	Aql.	New arc n	x
127.5	*Mh*	.15.20	120	—	b*		108	—	.26.51	43	Del. Peg.	k and a new arc k' over it	x
78	*M—Ak*	.16.18	85	—	b*		109	—	.29 07	37	Del. Aql.	k and k', very fine	x
127.6	*Mh*	.18.38	120	—	b*		110	—	.30.26	12	—	k, k'	
79	*M—Ak*	.19.23	118	Ari. Tau.	Spot f in east.		111	—	.30.48	10	—	k, k'	x
					Very fine	x	112	—	.31.10	20	—	k, k'	
128.1	*Mh*	.20.20	70	Oph.	b*		138.1	*Mh*	.34.50	180	Ori.	m	
80	*M—Ak*	.21.35	125	—	b* very fine	x	113	*M—Ak*	.35.06	15	Del. Peg.	k	x
128.2	*Mh*	.22.20	60	—	b*		114	—	.35.47	17	Aql.	n very fine	x
81	*M*	.24.52	52	Peg.	Pulsating arc g		138.2	*Mh*	.37.00	80	—	n	
128.4	*Mh*	.25.50	240	—	g		115	*M—Ak*	.37.47	17	—	n	
82	*M*	.26.16	87	—	g		138.3	*Mh*	.38 12	55	—	k	
83	*M*	.28.28	86	—	g very feeble		116	*M—Ak*	.39.25	41	Ori.	m	
84	*M*	.34.47	135	Oph.	b*		117	—	.40.21	12	Aql.	k and a new bit k_1 to the right, k strong, k_1 feeble	
128.6	*Mh*	.36 30	240	—	b*								
129.1	—	.57.30	120	Aql. Del.	Pulsating arc h		138.4	*Mh*	.40.35	70	Aql.	—	
129 2	—	23.08.25	180	Peg.	Pulsating arc i		118	*M—Ak*	.40.56	18	—	k feeble, k_1 strong and a new feeble k_2 to the right of k_1	x
129.3	—	.11.15	240	—	i								
85	*M—Ak*	.19.32	85	Peg.And.Lac.	i	x							
129.4	*Mh*	.20.30	60	—	i		119	*M—Ak*	.41.40	30	Aql.	k_1 and k_2 equally strong	x
86	*M—Ak*	.21 20	76	—	i with a new arc i_1 over it	x	120	*M—Ak*	.42.33	14	—	k_2	
129.5	*Mh*	.22.35	120	—	Both arcs disappeared		138.5	*Mh*	.42.40	40	Ori.	m very feeble	
87	*M—Ak*	.26.59	42	Peg. Cyg.	i		138.6	—	.44.00	40	Aql. Peg.	k and k_1	
129.6	*Mh*	.27.50	60	Peg.	i		139.1	—	.45.15	50	Aql. Del.	k, k_1	
88	*M—Ak*	.28.21	38	Cyg. Peg.	i		139.2	—	.47.55	180	Ori.	m	
130.1	*Mh*	.29.00	50	Cyg.	i very feeble		139.3	—	.50.40	120	—	New spot q	
89	*M—Ak*	.29.19	39	Peg.And.Lac.	i and i_1		139.4	—	.53.07	55	Aql. Del.	k_1 and k_2	
130.2	*Mh*	.30.10	60	Peg.	i, very faint		139.5	—	.55.10	120	Ori.	q	
90	*M*	.30.23	34	Cyg. Del.	i, very faint		139.6	—	01.00.20	80	Aql.	k_1 and k_2 both feeble	
130.3	*Mh*	.31.15	60	Aqr. Aql.	New arc k		121	*M—Ak*	.19.42	22	—	k_2	
91	*M—Ak*	.31.34	32	—	k	x	122	—	.21.26	29	Ori. Tau.	q, now 3 spots along an arc	x
92	—	.32.20	33	—	k		123	—	.22.00	10	—	q only one spot visible	
130.4	*Mh*	.32.25	50	—	k		124	—	.25.06	18	Lyr.	New arc o	
93	*M—Ak*	.33.20	35	Aqr. Aql.	k	x	125	—	.26.03	24	—	o	x
130.5	*Mh*	.33.20	60	—	k		126	*Ak*	.27.42	25	—	o	
94	*M—Ak*	.34.20	25	Cyg. Peg.	i	x	140.1	*Mh*	.32.59	90	—	o	
130.6	*Mh*	.34.40	60	—	i		127	*Ak*	.33.42	20	—	o	
95	*M—Ak*	.36.29	32	Aql. Aqr.	k	x	140.2	*Mh*	.34.04	30	—	o	
131.2	*Mh*	.37 00	30	—	k		128	*M—Ak*	.35.18	45	—	o and feeble thin arc o' under it	x
131.3	*Mh*	.37.35	30	—	k								
96	*M—Ak*	.37.39	31	—	k	x	140.3	*Mh*	.35.24	60	Lyr.	o, o'	
131.4	*Mh*	.38.10	20	—	k		129	*M—Ak*	.36.41	60	—	o, o'	
97	*M—Ak*	.38.45	30	Aqr.	k		140.4	*Mh*	.37.34	84	—	o, o'	
131.5	*Mh*	.39.00	60	Aqr.	k		140.5	—	.45.04	70	—	o, then it vanishes	
98	*M—Ak*	.41.22	30	Aqr. Aql.	k		130	*M—Ak*	.54.44	48	—	Feeble trace of o	
99	—	.42.51	27	—	k		140.6	*Mh*	.56.44	140	—	Feeble trace of o	
100	—	.44.43	30	—	k	x	131	*M—Ak*	03.04.36[1]	15	♂, Psc.	Feeble arc p in SW	
101	—	.46.50	60	♂, Psc.	New arc l	x	132	—	.06.06	25	Gem.	q	x
102	—	.48.24	28	Aqr. Aql.	k, very fine	x	133	—	.07.14	27	—	q	x
103	—	.49 24	32	Tau. Ori.	New spot in E, m, very feeble		134	—	.08.29	49	—	q	
							135	—	.10.53	24	♂, Psc.	p	
104	*M—Ak*	00.16.30	50	—	m, very feeble	x	136	—	.11.35	43	—	p	

[1] Between Nos. 140.6 and 131 no aurora was strong enough to be photographed.

Table 5 (continued).

No.	St.	M E T	Ex.	Const.	Remarks	Measured	No.	St.	M E T	Ex.	Const.	Remarks	Measured
138	*M—Ak*	03.12.51	10	♂, Psc.	p	x	157	*M—Ak*	04.00.20	70	UMa. Dra.	s	
139	—	.14.28	20	—	p		142.4	*Mh*	.00.22	180	Psc.	Rest of p	
140	—	.15.16	16	—	p	x	158	*M—Ak*	.03.18	60	UMa. Dra.	s	
141	—	.16.01	16	—	p		142.5	*Mh*	.03.32	60(?)	Psc.	Rest of p	
143	—	.23.31	30	CMi. Ori.	New pulsating arc r		142.6	—	.05.32	60	UMa.	s	
144	—	.25.05	45	—	r	x	143.1	—	.06.50	50	—	s	
145	—	.26.12	45	—	r	x	143.2	—	.07.55	70	—	s	
148	*M*	.33.47	17	♂, Psc.	Rest of p		143.3	—	.10.10	70	—	s	
149	*M*	.34.19	8	—	Rest of p		143.4	—	.11.30	50	—	s	
150	—	.34.42	8	—	—		143.5	—	.14.00	60	Psc.	Rest of p	
141.1	—	.34.59	20	—	—		143.6	—	.15.55	60	UMa.	s	
151	*M*	.35.26	15	—	—		159	*M*	.16.44	59	Dra.	s	
141.2	*Mh*	.36.04	50	—	p stronger		160	*M*	.18.18	60	Psc.	p	
141.3	—	.37.29	60	—	p strong		144.1	*Mh*	.18.55	160	—	p	
152	*M—Ak*	.37.41	13	Cet. Psc.	p strong		161	*M*	.19.33	30	Dra.	s	
153	—	.38.32	17	—	p strong	x	162	*M—Ak*	.20.11	60	Dra. Lyr.	s	x
154	—	.45.34	23	CMi. Ori.	r	x	144.2	*Mh*	.20.55	60	Cet. Psc.	p	
155	—	.46.17	17	—	r	x	164	*M—Ak*	.26.48	30	Psc.	n	x
141.5	*Mh*	.46.59	50	—	r		144.3	*Mh*	.27.50	130	—	p	
141.6	—	.48.04	40	—	r		165	*M*	.29.41	45	—	p	
142.1	—	.49.12	40	—	r		167	*M—Ak*	.33.27	34	—	p	x
142.2	—	.50.09	45	—	r		168	—	.35.30	32	—	p	
142.3	—	.51.12	40	—	r		169	—	.36.31	32	—	p	
156	*M—Ak*	.58.50	60	UMa. Dra.	New pulsating arc s		170	—	.37.15	17	—	p	

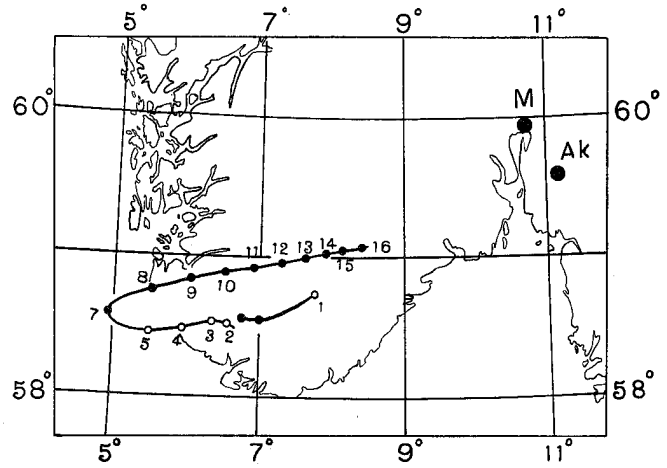

Fig. 8. Geographical situation of the pulsating arc b, at $20^h\ 41^m\ 53^s$ M E T. Open circles for the points whose heigths are measured, filled in for the rest.

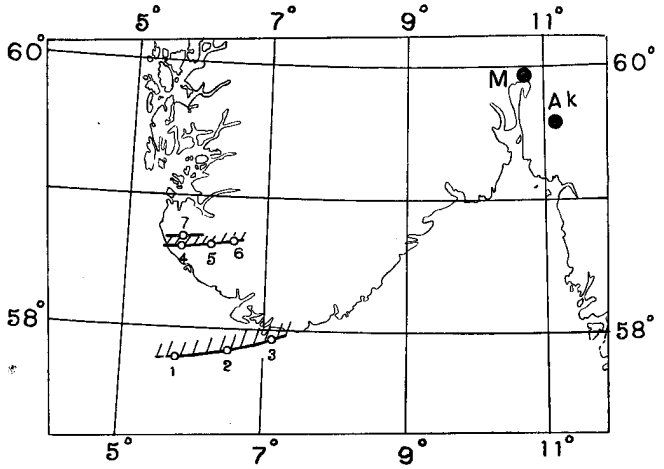

Fig. 9. Geographical situation of b and b', at $21^h\ 26^m\ 49^s$. Same remark as for Fig. 8.

The sketches are seen on Plate 4, the pictures on Plate 16. The negatives have been copied on Lupex paper to strengthen the contrasts.

No. 53. Bits of Pulsating Arcs b and b', $21^h\ 26^m\ 49^s$. Same base line.

P	ε_2	p	h	a	D	H
1	— 1.0	7.0	14.9	52.2	369	111
2	1.9	7.7	16.7	48.4	333	110
3	4.3	8.4	18.5	45.1	301	109
4	—14.0	7.9	16.7	64.8	316	104
5	—12.7	8.4	18.8	62.9	293	108
6	—11.9	8.9	20.9	61.6	275	112
7	—15.1	7.9	18.7	66.0	310	113

b lies to the right, b' to the left. The situation is seen on Fig. 9, the sketches on Plate 4, and the pictures on Plate 16.

No. 71. Pulsating Aurora b', $21^h\ 52^m\ 40^s$.
Same base line.

P	ε_2	p	h	a	D	H
1	— 4.5	6.3	12.7	56.7	413	108
2	— 1.0	6.8	14.6	52.5	379	112
3	1.5	7.4	16.5	49.2	346	113
4	4.0	8.0	18.3	45.8	325	117
5	—11.8	6.0	12.8	64.5	425	112
6	—10.8	6.8	14.8	62.8	374	112
7	— 9.3	7.6	16.8	60.4	332	110
8	— 7.0	8.2	18.8	57.4	306	113

This set belongs to a most interesting series of the arc, or rather pulsating spot b', Nos. 63—73, which is also shown on the cinematographic pictures mentioned later. Along the outline 11 more points have been chosen and their geographical position found, assuming the height to be 112 km, mean of the 8 measured heights. The result is seen on Fig. 10.

The sketches are seen on Plate 4, the pictures on Plate 16.

No. 102. Pulsating Arc k, $23^h\ 48^m\ 24^s$.
Same base line.

P	ε_2	p	h	a	D	H
2	8.2	10.1	21.6	38.5	244	102
3	3.9	9.0	18.3	44.8	281	100
4	1.5	8.1	16.6	48.4	315	102
5	25.8	8.1	18.6	22.5	281	102
6	23.0	7.8	17.7	25.9	300	104
8	15.7	7.6	15.4	34.3	326	100

This set is very fine with sharp outlines. 6 more points have been chosen and their situation found, assuming the height equal to 102 km.

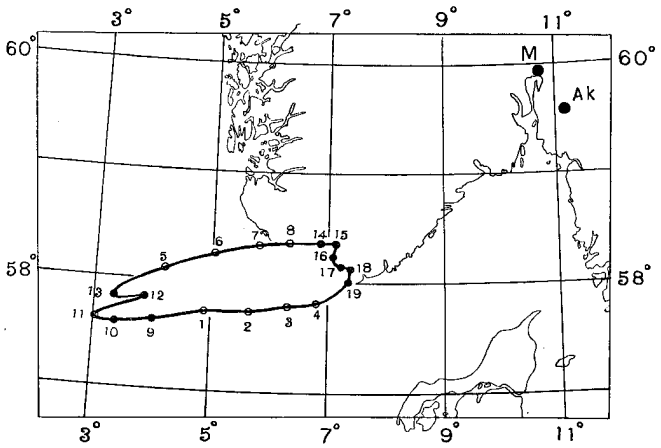

Fig. 10. Geographical situation of b', at $21^h\ 52^m\ 40^s$.
Same remark as for Fig. 8.

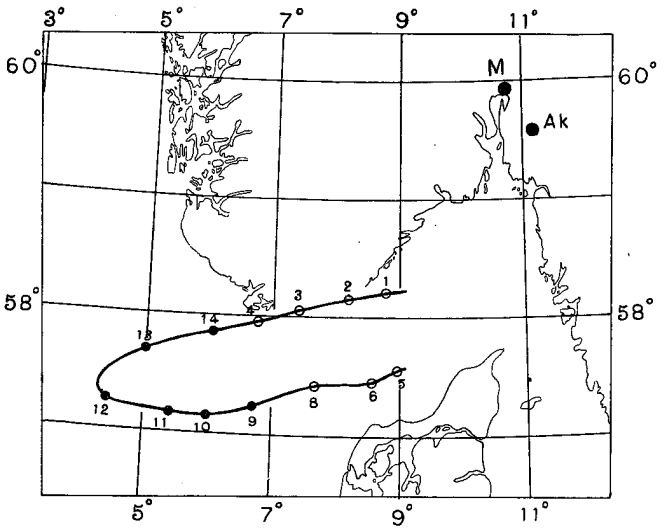

Fig. 11. Geographical situation of k, at $23^h\ 48^m\ 24^s$.
Same remark as for Fig. 8.

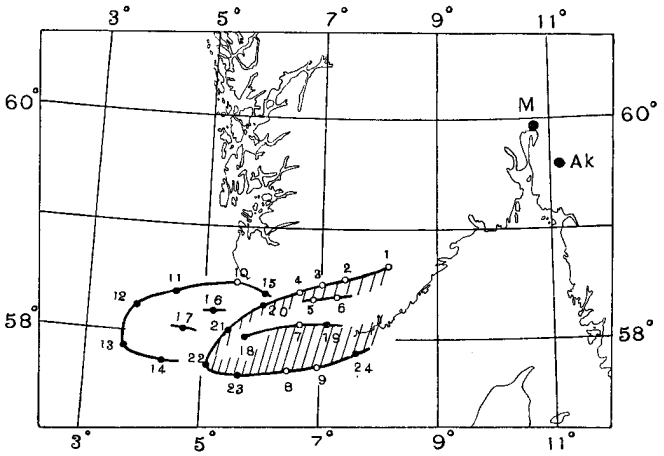

Fig. 12. Geographical situation of k and k', at $0^h\ 29^m\ 06^s$.
Same remark as for Fig. 8.

The sketches are seen on Plate 4, the pictures on Plate 17, and the geographical situation on Fig. 11.

No. 109. Pulsating Arcs k and k' and Feeble Remains to the Right, $0^h\ 29^m\ 07^s$ M E T.
Same base line.

P	ε_2	p	h	a	D	H
1	— 1.9	11.9	26.5	47.4	202	103
2	— 4.8	10.1	22.9	52.7	243	108
3	— 6.0	9.4	21.0	55.0	264	108
4	— 6.9	8.8	19.0	56.5	286	106
5	— 4.3	9.0	18.9	53.6	280	104
6	— 2.3	9.5	20.7	50.8	262	106
7	— 1.8	8.3	16.8	51.8	308	102
8	3.5	7.4	14.6	47.4	348	101
9	6.3	7.8	16.3	43.9	326	105
10	—12.9	7.5	15.1	64.2	335	101

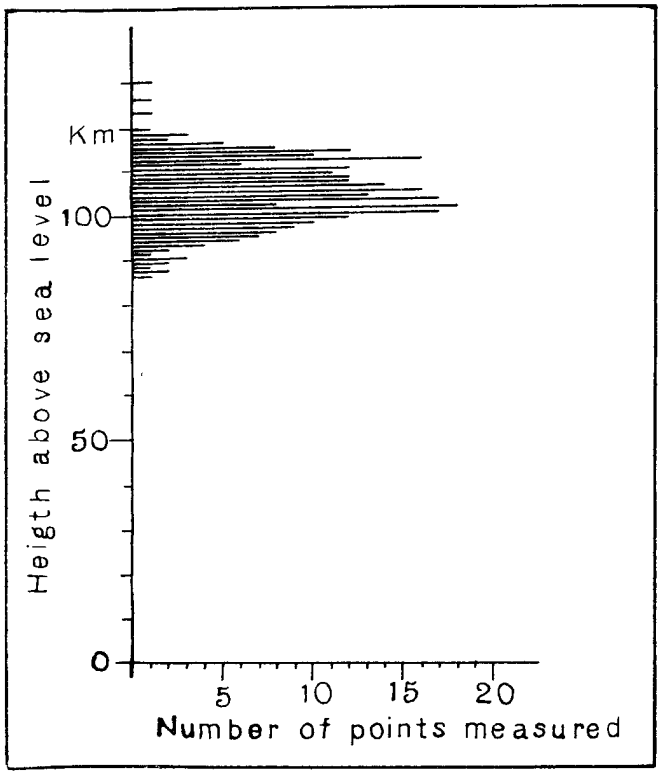

Fig. 13. Diagram of all the 283 heights measured.

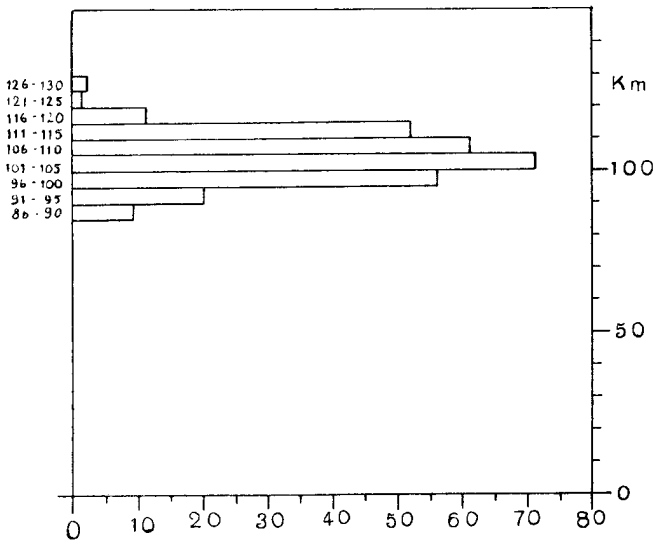

Fig. 14. Diagram of the 283 heights in intervals of 5 km.

This is a very fine set. The sketches are seen on Plate 4 and the pictures on Plate 17. On Fig. 12 the geographical situation is marked.

In Table 6 all the 283 heights measured[1] are given. The mean height of them all is

104.7 km.

[1] The work was done by my assistant Østvold.

It seems that they are a little lower after midnight, but the difference is not great: mean of 173 heights before midnight was 105.5 km and of the 110 heights after midnight 103.5 km.

Fig. 13 shows statistics on the heights. For each height the number of points with this height is marked by a dash line perpendicular to the height scale.

On Fig. 14 a similar figure is made for intervals equal to 5 km, in the same manner as in Fig. 1 for the pulsating arc of February 28th, 1929.

Table 6.

The Measured Heights of Pulsating Arcs and Spots on September 21st—22nd, 1941.

No.	Name	M E T	Heights in km
6	b	20.40.50	114, 114, 115, 104, 107, 116, 113, 112
7	b	.41.15	110, 110, 101, 105, 109
8	b	.41.53	103, 126, 118, 114, 112
11	b	.43.49	115, 109, 105
12	b	.44.40	107, 105, 102, 98
22	b	.52.36	94, 89, 103, 101
26	b	.55.36	109, 98, 101
	b'	.55.36	102, 98, 101
27	b	.56.34	110, 107
	b'	.56.34	112, 112, 116
28	a	.57.17	107, 106, 106, 104, 101, 107, 105, 105, 101
29	a	.58.14	99, 98, 97, 95, 110, 103
39	b'	21.06.15	123, 114, 109, 108, 105, 106, 107, 107, 112, 111, 113, 110
49	b	.22.05	98, 92, 94, 90, 115, 110, 112
	b'	.22 05	90
53	b	.26.49	104, 108, 112, 113
	b'	.26.49	111, 110, 109
55	b	.29.52	112, 110, 117, 114, 112
	b'	.29.52	104, 116
59	b'	.33.51	119, 109
66	b'	.47.40	115, 112, 106, 105, 111
67	b'	.48.32	103, 100, 94, 100, 103, 99
68	b'	.49.18	107, 100, 100
69	b'	.50.06	105, 99, 98, 99
70	b'	.51.20	99, 106, 105, 104
71	b'	.52.40	108, 112, 113, 117, 112, 112, 110, 113
72	b'	.55.41	98, 96, 96, 97, 97
79	f	22.19.23	111
80	b*	.21.35	114
85	i	23.19.32	113, 114, 110
86	i	.21.20	115, 108
91	k	.31.34	103, 102, 105, 106
93	k	.33.20	93, 92, 94, 90, 91
94	i	.34.20	108, 103, 103, 115, 115, 113
95	k	.36.29	96, 98, 100, 104, 105
96	k	.37.39	95, 96, 99, 96
100	k	.44.43	102, 101, 101, 99, 105, 96, 101
101	l	.46.50	103, 104, 104
102	k	.48.24	102, 100, 102, 102, 104, 100
104	m	00.16.30	86
107	n	.21.54	114, 112, 109, 98, 101, 111
108	k	.26 51	103
	k'	.26.51	103, 105, 104, 103, 103
109	k	.29.07	102, 101, 105, 101
	k'	.29.07	103, 108, 108, 106, 104, 106

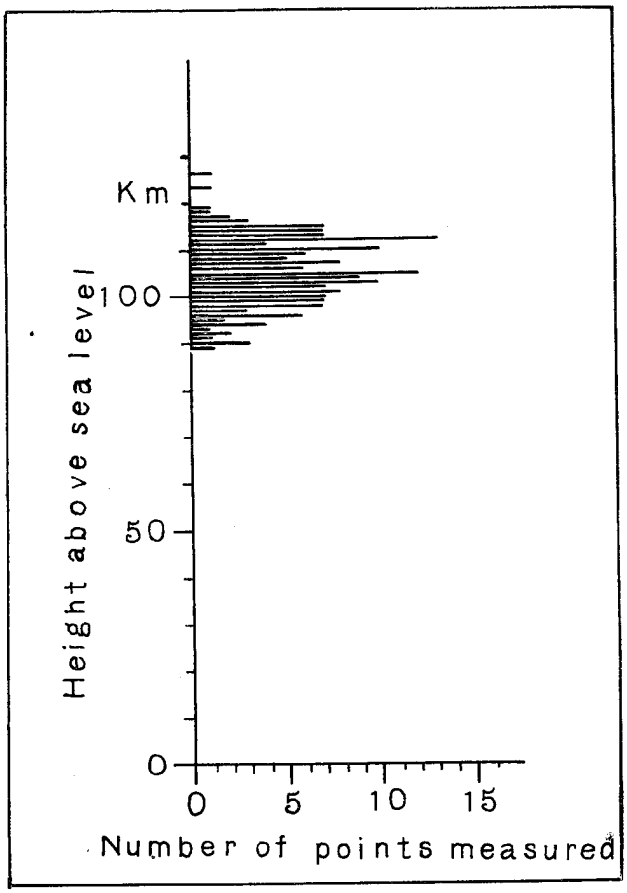

Fig. 15. Diagram of heights before midnight M E T.

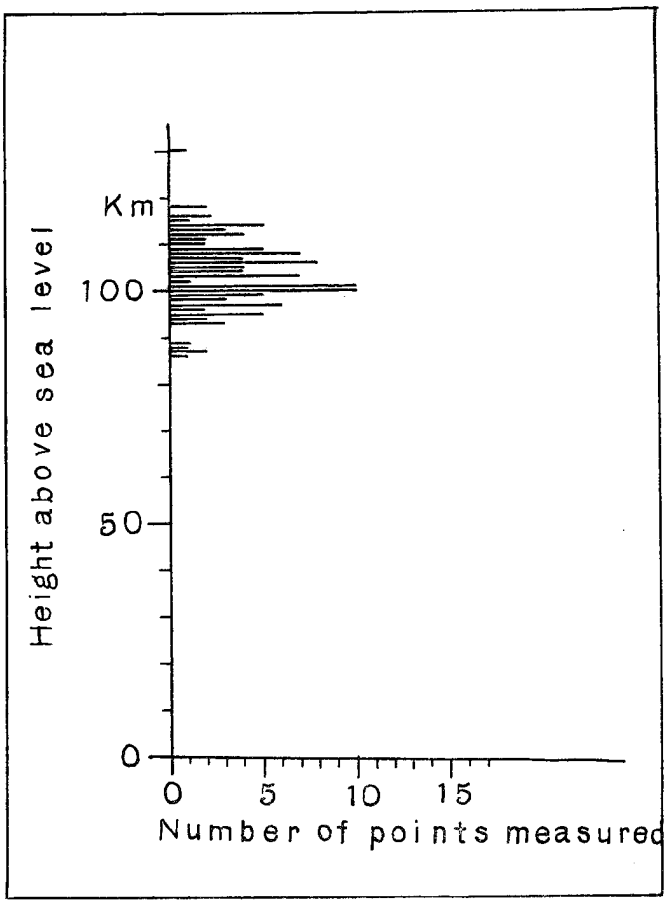

Fig. 16. Diagram of heights after midnight M E T.

Table 6 (continued).

No.	Name	M E T	Heights in km
111	k	00.30.48	114, 109, 107, 100
	k'	.30.48	103, 100, 95
113	k	.35.06	95, 99, 101, 97, 100
114	n	.35.47	114, 111, 113
118	k_1	.40.56	109, 109, 104, 105, 98, 106, 93
119	k_1	.41.40	100, 101
	k_2	.41.40	109, 101, 105, 100, 106
122	q	01.21.26	108, 106, 108
125	o	.26.03	112, 118, 130
128	o	.35.18	114, 112, 110
132	q	03.06.06	107, 106, 97, 116, 113, 115
133	q	.07.14	106, 106, 104, 116, 118
138	p	.12.51	97, 99, 96, 97, 100, 110, 108, 108
140	p	.15.16	93, 95, 101, 99, 94, 93
144	r	.25.05	87, 87, 88
145	r	.26.12	95, 97, 107
153	p	.38.32	114, 108, 89, 96, 100
154	r	.45.34	103, 101, 101, 100
155	r	.46.17	94, 95, 100, 99, 107
162	s	.20.11	113
164	n	.26.48	99, 100
167	p	.33.27	97, 103

The two figures Nos. 15 and 16 give the statistics before and after midnight.

As to the geographical situation of all the sets measured, we come back to this in the next section.

10. Results for the Individual Pulsating Arcs.

It is most interesting to study the individual bits of arcs and spots, especially the arcs b, b', and k. In fact these bits of arcs have *been stationary in the atmosphere* for a rather long time.

We first consider the bits called b.

Of the about 100 photographs of b, 12 sets have been measured, from $20^h\ 40^m$ to $21^h\ 34^m$, and on Fig. 17 the geographical situation of the outlines has been marked, which clearly shows the stationary situation.

The distribution of 50 heights is seen on Fig. 18. The mean of them all is 107.4 km.

We next consider b'.

Of this 84 pictures were taken, among which 14 sets from $20^h\ 55^m$ to $21^h\ 56^m$ were measured. This bit of arc was also stationary, which is very clearly seen on the same Fig. 17.

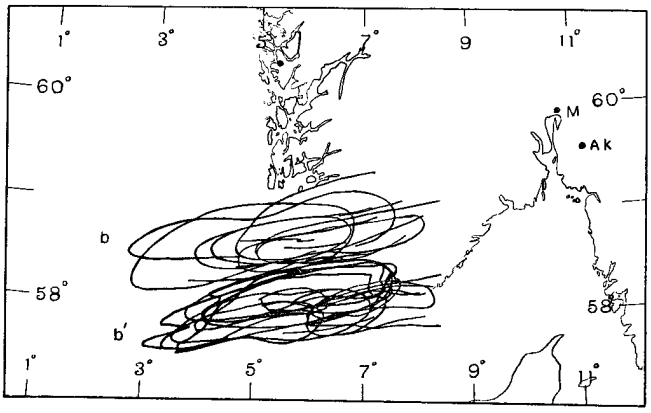

Fig. 17. Geographical situation of the pulsating aurorae b and b'.

The mean of 61 heights was 106.3 km, and their distribution is seen on Fig. 19.

The Arcs Called k.

Later, from $23^h 31^m$ to $0^h 46^m$ a new pulsating and very fine bit of arc appeared almost at the same place as b'. 29 pictures were taken, among which 11 sets were calculated. The situation is seen on Fig. 20.

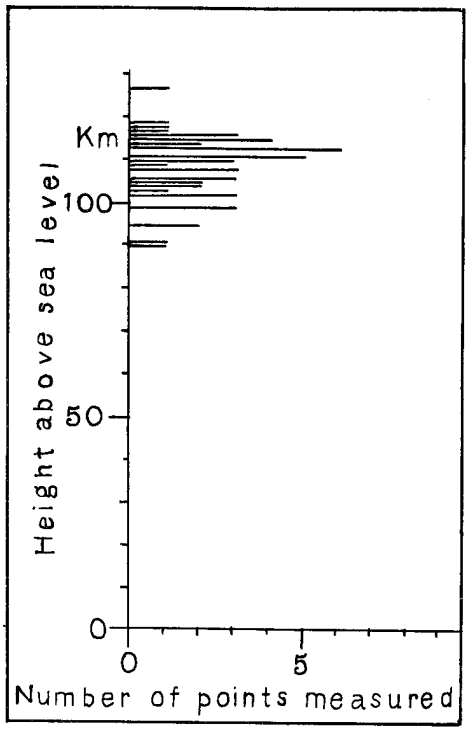

Fig. 18. Diagram of heights of b.

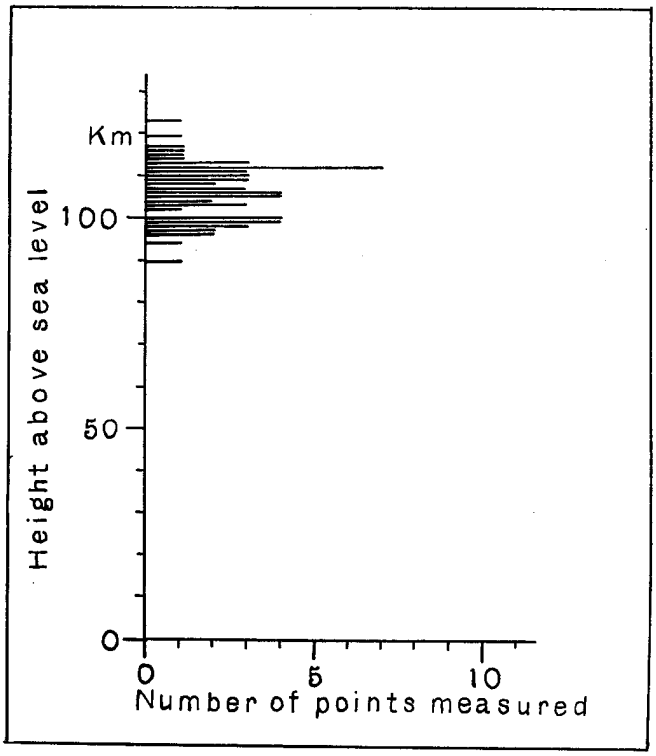

Fig. 19. Diagram of heights of b'.

Mean of 45 heights was now 100.3 km and their distribution is seen on Fig. 21.

As to the *other bits of arcs and spots* their geographical situation is seen on the map Fig. 22.

They are distributed from the Finnish Gulf to Scotland between 57° and 62° Latitude.

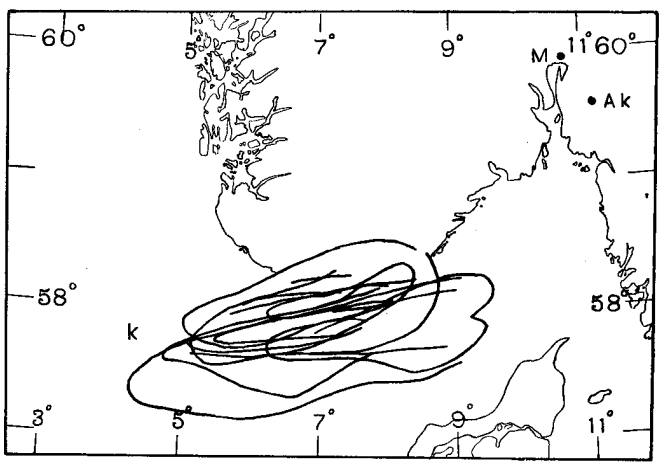

Fig. 20. Geographical situation of the pulsating aurorae k.

11. Moving Picture Series of the Pulsating Aurorae b and b'.

During the pulsations of the bits of arc b and b', I took a long series of pictures with a cinematograph with objective Astro R. K. F 1.25 and Agfa Isopan Ultra rapid film. I began the work at about $20^h\ 54^m$ with a new picture each 5th second. This film was, however, underexposed.

Later, at about $21^h\ 24^m$ I began a new series, exposing each picture about 10 seconds, and then shifting rapidly over to the next picture. Later my assistant Nygaard continued the work. In all 139 pictures were taken, but unfortunately I had no assistant to make notes and give the 10 second intervals; they were only judged by counting 1, 2, 3, ... etc. For this reason it is impossible to coordinate the single pictures with those taken from the stations and given in Table 5.

Notwithstanding, the pictures Nos. 18 to 24 are clearly of the same aurora as the pictures 53 to 55 in Table 5. Also cino Nos. 25, 26, 27 are the same as Nos. 56 and 57.

The pulsations of b and b' are beautifully shown on the film and the later cino numbers 60 to 140 give very good pictures of the spot b' and its pulsations, corresponding to Nos. 65—72 in Table 5.

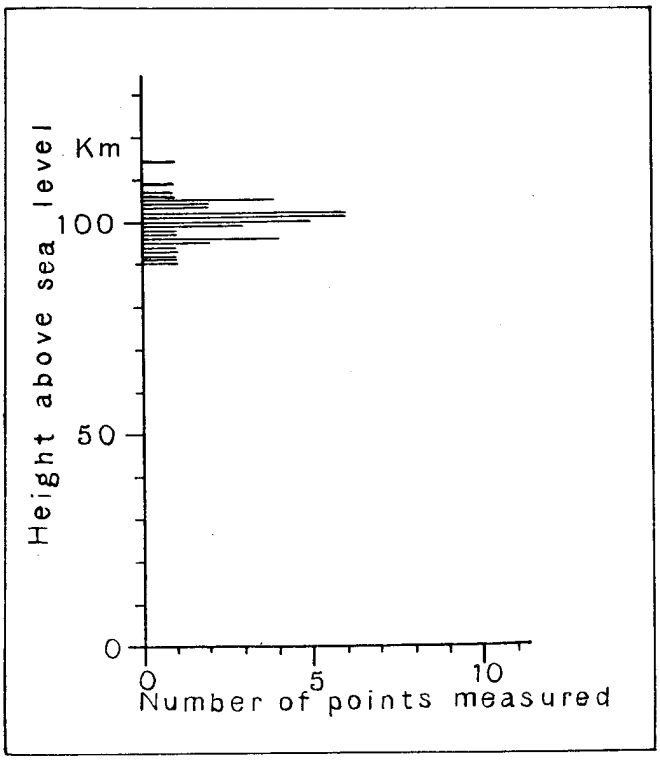

Fig. 21. Diagram of heights of k.

On these last pictures the stars 66, 67, 68, 70, 73, β and γ Ophiuchi are very readily seen in the middle of each picture.

A reproduction of the film is seen on Plate 18.

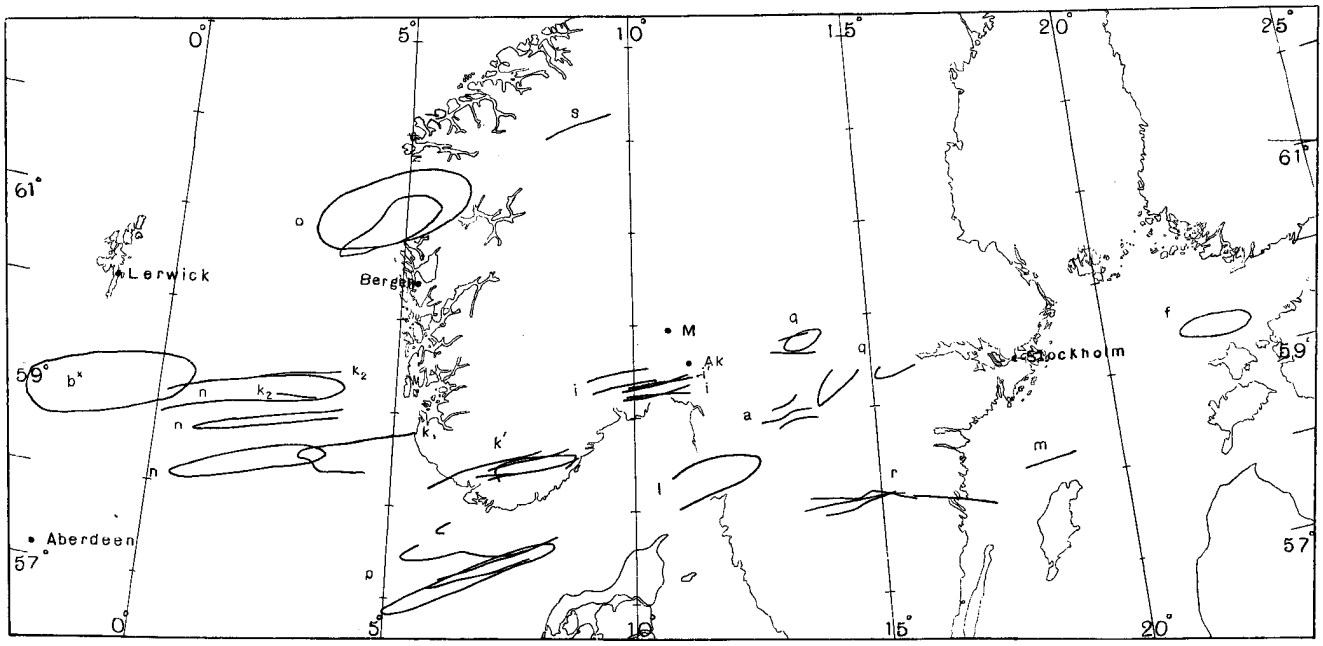

Fig. 22. Geographical situation of the rest of the pulsating patches and arcs on the night of September 21st—22nd, 1941.

12. The Spectrum.

Of great interest are 7 spectra taken of the pulsating arcs by my assistant Herlofson[1]. It is the first time that spectra have been taken of this aurora form from southern Norway.

The following spectra were taken[2]:

1. With the flintglass spectrograph loaned from the Auroral Observatory in Tromsø:
   a. Exposed from $20^h\,45^m$ to $21^h\,15^m$ M E T on an arc in the south and on arc b in SW.
   b. Exposed from $21^h\,15^m$ to $21^h\,45^m$ on arcs b and b'.
   c. Exposed from $23^h\,44^m$ to $23^h\,53^m$ on arc k.
   d. Exposed from $23^h\,55^m$ to 0^h on the same.
   e. Exposed from $0^h\,2^m$ to 1^h on arcs in S (k, k', k_1, n).
2. With a small crownglass spectrograph:
   f. Exposed from $21^h\,30^m$ to $23^h\,50^m$ with some interruptions, on arcs in S.
   g. $23^h\,52^m$—1^h on the same.

[1] Carl Størmer: Types remarquables d'aurores boréales observées dans la Norvège méridionale Comptes Rendus des séances de l'Académie des Sciences, Paris, Vol. 213, p. 804.

[2] More details on the spectrographs are given in the paper: Carl Størmer: Some Auroral Spectra from Southern Norway 1940, Astrophysica Norvegica Vol. III, No. 10.

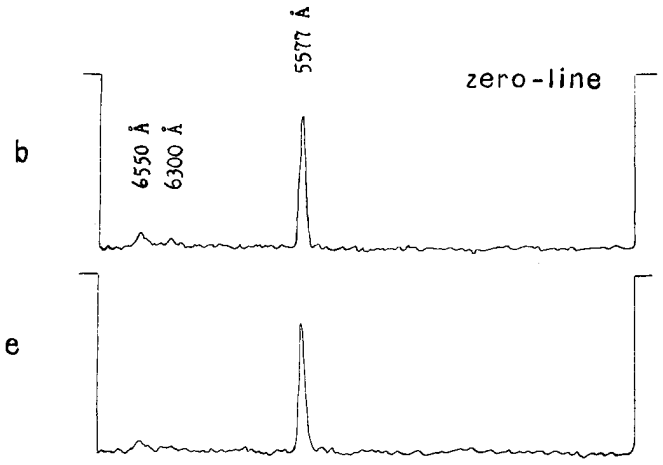

Fig. 23. Registram of the spectra Nos. b and e.

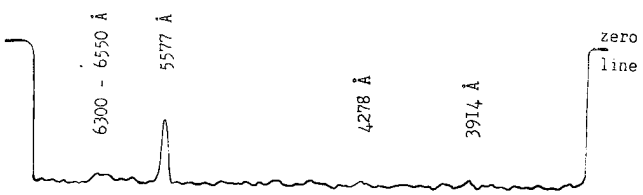

Fig. 24. Registram of spectrum No. g.

As plates were used Agfa Isopan ISS and as comparison spectra the spectra of Hydrogen and Helium.

The spectra b, e, and g are reproduced on Plate 17. The other spectrograms have the same characteristic feature as these 3 spectra, *namely that the aurora line 5577 Å dominates the whole spectrum.*

Of the other lines and bands of oxygen and nitrogen there are only very faint traces.

On Fig. 23 are seen registrams of the spectra b and e, on Fig. 24 a registram of the spectrum g.

13. Other Observations of the Same Aurora.

The pulsating aurora was seen not only in Norway, but also in Holland and in Germany. Here are some observations of it:

Mr. Hveding saw it from Homborsund (58° 15′, 8° 30′ E. Gr.) about 21^h M E T as two big pulsating surfaces in W. He sent me a map where the direction of the aurora was marked and its agrees with the direction of the pulsating bits of arc we have called b and b'. He also gave me a sketch, but this was without reference stars, so more accurate measurements could not be made.

From the amateur astronomer *Gunnar Peterson* in Göteborg (Latitude 57° 47′, Longitude 11° 55′ E. Gr.) I got a more detailed description accompanied by sketches on starmaps.

He writes:

"On September 21st several pulsating patches were observed. The observations started at $23^h\,40^m$ M E T when a pulsating spot between ζ and η Ursa Majoris was sketched. At $23^h\,45^m$ this spot had disappeared. At this time a big patch between Aquila, Cygnus, and Hercules was sketched. Its intensity was very variable, but it was stationary all the time. The variation of the intensity was very irregular without any period, and it was not the same all over; sometimes one part began to light up before another part. In the lowest part in Ophiucus, however, the light was more steady and the outline of the patch was here very sharp. In the upper part it was difficult to fix its boundary. The intensity was sometimes so strong that stars of the second magnitude were invisible.

At $0^h\,10^m$ two patches in Orion were seen, pulsating with a period of 10^s. At $0^h\,11^m$ they had disappeared. At $0^h\,24^m$ a new spot near α Ophiuchi.

At $0^h\,25^m$ only the right border of the great patch and the lowest part of it still remained. Here the observations ceased."

If we compare these observations with those in Table 5 we get the following results:

The spot at $23^h\,40^m$ was not photographed at our stations.

The big patch from $23^h\,45^m$ to $0^h\,25^m$ was the aurorae here called k and k'. By inspecting his sketch and comparing it with the geographical situation of the patch k, picture No. 100, it is also evident that the patch must have had just the form observed by Mr. Peterson.

The two spots in Orion at $0^h\,10^m$ were not photographed in Oslo and Askim.

From director *Cannegieter*, the Meteorological Institute, *De Bilt*, *Holland*, I got the following observation:

"Luminous lens shaped aurora parallel to the horizon and to the 40th degree of latitude stretching away from $8^h\,20^m$ R. A. to $12^h\,20^m$ R. A. and from 3° north to 3° south of the 40th degree of latitude. The aurora was yellow white and pulsating to the intensity of twilight."

It was accompanied by a sketch where the time 22^h M E T and the coordinates of the place of observation $6^\circ\,15'$ E Gr. and $52^\circ\,10'$ North were given.

Comparing this with our list and with the geographical situation of the aurorae, we found that the pulsating aurora in question must have been No. b', lying as seen on Fig. 17.

An interesting photograph from the observatory *Sonneberg* (Latitude $50^\circ\,21'\,24''$, Longitude $11^\circ\,10'\,45''$ E. Gr.), exposed from $0^h\,1^m\,35^s$ to $0^h\,4^m\,35^s$ by Professor *C. Hoffmeister*, was newly published[1]. From this figure we made a negative and on projecting it on a wall the stars and situation of the pulsating aurora near the northern horizon could easily be found. Comparing it with our Table 5 and Fig. 20 the aurora was identified with the arc k.

14. Observations of Isolated Pulsating Arcs from 1911 to 1922.

Since 1911 I have observed such isolated pulsating arcs a few times only. In my French report[2] on the aurorae from 1911 to 1922 I have given the following cases:

1919, March 23rd. Remarkable pulsating arc. This curious phenomenon appeared between 23^h and 24^h M E T. A diffuse and quiet arc was seen at the northern sky passing through Cassiopeia. It was quite isolated in the sky. This arc showed very slow pulsations. Parts of it appeared, were visible some time, and then disappeared and reappeared. The arc was feeble and diffuse and without any rays. Some simultaneous photographs were taken from my stations Bygdø and Kongsberg, but did not succeed very well. The height was found to be from 130 to 150 km, but this is very doubtful.

1919, October 3rd. Only visual observations. A pulsating arc was seen from Aquila towards the zenith about 23^h—24^h.

1919, December 19th. This case has already been mentioned in section 2.

1920, April 17th. From the station Kongsberg my assistant Busengdal observed about 23^h a pulsating arc going through Perseus and Andromeda. For some time another arc was seen just under Cassiopeia.

1921, September 3rd—4th. About $1^h\,30^m$ at night I observed a remarkable pulsating arc, passing from α Aquilæ through the Great Bear and north of Gemini. Between $2^h\,15^m$ and $2^h\,50^m$ a series of photographs were taken, but with no result. Before sunrise the pulsating arc was still visible, from Venus to α and β Ursæ Majoris.

These few times no aurora was observed on the preceding two days, except on October 3rd, 1919, when a fine aurora with corona was seen through clouds on October 1st.

15. Pulsating Isolated Arcs Observed from 1922 to 1942.

Since 1922 pulsating isolated arcs have been observed on the following dates:

1926, March 13th. At $20^h\,14^m$ a very feeble isolated pulsating arc in the constellations Pisces and Pegasus. One picture only taken.

1929, February 28th, see the foregoing sections.

1929, October 10th. At $21^h\,10^m$ I discovered from Oslo a pulsating broad arc under the Great Bear; lower border at 12 Can. Venat. It was very similar to the arc of October 31st, 1931. At $21^h\,20^m$ it had disappeared. No photographs were taken.

1930, October 1st. Fine clear sky. At about $19^h\,50^m$ I discovered from Oslo towards W a strong broad bit of an arc. The aurora line was weak. Some minutes later it had disappeared.

[1] »Die Sterne«, 21. Jahrgang 1941, Heft 12, p. 211.

[2] Geof. Publ. Vol. IV, No. 7.

Mr. Olaf Hassel observed the same aurora from Krekling near Kongsberg. He says:

"At $19^h\ 43^m$ it streched from the western horizon between δ Serpentis and ζ Bootis up towards α Coronæ as a broad fragment of an arc. At $19^h\ 47^m$ it developed suddenly, passed α Coronæ and at $19^h\ 47^m\ 30^s$ even up to the head of Draco towards $\varkappa$ Cygni and then suddenly disappeared."

The pulsating arc reappeared later in the night, according to a letter from Mr. Arnfinn Refsdal of the Norwegian Meteorological Institute. He said that he observed from Oslo a bit of an arc at $2^h\ 55^m$ to 3^h, color grey white, near the horizon in SW. The western part was steady, but the eastern pulsated, sending a long appendix rhythmically eastward, in the direction of the arc.

1931, October 31st, see foregoing sections.

1932, September 4th—5th and 7th—8th. I got a long description of these aurorae from Mr. Hassel, part of which will be given in the next section.

1932, September 23rd. Same remark.

1937, October 2nd. Early in the evening, probably about 20^h, my assistant Egeberg called on the telephone and said there was a pulsating arc in the north. I looked out and saw a fine pulsating arc under the Great Bear. It was quite isolated in the sky. Immediately I warned my aurora stations, but before they managed to get in order the arc had disappeared. This time also the aurora had appeared the two foregoing nights, particularly very fine on September 30th, with high rays, red coloration, and so on.

1941, September 21st—22nd, see foregoing section.

16. Hassel's Observations of the Intervals between Successive Pulsations.

As I had enough to do with the height measurements I had no occasion to follow the pulsations in detail, and I therefore asked Mr. Hassel to observe, if possible, the intervals between successive pulsations. I here give his observations made at Darbu, not far from Kongsberg:

1932, September 7th—8th. A pulsating bit of an arc appeared about $22^h\ 28^m$ M E T. See Fig. 25. The successive maxima of intensity were as follows. (See Table 7.)

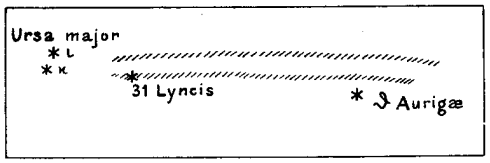

Fig. 25.

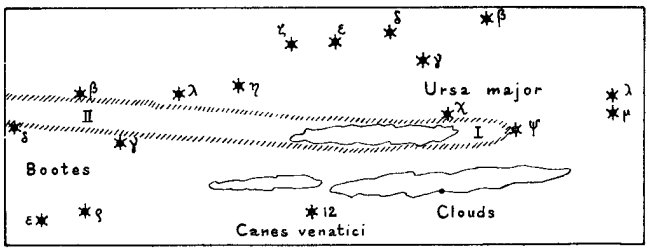

Fig. 28.

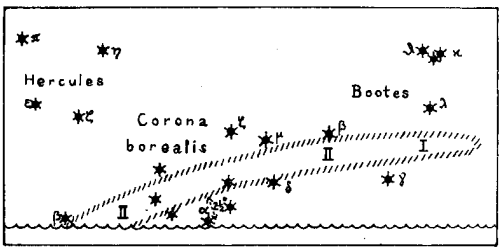

Fig. 27.

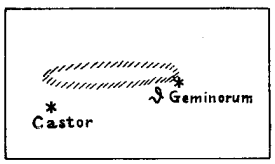

Fig. 26.

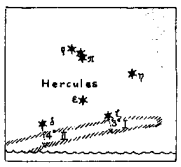

Fig. 29.

Fig. 25. Pulsating bit of an arc on September 7th, $22^h\ 30^m$ (Hassel).
Fig. 26. The same at $22^h\ 45^m$ (Hassel).
Fig. 27. Pulsating arc on September 8th, $0^h\ 56^m$ (Hassel).
Fig. 28. The same at $0^h\ 58^m$ (Hassel).
Fig. 29. Pulsating bit of an arc on September 8th, $1^h\ 45^m$.

The pulsating arc disappeared at $22^h\ 49^m$ and only a faint glow in N persisted to $0^h\ 56^m$ when a new pulsating arc appeared in W. See Fig. 27 and 28.

The successive maxima of this arc are tabulated in Table 8.

Table 7.

Maximum of intensity	Interval	Intensity 1 feeble 2 easy to see	Remarks
	sec.		
22.31.50—22.32.10		1	
22.33.05	70	2	
22.34.05—22.34.15	65	2	
22.35.40—22.35.45	93	1	
22.36.05—22.36.10	25		From 22.36.35 to 22.36.40 disappeared
	67		
22.37.10—22.37.20		2	From 22.37.50 to 22.38.20 disappeared
	65		
22.38.20			From 22.38.45 some rays under UMa. which disappeared 22.45.0
	Mean 64		From 22.40.00 to 22.40.43 the pulsating arc fainter
22.45.00		2	The maximum lasted only some seconds (See Fig. 26)

Table 8.

Maximum of intensity	Interval	Intensity 1 feeble 2 easy to see	Remarks
	sec.		
1.01 50		1	
1.03.25	95	1	
1.03.55—1.04.00	33	1	
1.04.50	52	2	
1.05.40—1.05.45	53	2	
1.06.20—1.06.25	40	3	Intensity 3 means bright
	42		
1.07.00—1.07.10	65		
1.07.40—1.08.40			
	Mean 54		
1.11.50		2	Clouds obscuring until 1.11.00
	30		
1.12.20	70	1	
1.13.00—1.14 00			The maximum of intensity between the two moments
	140		
1.15.50	30	1	
1.16.20	37	2	
1 16.55—1.17.00	23	2	
1.17.20		1	The arc stretched from δ Her. to β Boo.
	30		
1.17.50	33	0—1	
1.18.20—1.18.25	27	2	From β Her. to δ Boo.
1.18.50			At 1.20.00 the pulsations ended
	Mean 47		

In the next 25 minutes the pulsating arc was obscured by clouds. Then it appeared again (Fig. 29) and the following pulsations were observed:

Table 9.

Maximum of intensity	Interval	Remarks
	sec.	
1.50.00		
1.51.00	60	
1.51.37	37	
1.52.50	73	Strongest, intensity 2
1.53.20	30	Intensity 1
1.54.40	80	Intensity 1
1.56.48	128	Intensity 2 (near δ Herculis)
1.57.50	62	
2.00.30	160	
2.02.30	120	
	Mean 83	

1932, September 23rd. Pulsating bit of an arc under ψ UMa. Successive maxima of intensity seen in Table 10.

Table 10.

Maximum of intensity	Interval	Remarks
	sec.	
23.20.35		
23.21.35—23.21.40	63	
23 22.05—23.22.10	30	
23.22.40—23.22.45	35	Doubtful
23.23.20	37	
23.23.40	20	
	Mean 37	
23.26.12		
23 27.20	68	
23.28.00	40	Doubtful
23 28.35	35	Doubtful
	Mean 48	
23.44.00		
23.47.10	190	
23.48.10	60	
23.48.40	30	
	Mean 93	

The mean of all the individual intervals is 61.4^s, that is of the order of one minute. The mean of all the groups is 61.3^s, very nearly the same.

17. An Observation by Sophus Tromholt of a Pulsating Arc on February 24th, 1879.

I have not got time to look through the older aurora literature concerning pulsating arcs. I have only come over a most interesting description published by *Sophus Tromholt*, about a pulsating arc observed from Bergen, Norway, the night of February 24th—

25th, 1879[1]. He says: "The sky was on the whole evening quite clear. I observed from $18^h\ 51^m$.[2] Until $23^h\ 36^m$ I could not see any trace of aurora. At $23^h\ 51^m$ a very faint and low arc was visible. At $0^h\ 06^m$ it was a little stronger and broader upwards. At $0^h\ 21^m$ it was again faint, and during the following hour still fainter.

About $1^h\ 36^m$ a strange display began. The arc which had almost disappeared, suddenly reappeared as a rather luminous arc; this lasted some seconds and then it disappeared completely. Some seconds later it flared up again, lasted some seconds and disappeared, and 4—5 seconds afterwards it again flared up. These pulsations continued for at least a quarter of an hour. Never before have I seen anything so remarkable. When I finished my observations at $2^h\ 06^m$ the arc was almost steady, but rather luminous and broader than before."

18. Pulsating Arcs Forming the Southern Boundary of an Aurora.

In the preceding sections we have only studied *isolated* pulsating arcs. It happens, however, that an auroral display has a pulsating arc as a southern border and not very far from the main bulk of the aurora. This form shall not be studied here. As typical cases we may mention the aurorae of February 27th, 1920, April 25th, 1932, January 27th, 1935[3], and October 17th, 1939.

19. Summary.

Measurements and observations of the rare aurora form "pulsating arcs" are given. The mean height was on February 28th, 1929, equal to 115 km, on October 31st, 1931, 111 km, and on September 21st—22nd, when a great number of measurements were made, 105 km. The last time spectra were also taken on Agfa Isopan plates showing the aurora line 5577 Å as much stronger than all other aurora lines.

A series of observations on the time of pulsation were also made.

Of special interest were some rays on February 28th, 1929, not observed visually, but appearing on the plates. They were lying in *sunshine* over the pulsating arc in the layer from 300—400 km above the earth.

[1] Sophus Tromholt: Iagttagelser over Nordlys anstillede i Norge, Sverige og Danmark September 1878—April 1879. Christiania Videnskabsselskabs Forhandlinger 1880, No. 6.

[2] The time is here converted into Middle European Time.

[3] Geof. Publ. Vol. XI, No. 3, 1935.

PART II. PULSATING SURFACES (IV)

20. Introduction.

Measurements of pulsating surfaces have been made from northern Norway on several occasions, but from southern Norway no measurements have as yet been published. In fact in the report from the years 1911—1922 no case was given. But in the very extensive material from 1923 to 1941 there are several interesting cases when good simultaneous photographs of pulsating surfaces were taken from two or more stations.

The dates when such simultaneous pictures were obtained are the following:

1925: November 10th—11th,
1928: March 14th—15th, August 26th—27th,
1929: November 3rd—4th,
1930: September 3rd—4th, 14th—15th, and 18th—19th,
1931: September 20th—21st,
1933: March 18th—19th, 21st—22nd, 23rd—24th, 24th—25th,
1936: January 24th—25th, March 27th—28th, October 16th—17th,
1937: January 7th—8th, October 12th—13th,
1938: January 21st—22nd, 25th—26th, March 5th—6th, September 30th—October 1st,
1939: February 6th—7th, March 29th—30th, October 17th—18th,
1941: September 21st—22nd, 22nd—23rd.

For the material 1923—1937 a detailed log of all pictures taken has been worked out, but for the following years 1938—41 this has not yet been done. Therefore it may be possible that some cases have escaped attention during these last years.

In the following we shall among the enumerated cases choose some characteristic ones and give the corresponding height measurements.

21. Pulsating Patches on November 10th—11th, 1925.

During the aurora that night a series of my stations were in action from 21^h to 3^h. From $0^h\ 40^m$ to $1^h\ 26^m$ a series of pictures with base-line Bygdø—Kongsberg (63.74 km) were taken of a curious form of aurora. Low in the north a series of pulsating patches appeared *along a faint arc.* The period of pulsation was only a few seconds. 12 usable sets were taken which gave 69 determinations of height and position. Among these the following were near the lower or upper part of the pulsating patches:

Table 11.

Height of Pulsating Patches on November 10th—11th, 1925.

No.	Time	Heights near lowest points	Heights near highest points
32	0.40.35	88, 89	
34	0.51.35	84, 93	97, 122
35	0.55.20	98, 93, 104, 96	115, 118, 125, 116
36	0.56.35	94, 88, 89, 87, 83	116, 117, 116, 102
37	0.58.50	82, 85, 97, 98, 94, 100	104, 104, 112, 112
38	1.00.25	89, 89	
39	1.05.35	90, 90	
40	1.06.35	83, 82, 81	104, 100, 100
41	1.11.35	80	110
42	1.14.05	83, 83, 83, 90	104, 105, 104, 113
43	1.18.05	85	105
44	1.25.35	79	100
		Mean 89 km	Mean 110 km

The difference in height between the two means is 21 km, very near the mean of the difference in height of foot and summit of each individual patch (21.3 km).

From the notes made during the work we quote:

First there was an arc with very sharp lower border. Then the arc became pulsating and then dissolved in pulsating patches (pictures Nos. 32, 33). Then irregular flames were thrown upwards from these patches up to the height of γ Draconis (picture 34). These flames continued during the following minutes when pictures 35—44 were taken, at the same time as the pulsating patches appeared and disappeared rhythmically (up to 5 times at the same place) under the flames. Sometimes the flames reached the height of Deneb. On Fig. 30 is seen the geographical position of all the points measured.

As typical cases we give two sets, No. 36 and No. 40.

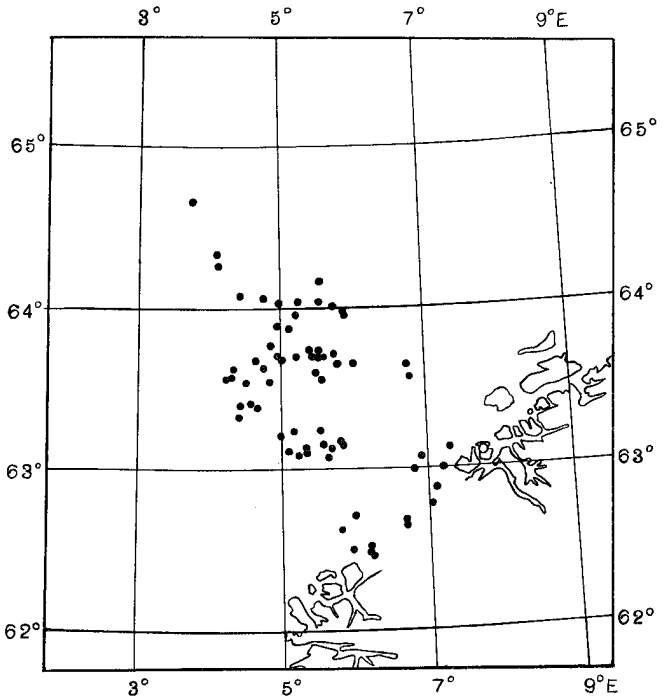

Fig. 30. The measured points of the pulsating patches on November 10th—11th, 1925.

No. 36, $0^h\ 56^m\ 35^s$ MET.

Base line Bygdø—Kongsberg 63.74 km.

P	u_2	*p*	*h*	*a*	*D*	*H*
1	83.9	6.8	7.8	143.2	524	94
2	84.2	6.7	10.1	143.6	524	116
3	86.9	7.0	7.3	146.0	513	88
4	86.7	6.8	10.2	145.9	519	117
5	88.2	6.9	7.3	147.2	522	89
6	88.2	6.9	10.3	147.3	515	116
7	91.4	6.7	6.7	150.9	537	87
8	91.2	7.1	13 0	150.2	495	136
9	92.9	6.8	6.5	152.3	527	83
10	93.5	6.6	7.7	153.2	541	97
11	93.8	6.8	9.3	153.1	521	98
12	92.9	7.4	10.9	152.0	480	102

The sketches are seen on Plate 5, the pictures on Plate 19.

No. 40, $1^h\ 06^m\ 35^s$ MET.

Same base line.

P	u_2	*p*	*h*	*a*	*D*	*H*
1	86.1	7.9	8.3	144.4	453	83
2	85.8	7.8	10.8	144.2	452	104
3	87.7	8.0	8.3	145.8	448	82
4	87.5	8.1	10.8	145.5	439	100
5	88.3	8.1	8.4	146.4	443	81
6	88.2	8.1	10.8	146.3	439	100

The sketches are seen on Plate 5.

Such cases where pulsating patches appear along a faint arc are rather infrequent. Only once since have we measured the same phenomenon, namely on January 7th—8th, 1937 (see below).

22. Pulsating Surface on March 13th—14th, 1928.

The pulsating aurora in question occurred from about $0^h\ 30^m$ to $0^h\ 40^m$ and was photographed simultaneously from Oslo (*C*) and Tømte (*T*), base line 46.7 km. Before that time, homogeneous arcs and some cases of bands and rays in the north had occurred.

Here are two of the best pictures.

20 Pulsating surface,* $0^h\ 36^m\ 15^s$ MET.

Base line Tømte—Oslo 46.7 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—29.6	7.0	13.8	137.5	320	88
2	—28.1	6.9	16.2	136.3	324	104
3	—26.3	6.7	18.3	135.0	334	122

*21** The same $0^h\ 37^m\ 15^s$ MET.

Same base line.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—31.3	5.9	13.0	140.4	373	99
2	—30.7	6.0	14.7	139.8	367	108
3	—29.9	6.2	17.4	139.1	352	123

The sketches are seen on Plate 5, and corresponding pictures C 21* and T 21* on Plate 19.

23. Pulsating Surface on March 27th—28th, 1936.

This pulsating aurora occurred from about 2^h to $2^h\ 20^m$ after a long period of common aurora forms in the north. We give only one characteristic case measured with long base line:

49. Pulsating surface $2^h\ 04^m\ 04^s$ MET.

Base line Lillehammer—Kongsberg 165.35 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—32.4	23.4	12.2	115.7	339	83
2	—32.0	24.0	15.0	114.7	328	99
3	—31.5	23.9	18.9	114.6	323	122

The sketch is seen on Plate 5.

24. Pulsating Patches on January 7th—8th, 1937.

On January 7th, 1937, a very fine aurora appeared over southern Norway. From 18^h to 4^h I had several stations in action and at times the aurora was seen all over the heaven. More than 750 successful pictures were taken among which are several of great interest. Pulsating patches also occurred and some characteristic cases are measured below; the first one was early in the night and the last and most interesting one about $2^h\ 40^m$ in the morning; here they are:

31. Pulsating patch $20^h\ 54^m\ 32^s$ MET.

Base line Oslo—Oscarsborg 27.35 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	41.5	7.8	39.2	1.0	116	98
2	41.4	7.2	40.5	3.2	123	108
3	45.1	5.7	39.2	11.2	148	125

The sketch is seen on Plate 5. The patch lay on the southern hemisphere and occurred after an outburst of strange *quiet* draperies all over the heaven. (See section 74.)

The next sets are very similar to those from November 10th—11th, 1925. The pulsating patches occurred *along a faint arc* in the north, and formed the last feature of the aurora that night. A long series of pictures was taken.

No. 230. Pulsating patches $2^h\ 36^m\ 14^s$ MET.

Base line Oslo—Kongsberg 65.5 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—19.5	7.1	8.2	168.8	488	90
2	—22.3	7.1	8.1	171.7	477	87
3	—22.5	7.1	11.3	172.0	472	113
4	—19.6	7.2	11.4	168.9	475	116
5	—11.0	7.9	8.4	159.4	458	85
6	—10.9	7.8	12.3	159.5	456	118
7	— 7.9	7.7	12.2	156.6	464	119
8	— 8.0	7.6	8.4	156.9	477	89

From this it is seen that the aurora descended to 85—90 km and that the vertical extension of the patches was from 26 to 33 km.

The sketches are seen on Plate 6 and the pictures on Plate 19. The geographical situation is seen on Fig. 31.

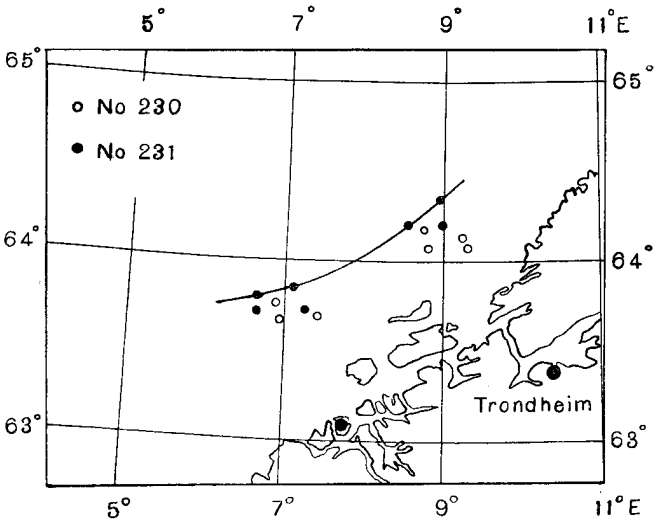

Fig. 31. Geographical situations of the pulsating patches from $2^h\ 36^m$ to $2^h\ 38^m$ on January 7th—8th, 1937.

No. 231. The same at $2^h\ 37^m\ 10^s$ MET.
Base line Tømte—Kongsberg 104.95 km.

P	ε_2	p	h	a	D	H
1	—26.9	11.9	8.9	154.2	445	85
2	—26.8	12.1	12.7	154.2	430	113
3	—23.4	11.8	12.7	150.9	447	118
4	—23.9	11.9	8.9	151.2	453	88
5	—37.9	10.1	9.2	167.2	462	93
6	—37.6	10.3	13.0	167.1	446	120
7	—35.0	10.4	12.8	164.3	456	122
8	—35.5	10.6	9.1	164.3	453	90

As in the former case the measurements show that the dots descended to 85—90 km and that their vertical extension was from 27 to 32 km. See Plate 6 and 20, and Fig. 31.

25. Pulsating Surface on January 21st—22nd, 1938.

On the night of January 21st—22nd, 1938, we had a fine aurora over southern Norway, which died away gradually and at about $4^h\ 30^m$ only very feeble traces were left. But at 7^h it had a very vigorous recrudescence with a big red arc in the north. (See the following part VII.) During the night about 200 usable pictures were taken among which 70 sets for measuring the heights.

Until midnight there were feeble arcs and rays in the north, but after midnight we had for a long time pulsating surfaces and patches in the north. From $0^h\ 05^m$ to $0^h\ 19^m$, 24 sets of these were photographed simultaneously from Oslo, Lillehammer, and Askim. Then arcs and rays appeared with pulsating patches from time to time.

Of this extensive material only the two following cases are measured.

No. 14. Pulsating surface $0^h\ 13^m\ 14^s$ MET.
Base line Lillehammer—Oslo 132.65 km.

P	ε_2	p	h	a	D	H
1	—75.5	6.5	19.0	164.1	273	102
2	—76.7	6.3	18.8	166.6	259	94
3	—77.4	6.0	18.7	169.5	258	93
4	—77.7	5.7	18.7	172.3	266	96
5	—76.0	6.7	21.4	172.5	253	104
6	—75.8	7.1	21.7	170.2	241	102
7	—75.5	7.4	21.8	168.4	236	100
8	—74.8	8.2	22.7	166.0	224	98
9	—73.0	8.6	24.0	163.6	233	109

Of these Nos. 1, 2, 3, 4 lie on the lower border, Nos. 5, 6, 7, 8, 9 on the upper. Nos. 1 and 9 are not as good as the rest. The sketches are seen on Plate 6, the pictures on Plate 20, and the geographical position on Fig. 32.

No. 15. The same $0^h\ 13^m\ 35^s$ MET.
Same base line.

P	ε_2	p	h	a	D	H
1	—75.2	6.9	19.9	164.0	262	101
2	—76.7	6.3	18.8	166.5	259	94
3	—77.4	6.2	18.8	169.1	250	91
4	—77.6	6.1	19.1	171.8	253	93
5	—75.6	7.3	22.3	171.7	237	103
6	—75.5	7.5	22.2	169.3	233	100
7	—75.0	7.9	22.3	166.3	228	99
8	—73.8	8.8	23.5	163.8	220	100
9	—72.5	9.0	24.4	162.2	229	109

Here 1, 2, 3, 4 are on the lower, 5, 6, 7, 8, and 9 on the upper border. Nos. 1 and 9 are not as good as the rest. The sketches are seen on Plate 6, the pictures on Plate 20, and the geographical situation on Fig. 32.

26. Pulsating Patches on March 5th—6th, 1938.

On March 5th—6th, 1938, we had a fine aurora with different strange forms, in particular some high arcs on the southern hemisphere[1]. After this some pulsating patches were observed and a good set is the following:

[1] Carl Størmer: Auroral Work in Southern Norway in the Year 1938. Terr. Magn, September 1939.

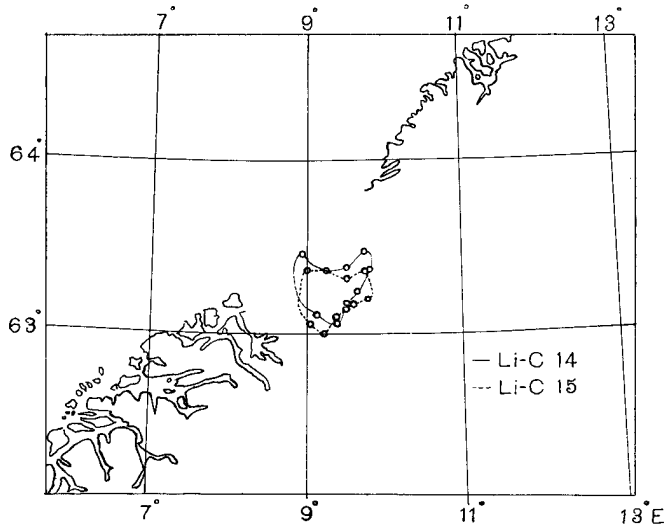

Fig. 32. Geographical situations of the pulsating patches on January 21st—22nd, 1938.

No. 68. Pulsating Patch $21^h\,57^m\,47^s$ MET.
Base line Tømte—Askim 80.05 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—55.4	9.3	20.8	136.4	259	105
2	—54.3	11.0	23.2	134.2	222	100
3	—51.3	11.0	22.9	130.5	238	106
4	—51.9	10.8	21.2	130.8	244	100
5	—52.9	9.8	19.2	132.4	266	99

The sketches are seen on Plate 6. The geographical situation was over the glacier Jostedalsbreen.

27. Pulsating Patch on February 6th—7th, 1939.

This case is remarkable because of the very great parallaxe of about 55°, which, in spite of the diffuse outline gives a rather good determination of height. The result was

No. 31, $20^h\,04^m\,17^s$ MET.
Base line Lillehammer—Oscarsborg 158.65 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—22.4	56.2	34.2	45.0	144	101
2	—20.9	54.6	32.0	46.3	153	99

The sketches are seen on Plate 6 and 7; the patch lay over Numedal west of Oslo.

28. Pulsating Patch on March 29th—30th, 1939.

This case is a pulsating patch on March 29th—30th, photographed with base line Kongsvinger—Oslo. Here are the results:

No. 15, $23^h\,55^m\,33^s$ MET.
Base line Kongsvinger—Oslo 78.8 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	17.2	12.7	17.2	124.9	321	109
2	17.9	11.7	13.9	125.9	354	99
3	24.0	11.3	13.9	120.0	352	98
4	24.4	10.7	16.2	119.6	366	119

The sketches are seen on Plate 7. The geographical situation was very nearly the same as No. 68 on March 5th—6th, 1938.

29. Pulsating Patch on September 22nd, 1941.

A pulsating patch of unusual interest occurred on September 22nd, 1941, during a series of remarkable aurora nights, from 18th to 23rd of the same month, already mentioned in section 7.

As pulsating arcs of great interest were observed the whole night of September 21st—22nd I watched the sky carefully the next evening, September 22nd, hoping for pulsating aurora again. At about 20^h a remarkable patch occurred on the eastern sky, near Mars. I did not get in telephonic connection with my other stations before the disappearence of the patch, but fortunately the patch was discovered independently by my two most zealous observers, Olaf Hassel and Einar Schrøder. Olaf Hassel took a series of photographs from my station *M* near Oslo, and Einar Schrøder many pictures from his station *Hs* in Holmestrand.

Here is the list of their photographs. (See Table 12 on the next page.)

Among these pictures some happened to be taken almost simultaneously from the two stations and as the position of the patch was stationary in the atmosphere, they could be used for height determination.

For this purpose we have chosen the two pictures Nos. 146.3 at $21^h\,33^m\,10^s$ from *M* and 3.4 at $21^h\,33^m\,00^s$ from *Hs*. As the base line *M—Hs* is 55.35 km the parallaxe was found to be about 6° and gives a fairly reliable result. We have chosen the centre of the spot which gave:

Height and Position of Pulsating Patch on September 22nd, 1941, $21^h\ 33^m$ MET.

P	ε_2	p	h	a	D	H
3	0.7	6.3	10.3	—59.3	500	110

Table 12.

Photographs of Pulsating Patch from Oslo (*M*) and Holmestrand (*Hs*) on September 22nd, 1941.

No.	MET	Ex.	St.	Remarks
145.2	20.45.10	180	*M*	Feeble trace on the plate
145.3	.49.05	180	—	Nothing
145.4	.56.00	240	—	Good picture
1.1	21.03.27	50	*Hs*	Feeble picture
1.2	.04.30	55	—	Only a trace
1.3	.04.00	55	—	Fine picture
1.4	.07.00	55	—	Fine picture
145.5	.07.58	240	*M*	Fine picture
1.5	.08.00	55	*Hs*	Good picture
1.6	.09.00	50	—	Feeble picture
2 1	.10.00	50	—	Nothing
145.6	.10.58	90	*M*	Nothing
2.2	.11.20	80	*Hs*	Nothing
2.3	.24.47	70	—	Feeble trace
146.1	.25.30	180	*M*	Good picture
2.4	.26.00	55	*Hs*	Feeble picture
2.5	.27.00	55	—	Feeble picture
2.6	.28.00	55	—	Good picture
146.2	.29.30	240	*M*	Fine picture
3.1	.30.00	55	*Hs*	Good picture
3.2	.31.00	55	—	Good picture
3.3	.32.00	55	—	Feeble picture
3.4	.33.00	55	—	Feeble picture
146.3	.33.10	180	*M*	Fine picture
3.5	.34.00	55	*Hs*	Good picture
3.6	.35.00	55	—	Feeble picture
146.4	.36.50	240	*M*	Good picture
4.1	.37.00	80	*Hs*	Feeble trace
4.2	.39.00	80	—	Nothing

Along the outline of the patch a series of points were chosen and their geographical position was found, assuming the height to be 110 km.

The pictures are seen on Plate 17, the sketches on Plate 4, and the geographical position on Fig. 33.

Schrøder has added the following remarks to his photographs:

"The color of the patch was yellow green. It pulsated the whole time, but the periods of pulsation varied from 15 seconds up to one minute. Sometimes it disappeared for some minutes, but reappeared later. But at $21^h\ 38^m$ it was visible for the last time. During the last exposure, No. 4.2, the patch was hardly visible at the beginning of the exposure, and disappeared soon afterwards completely. It did not reappear.

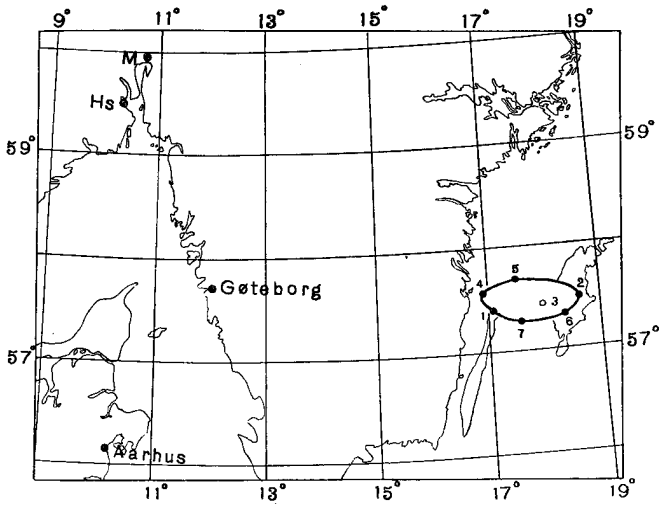

Fig. 33. Geographical situation of the pulsating patch on September 22nd, $21^h\ 33^m$ MET.

The sky was dark with many stars, but no aurora was visible except this pulsating patch.

After midnight the sky became overcast."

Hassel also observed the pulsations carefully. Here is the report:

A feeble pulsating arc appeared already at $20^h\ 05^m$ MET in the east at an elevation of 10 to 15 degrees.

Later, at $20^h\ 43^m$ I observed the patch in ESE carefully and made the following notes: (See Table 13.)

For the rest of the observations I preferred to make the following diagrams of the pulsations:

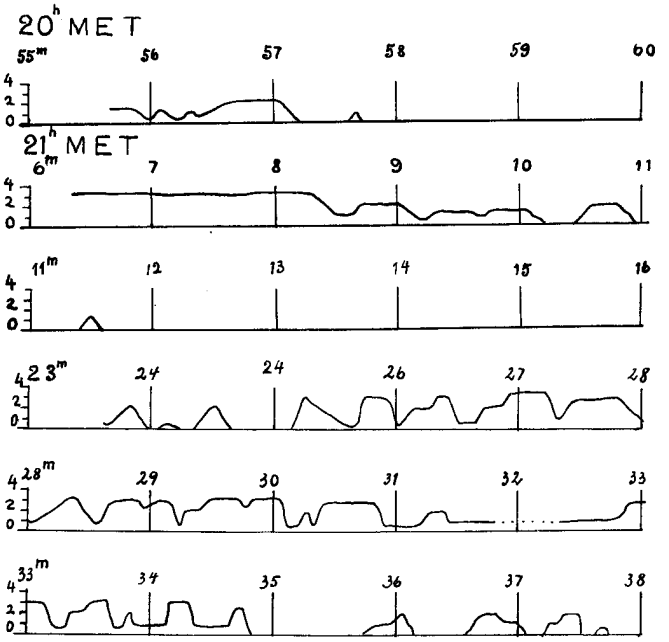

Fig. 34. Diagram of pulsations from $20^h\ 55^m$ to $21^h\ 38^m$. The intensity is chosen as ordinate.

Table 13.

Pulsations and Intensities of a Pulsating Patch in ESE.

MET	Remarks	Intensity
20.43.40	Maximum	
.44.00	Maximum	
.44.35	Maximum Short minimum	
.44.55	Maximum Short minimum	2
.45.15	Short maximum Longer minimum	2
.45.40	Short maximum Longer minimum	1
.46.00	Short maximum Longer minimum	1
.46.20	Short maximum Longer minimum	2
.46.35	Short maximum Longer minimum	1
.47.15	Short maximum Longer minimum	1
.47.25	Short maximum Short minimum	3
.47.55	Short maximum Short minimum	2
.48.05	Short maximum Longer minimum	3
.48.35	Longer maximum Disappeared until	3
.52.00	Short maximum Longer minimum	1
.52.35	Short maximum	3
.53.55	Longer maximum	1
.54.00	Maximum	3
.54.30	Maximum Short minimum	3
.54.45	Longer maximum	2

30. Visual Observations of the Same Patch from Göteborg and Aarhus.

Most interesting visual observations were received from Gunnar Peterson in *Göteborg* and from Axel V. Nielsen at the Ole Rømer Observatory in *Aarhus*.

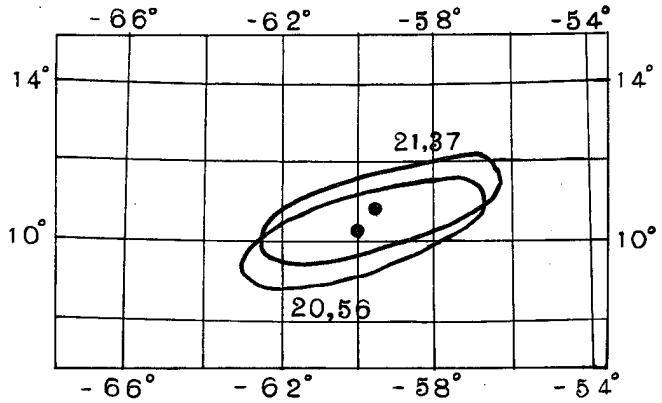

Fig. 36. Situation in the sky of the pulsating spot as seen from station *M*. (Altitude and Azimuth.)

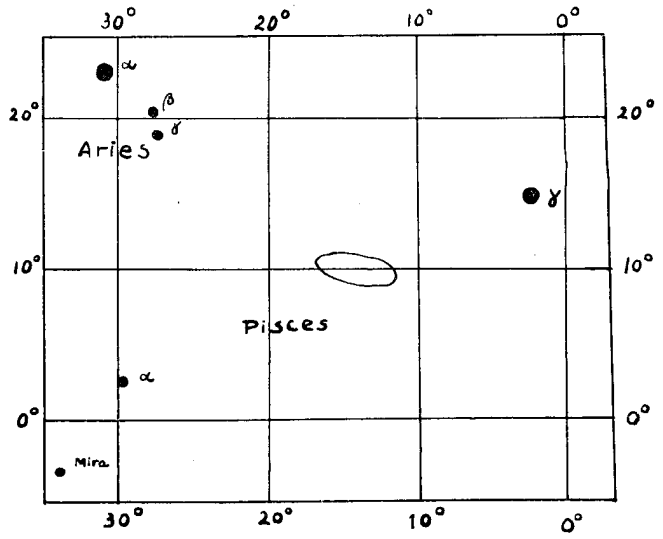

Fig. 35. Situation among the stars of the spot seen from Göteborg. (Declination and Right Ascension.)

These observations are very accurate and as the observation from Aarhus was within the time interval of the photographs from *M*, we have used it here, and have received independant verifications of the photographic determination just mentioned.

Gunnar Peterson writes:

"I did not see the pulsating arc on the morning of September 20th, but on the evening of September 22nd I saw the pulsating spot in NE. It was stationary and therefore I could fix its situation very exactly by means of a more detailed star map. The spot was lying over δ, ε and ζ Pisces as seen on Fig. 35. It was visible 6—10 seconds and then disappeared for about 30 seconds, and so on. The observation was made at $20^h\,8^m$ MET from the same place as before (Latitude 57° 47′, Longitude 11° 55′ E Gr.). Later the weather was not good enough for more observations. When I looked for the spot at $0^h\,15^m$ it had disappeared."

From this it is probable that the spot observed by Peterson was a bit of the pulsating arc seen by Hassel in east at $20^h\,05^m$.

The observations from *Axel V. Nielsen* at the Ole Rømer Observatory, Aarhus (Latitude 56° 12′, Longitude 10° 30′ E Gr.), however, gave most interesting results.

He writes:

"This evening I have seen a remarkable isolated 'aurora cloud' in E, the only aurora visible on the sky. It varied in intensity and was most of the time invisible. Between $20^h\,15^m$ and $21^h\,40^m$ MET it was often visible, but immediately after the sky became

overcast. The reason why I write to you is that I have a good observation: At $21^h\,15^m$ MET the center of the spot was situated on the line from the Pleiades to Saturn, near the middle of the line, a little nearer to the Pleiades.

When first I saw the spot it was to the right of the Pleiades, but very nearly at the same elevation. When I saw it for the last time it was vertically over Aldebaran and in the same height as Saturn. I had the impression that the spot was stationary in the atmosphere."

As the observation at $21^h\,15^m$ was within the interval of our photographs and during the time when the spot had been almost stationary according to Fig. 36 it seemed worth while to put this observation to a decisive test. In fact, the displacement of the spot as seen from Oslo and Aarhus must take place along the Great circle going through two points in the sky where the base line Oslo—Aarhus cuts the celestial globe.

Using the formula given in an earlier paper[1] my assistant Østvold, who made this calculation, has found:

Base line station *M*—Ole Rømer Observatory = 417.5 km. Situation of the point where this base line cuts the celestial globe:

Declination —31.88°
Hour angle 2.26°

We now combined the photograph taken by Hassel at $21^h\,33^m$ with Nielsen's observation and calculated where the Great circle from the center of the spot in Hassel's photograph would cut the line from the Pleiades to Saturn. The calculation was made by the method given in the reference below and the necessary values for the reference stars were calculated separately for Hassel's photograph at $21^h\,33^m$ and for Nielsen's observation at $21^h\,15^m$.

The result was startling as seen on Fig. 37. The Great circle AB in question cuts the line Pleiades —Saturn just near the middle.

Using this for height measuring we found the values (see loc. cit., Geof. Publ.).

Pulsating Patch on September 22nd, 1922.

Base line *M*—Aarhus 417.5 km.

Point	ε_2	p	h	a	D	H
center of spot	—21.4	49.5	10.6	—59.1	495	112

[1] Carl Størmer: Some Results Regarding Height and Spectra of Aurorae over Southern Norway during 1936, § 6. Geofysiske Publikasjoner, Vol. XII, No. 7.

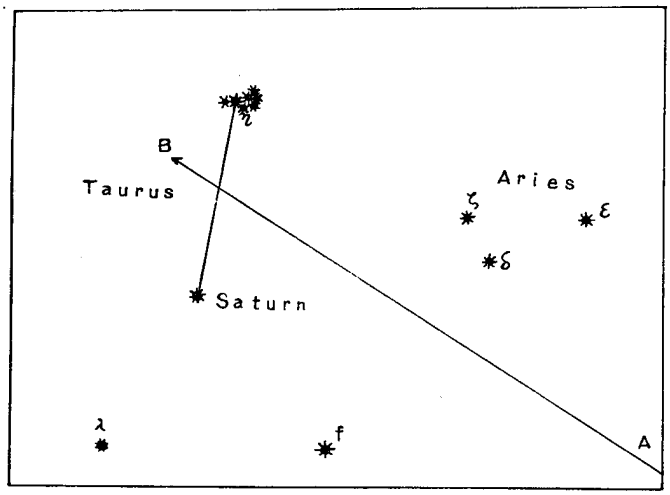

Fig. 37. Verification of the observation from Aarhus of the same spot.

That is very near the value $H = 110$ found with base line *M*—*Hs*.

To find the geographical situation we have, along the outline of the spot, chosen a series of points with supposed height 112 km. The result was the same as before, situation between Gotland and the coast of Sweden.

The spot was also seen at $21^h\,35^m$ by Mr. Nils Lindström in Arvika (59° 37.8′ N, 12° 32.5′ E).

31. Some Single Pictures of Remarkable Pulsating Surfaces.

Finally we shall mention some cases of strange pulsating surfaces only photographed from one station and whose height could therefore not be determined.

The first case occurred during the great aurora of May 13th—14th, described in my report[2] from 1911—22. These pulsating surfaces had on that occasion the form of arcs of circles; they appeared suddenly, lasted few seconds, disappeared and again reappeared etc. Drawings were made after the negatives and reproduced on Plate 39 of that report as

No. S 156 at $0^h\,18^m\,31^s$ MET
S 157 at $0^h\,19^m\,10^s$ MET
S 159 at $0^h\,21^m\,58^s$ MET
S 160 at $0^h\,22^m\,23^s$ MET

[2] Résultats des mesures photogrammétriques des aurores boréales observées dans la Norvège méridionale de 1911—1922. Geof. Publ. Vol. IV, No. 7, p. 52—54.

The second time was during the great aurora on September 15th—16th, 1926, and pictures have been published in 1926[1] and 1930[2]. Reproductions of these are seen on Plate 21. The first one photographed at $23^h\ 51^m$ and the second one at $23^h\ 52^m\ 50^s$ MET, both from Bygdø near Oslo.

As the aurora on the first of these pictures had the form of a part of a circle it would be of interest to know the diameter of this circle. For this purpose 9 points were chosen along the circle, and their projection found on the earth's surface, supposing the height of the aurora equal to 100 km. The diameter was found to be 32 km.

[1] Zwei Nordlichtaufnahmen von 15. September 1926. »Das Weltall«, Vol. 26, December 1926.

32. Summary.

From 26 dates of pulsating surfaces or patches from 1925 to 1939 a series of cases have been measured out.

Of particular interest were the patches along arcs in the north because these patches seemed to reach lower down, to 80—85 km, than most of the others, and an isolated patch on September 22nd, 1941, occurring after a series of nights with aurorae of particular interest.

Some single pictures of remarkable patches from May 13th—14th, 1921, and September 15th—16th, 1926, were also mentioned.

[2] Photographic Atlas of Auroral Forms, Picture No. 24, Oslo 1930.

PART III. FLAMING AND FLASHING AURORAE (V)

33. Flaming Aurorae.

The flaming aurora is a characteristic form consisting of strong waves of light moving rapidly upwards one after another in the direction of the magnetic zenith. The waves may have the form of detached arcs which move upwards perpendicular to the direction of the arcs, or they may be compared with invisible waves which in their passage illuminate broad rays and patches, which appear and disappear when the waves pass them[1]. Such flaming aurorae occur in southern Norway during strong auroral displays, often after the appearance of vivid rays and curtains and are often followed by the formation of a corona.

As I have already pointed out in an earlier paper[2] these waves certainly move upwards from the atmosphere towards space. In fact during the work on aurora in the night of April 21st—22nd, 1936, I was in telephonic connection with the station Trondheim, 391 km to the north of Oslo. During a period of strong flaming aurora, Mr. Westin in Trondheim and I myself in Oslo observed simultaneously that the flames went upwards with great velocity. I saw them in the northern sky and Westin in the southern. We spoke about it as we observed the motion. *From this it is evident that the flames really went upwards.* It seemed as if electric discharges were sent out in space from the auroral region at a level of about 100 km, which probably was overloaded with electricity by the foregoing strong precipitation of auroral particles from without.

At several occasions I have tried to photograph these rapidly moving waves and flames, but without success. The short rays and patches, however, which lighted up when the flames passed them, were easier to photograph. During the gorgeous aurora on January 25th—26th, 1938[1], such short rays and patches were very pronounced from 3^h in the morning towards dawn, and we succeeded in taking a series of pictures of them from two stations together with some spectra. The color was yellow green to blue green and they occurred on the whole sky and were almost the only form seen during some time.

Some of these forms from January 25th—26th, 1938, are given below.

No. 201, $3^h\ 08^m\ 22^s$ MET.

Base line $C—Ak$ 44.75 km.

P	ε_2	p	h	a	D	H
1	—43.7	10.8	47.8	110.5	114	129
2	—46.6	10.4	44.2	111.9	120	120
3	—48.5	11.3	42.4	111.3	110	103
4	—48.7	12.2	41.7	109.2	103	94
5	—46.3	8.9	37.6	106.0	155	123
6	—48.0	9.8	35.7	105.8	141	104

[1] Photographic Atlas of Auroral Forms, published by the International Geodetic and Geophysical Union, Oslo 1930.

[2] Some Results Regarding Height and Spectra of Aurora... Geofysiske Publikasjoner, Vol. XII, No. 7, p. 11.

[1] Carl Størmer: Nature (London) 1938, Vol. 141, p. 955. Die Naturwissenschaften 26. Jahrgang 1938, p. 633—638.

The sketches are seen on Plate 7, the geographical situation on Fig. 38.

No. 206, $3^h\,11^m\,54^s$ MET.
Same base line.

P	ε_2	p	h	a	D	H
1	30.9	15.6	45.5	78.9	99	102
2	33.2	15.0	41.0	81.3	108	96
3	30.6	12.6	43.3	67.4	137	132
4	29.1	13.7	30.5	74.7	140	85
5	30.1	15.5	41.0	76.1	108	96
6	31.7	14.0	31.9	78.0	131	84

The sketches are seen on Plate 7, the geographical situation on Fig. 38.

No. 220, $3^h\,26^m\,18^s$ MET.
Same base line.

P	ε_2	p	h	a	D	H
1	—48.0	11.4	39.8	107.0	116	98
2	—48.6	13.3	46.0	112.6	88	93
3	—48.1	14.8	51.5	118.5	72	92
4	—46.1	10.5	32.8	100.0	140	94
5	—41.5	10.7	38.8	97.4	138	115

The sketches are seen on Plate 7, the geographical situation on Fig. 38.

No. 124,* $5^h\,51^m\,35^s$ MET.
Base line *C—O* 27.35 km.

P	ε_2	p	h	a	D	H
1	—16.6	16.1	67.1	104.6	37	88
2	—17.7	16.5	68.0	106.4	33	85
3	—19.5	16.8	69.2	110.0	32	84
4	—21.7	16.9	70.9	118.2	28	83
5	—25.0	15.2	72.4	138.0	28	89
6	—27.1	14.7	74.3	157.0	25	90
7	—28.2	13.7	73.9	170.5	27	96
8	— 9.0	14.0	74.9	83.5	28	106
9	—10.0	14.2	75.4	86.0	27	106
10	—11.9	14.0	76.3	91.0	24	102
11	—12.7	14.5	78.3	94.0	22	103
12	—15.0	14.1	81.3	109.5	17	107
13	—14.6	12.3	84.4	128.5	12	122
14	—15.0	11.0	85.2	160.0	10	137

This aurora is very interesting. It occurred near the zenith and was a feeble patch mingled with rays. The height of its lower border is rather low. The pictures are seen on Plate 21, the sketches on Plate 7. The geographical situation is given on Fig. 38.

As remarked in the papers referred to, spectra of these forms from January 25th—26th were taken

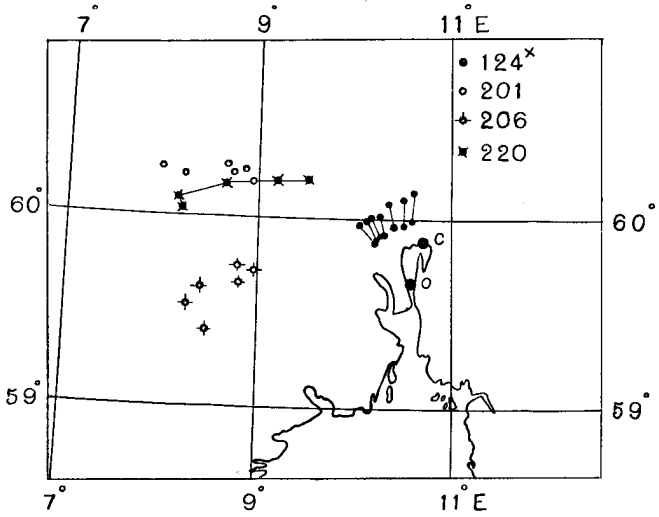

Fig. 38. Geographical situations of flaming aurora patches on January 25th—26th, 1938.

on an Agfa Ultra red rapid plate. The 4 lines and bands with corresponding registrams 6550, 6300, 5577, and 4278 are seen on Plate 21.

34. Flashing Aurorae.

On only a few occasions has the aurora appeared as intense, very short lasting precipitations, either like thin arcs close to each other or as isolated irregular bands or patches. I shall try to describe the few displays of this kind observed since 1922:

Flashing Arc on September 15th—16th, 1926.

Until about 22^h on that day the sky was overcast, but I could see the aurora line 5577 in a pocket-spectroscope through the clouds. When the sky cleared a fine arc was seen from Aquila through the zenith eastwards. This arc was divided in lamels as on the picture 8 in the Photographic Atlas of Auroral Forms. At about $22^h\,24^m$ the arc began to flicker: Narrow arcs appeared suddenly over the whole heaven, lasted one to two seconds, suddenly disappeared and then reappeared at another place near the first one. Sometimes two or three such arcs were seen at the same time and they all appeared and disappeared in a zone from east to west over zenith. One had the impression that electric discharges went along the arc with great rapidity, either from W to E, or in the opposite direction, but the motion along the arc was so rapid that it was impossible to decide the direction of the discharges.

Later the narrow arcs were again quiet and formed a sort of broad divided arc or zone, reproduced as picture 10 in the above mentioned Atlas.

At the time of the flickering arcs the sky at the other station was overcast so no height determinations could be made.

Later, at about 23^h, rays and curtains began to develop, and near midnight strange pulsating patches appeared, some of which are described in Section 31 of the present paper.

Flashing Aurora on August 20th—21st, 1927.

On August 20th, 1927, at $22^h\,30^m$ I happened to see from Drøbak, 30 km south of Oslo, a strange aurora which lasted at least to $2^h\,30^m$ in the morning. When I discovered the aurora I telephoned to my aurora stations Oslo, Oscarsborg, Kongsberg, and Tømte. At Kongsberg and Tømte the sky was overcast and from Oslo I did not get any answer. Therefore no height determinations could be made. Here are my observations:

$22^h\,30^m$ Violet gray color in W.
$22^h\,32^m$ Diffuse aurora in zenith and a little south of it. Ray in Hercules.
$0^h\,06^m$ Diffuse pulsations in zenith.
$0^h\,25^m$ High pale rays near Polaris, probably sunlit.
$0^h\,31^m$ Pale flames go from Ursa Major with great velocity towards zenith.
$1^h\,30^m$ Pulsating arc from NW to N.
$1^h\,47^m$ Strong pulsations in N to NW.

Now come the remarkable flickering aurorae.

$2^h\,00^m$ Remarkable flashes, very intense and lasting a fraction of a second, like bits of arcs or surfaces high in the northern sky, and even to the zenith. Color red green.
$2^h\,23^m$ The same flashes continue. From a bank of green cloudlike aurora under the Great Bear, bits of arcs are thrown, one after another, towards the zenith, and near the zenith *irregular patches suddenly flashed up and disappeared in a small fraction of a second.* Color often violet green to violet.
$2^h\,36^m$ Yellow green draperies develope from N with long violet rays towards the zenith. Flashes begin again.
$2^h\,42^m$ Curtains low in N. The sky filled with diffuse light. Aurora line 5577 visible to the zenith.
$2^h\,50^m$ The aurora was drawn away to the north where yellow red pulsations continue.

Observations ended at dawn.

Flashing Aurora on March 30th—31st, 1941.

On March 30th—31st a remarkable aurora was seen. It began just after dusk with long sunlit rays near the zenith. As soon as I observed these rays I alarmed my stations and at about 22^h I got in telephonic connection with Kongsberg and Askim and the work continued until dawn. The whole night the aurora had a peculiar character. All forms, except some cloudlike ones, were of very short duration. They were like flashes, lasted not more than one or two seconds, disappeared and reappeared at another place.

This made it very difficult to get simultaneous photographs of them from two stations, and in spite of 179 sets of photographs taken, only one tenth of them succeeded. From about 22^h to about $23^h\,40^m$ a fine arc extended from E to W near the zenith. This arc had the form of a series of lamels, appearing and disappearing like horizontal flashes. In spite of the great number of sets taken, only one was usable. The color was blue green to blue white. At about $23^h\,40^m$ a beautiful flashing corona was formed and later on figures appeared of the most irregular forms, like detached bands and multiformed patches flashing up for a fraction of a second, especially around the zenith.

The only reliable set of pictures of the flashing arc was taken with base line *M* (Meteorological Institute)—Askim, 47.33 km, at $22^h\,35^m\,43^s$ MET, exposure 5^s. The result was:

No. 64, $22^h\,35^m\,43^s$ MET.

P	ε_9	p	h	a	D	H
1	8.8	8.8	63.0	—79.6	133	274
2	8.6	8.6	66.0	—74.3	122	288
3	8.4	8 6	68.7	—67.4	110	293
4	4.7	12.1	64.1	—82.8	95	203
5	4.5	12.1	67.2	—77.3	84	207
6	4.4	11.9	70.0	—70.3	74	214

The points 1, 2, 3 belong to the upper, the points 4, 5, 6 to the lower border. The sketches are seen on Plate 8.

It is astonishing that we got such great heights.

As a verification we have also used the picture from Kongsberg taken simultaneously with the two above; but as the direction of the arc made only a slight angle with the base line from *M* to Kongsberg the determination is not good, but the same order of heights was found.

More flashing arcs ought to be measured before we can accept this great height as a well established

fact. When the corona began to be formed I pointed a cine-camera from my station M towards the point of radiation, and began to take single pictures in slow succession, a picture every 3 or 4 seconds. The camera had an Astro lense of luminosity F 1.25 and with Agfa ultra red sensitive film a series of good pictures was obtained. It is astonishing to see how rapidly the flashing corona changed. On Plate 22 some characteristic pictures are reproduced, whose contrasts have been considerably strenghtened by copying them on Agfa Lupex ultra hard paper. The first one at $22^h\ 52^m\ 51^s$ MET is a fine corona and the 3 others at $22^h\ 53^m$ taken in succession every 3 seconds are of flashes near the point of radiation, which lasted only for a very short time. No set of simultaneous pictures of the flashing patches succeeded. The point of radiation of the corona at $22^h\ 52^m\ 51^s$ could be determined with great accuracy, the stars ψ, ω, λ, and μ Ursae Majoris being in the neighbourhood; its height and azimuth were found to be

Height 72.1° Azimuth —2.6°,

the azimuth counted negative from south towards east.

35. Summary.

From simultaneous observations from Oslo and Trondheim it is proven that the aurora flames went upwards from the atmosphere towards space. Some measurements of flaming patches on January 25th —26th showed heights which before sunrise reached down to about 83 km.

Some rare cases of flashing aurorae are described; only on one occasion was a flashing arc measured; it lay from 200 to 300 km above the earth. Some moving pictures of a flashing corona were reproduced, from which it was found that the radiation point over Oslo had the coordinates: Height 72.1°, Azimuth —2.6°.

PART IV. CERTAIN CLOUDLIKE AURORAE (VI)

36. Introduction.

Among the quiet and feeble aurorae without ray structure the non-pulsating cloudlike forms are of great interest. They belong to the type DS, called diffuse luminous surfaces in the Photographic Atlas of Auroral Forms[1].

These cloudlike aurorae appear very often as remains of strong curtains, when the latter have disappeared. Their color is in general grey to greenish[2], and their light feeble and diffuse. They can remain at the same place for a time and vanish successively.

A typical case is given in the report[3] of my auroral expedition to Bossekop in 1910, on Tafel 6, pictures 14 and 15, of which the first one is taken of strong curtains already beginning to fade and the second one represents the typical cloudlike aurora taken towards the same region about 2 minutes later. The last picture is also reproduced in larger scale on Tafel 64, and in the Photographic Atlas of Auroral Forms as No. 20.

Another illustration of the transformation of curtains to cloudlike forms is given on a film taken on September 15th, 1938, and reproduced in Terr. Magn. for the year 1939[1].

As to height determinations of cloudlike aurorae, only few have yet been published. In their first paper on the subject[2] Harang and Tønsberg only give 13 heights of cloudlike aurorae observed in Tromsø 1929 —1930. These heights vary from 84—119 km with mean 103 km. Later Krogness and also Harang[3] and Tønsberg[4] have made statistics of what they call auroral clouds, but these were a combination of the two forms DS, diffuse surfaces, and PS, pulsating surfaces, and are not the pure form considered here, auroral clouds without pulsations.

In a paper published in 1938[5] I have given some measurements of cloudlike aurorae, photographed in southern Norway with the long base lines Oslo—Lillehammer (133 km) and Oscarsborg—Lillehammer (159 km) which gave parallaxes from 12 to 24 degrees and very reliable measurements.

The lower parts of these cloudlike aurorae, from April 1936, lay between 91 and 93 km above the earth.

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[1] Published by the International Geodetic and Geophysical Union, Oslo 1930, A. W. Brøggers Boktrykkeri.

[2] Red patches will be dealt with in a later part of this work.

[3] Videnskabsselskabets Skrifter, Kristiania 1911, Math. Naturv. Klasse no. 17.

[1] Auroral Work in Southern Norway in the Year 1938, Plate II. On account of the quality of the paper this reproduction is not good.

[2] Geofysiske Publikasjoner, Vol. IX, No. 5.

[3] Ibid. Vol. XI, No. 8.

[4] Ibid. Vol. XII, No. 1.

[5] Ibid. Vol. XII, No. 7.

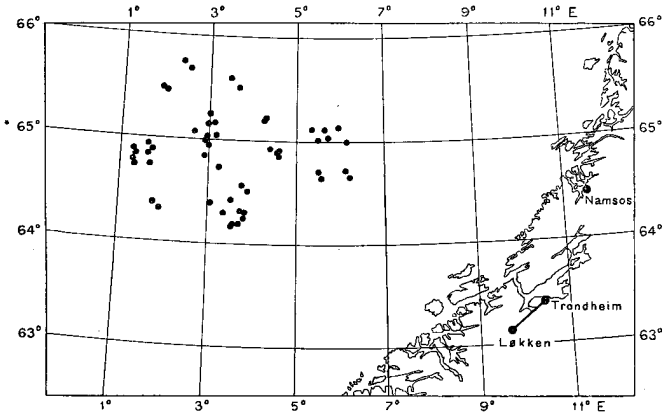

Fig. 39. Situation of cloudlike aurora on March 24th—25th, 1933. Base line Trondheim—Løkken.

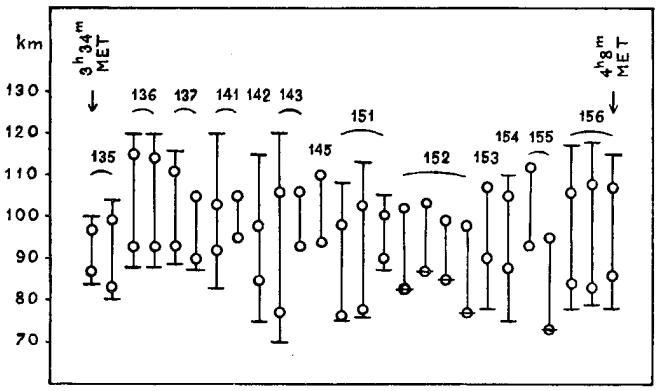

Fig. 40. Heights of measured points and upper and lower limits of the cloudlike aurora on March 24th—25th, 1933.

Among the very great number of simultaneous photographs, more than 6000 sets taken from my stations in southern Norway, there are some most interesting cases of cloudlike aurorae which shall be mentioned in the following.

37. Cloudlike Aurorae on March 24th—25th, 1933.

During the polar year 1932—33 I had for some time at my disposal a base line from Trondheim to Løkken verk (about 48 km),[1] and during the nights of March 18th—19th, 19th—20th, 23rd—24th, and 24th—25th I obtained a great many simultaneous photographs from the two stations. The compilation of the material is now completed, but not yet published. From 141 good sets we obtained 630 height measurements of the different aurora forms observed. Among these forms some cloudlike aurorae from $3^h\,34^m$ to $4^h\,08^m$ MET before sunrise on March 25th were of special interest.[2] They were situated in the earth's shadow over the sea north-west of Trondheim as seen on Fig. 39.

From the 13 sets of pictures taken simultaneously from Trondheim and Løkken verk about 50 points along the aurora and 22 lower limits were determined.

The lower limits were, in kilometers, 84, 80, 88, 88, 89, 87, 83, 75, 70, 75, 76, 87, 83, 87, 85, 77, 78, 75, 73, 78, 79, 78, mean 80.7 km. Very low indeed!

[1] See the preliminary report: Über eine Nordlichtexpedition nach Trondheim in März 1933, Gerlands Beiträge Bd. 41, p. 382.

[2] These were briefly mentioned and pictures of some of them reproduced in the preliminary report. The lower limits of height were, however, not yet measured.

On Fig. 40 are seen measured points (circles) and lower and upper limits (dashes) for each of the short dots or edges measured. The current numbers of the corresponding sets are given on the figure.

As the parallaxes are of the order of five to eleven degrees, the height determinations are rather good; the measurements of the plates were made by my assistants Egeberg and Herlofson.

Among these sets we shall give two characteristic ones, No. 151 and No. 156.

No. 151, $4^h\,04^m\,04^s$ MET.

On Plate 22 are seen the two pictures with Castor and Pollux as background. The sketches are given on Plate 8.

The result of the measurements was as follows (Trondheim main station).

P	ε_2	p	h	a	D	H
1	—3.9	9.5	18.4	132.9	273	98
2	—4.6	9.2	13.6	134.0	289	76
3	—0.6	8.6	12.8	130.3	311	78
4	0.0	8.8	17.6	129.4	298	103
5	7.7	8.0	15.6	122.4	325	100
6	7.4	7.8	13.4	123.0	337	90

Lowest point along the edge 1—2 was 75, highest 108 km
— — — 3—4 » 76 — 113 »
— — — 5—6 » 87 — 105 »

The color was gray to yellow green and the outlines diffuse. The aurora was quiet.

No. 156, $4^h\,08^m\,51^s$ MET.

The southern part of the same aurora. See Plates 23 and 8.

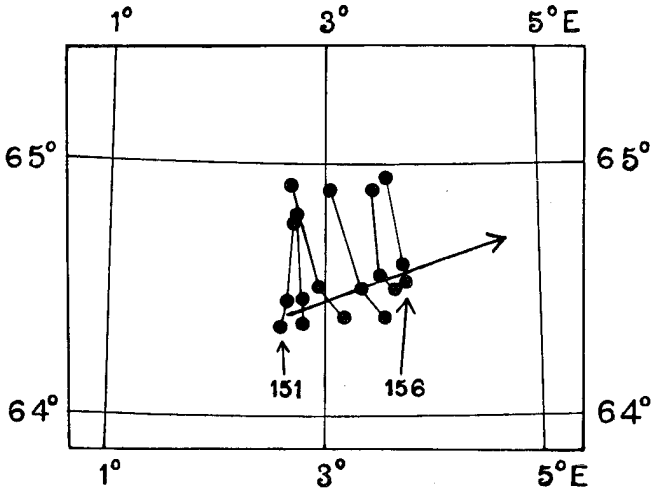

Fig. 41. Successive geographical positions of the same part of the cloudlike aurora on March 24th—25th, 1933.

P	ε_2	p	h	a	D	H
1	16.5	7.4	15.6	113.9	342	106
2	16.0	7.4	12.1	114.7	350	85
3	21.2	7.2	15.9	109.1	339	108
4	20.5	7.3	11.9	110.2	344	83
5	23.3	6.9	15.3	107.3	350	107
6	22.7	7.2	12.6	107.9	341	86

Lowest point along the edge 1—2 was 78, highest 117 km
— — — 3—4 » 79 » 118 »
— — — 5—6 » 78 » 115 »

On the Løkken pictures Nos. 151 to 156 the same aurora can be recognized on all pictures. It has essentially retained its form as seen on Plate 23. If we plot the geographical situation of the left border, giving reasonable height to corresponding points, it is seen that it has moved with a velocity of the order of 200 meters per second towards a point about 20° north of east as seen on Fig. 41.

38. Cloudlike Aurora on January 27th—28th, 1935.

On January 27th—28th, 1935, a fine aurora was seen in Oslo and adjacent stations. It has been preliminarily described in a paper[1]: "Measuring of Aurorae with Very Long Base Lines", and some measurements have been published there.

The maximum activity of that aurora occurred from $1^h\,51^m$ to about 2^h when beautiful multicoloured curtains developed with great rapidity from west to-

[1] Geofysiske Publikasjoner, Vol. XI, No. 3, 1935.

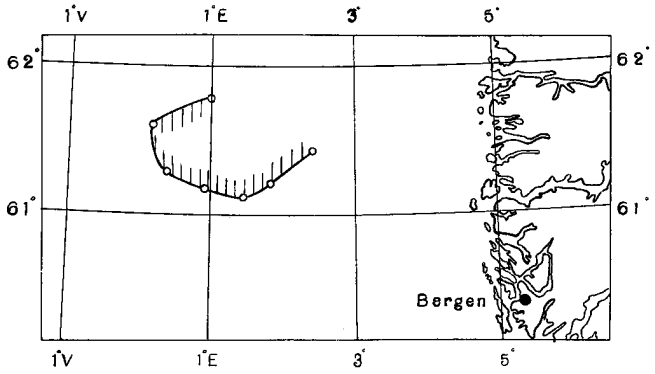

Fig. 42. Geographical situation of cloudlike aurora on January 27th—28th, 1935.

wards north east. The rays of the curtains were red at the lower border and on the forward side of the movement. Some good measurements of one of these curtains are published in the above mentioned paper and showed that its lower border was at a height of 94—97 km.

After this outburst only faint cloudlike forms remained, and of these some very interesting pictures were taken with the base lines Oscarsborg—Lillehammer, (159 km), and Oslo—Lillehammer (133 km).

The first one, No. 142, was taken simultaneously from Oscarsborg, Oslo and Lillehammer at $2^h\,27^m\,19^s$. It was measured with base line Oslo—Lillehammer by my assistant Anda in 1935. He used the angle u_2 instead of $\varepsilon_2 = 90° - u_2$ later introduced. The results of his measurements were:

No. 142, $2^h\,27^m\,19^s$ MET, January 27th—28th, 1935.

P	u_2	p	h	a	D	H
1	70.7	15.3	8.7	169.0	465	89
2	73.5	14.4	8.2	170.0	500	92
3	78.0	15.4	8.1	170.6	479	88
4	80.0	16.5	9.9	168.7	449	95
5	81.2	17.6	12.3	166.0	419	106
6	80.0	18.1	13.9	164.0	402	114
7	75.9	18.7	14.9	162.0	382	114

This cloudlike aurora lay in the earth's shadow over the North Sea as seen on Fig. 42.

The pictures are seen on Plate 24 and the sketches on Plate 8.

A series of pictures of the same cloudlike aurora was taken with the smaller base line Oscarsborg—Oslo of 27 km but are not as good as this one.

39. The Cloudlike Aurora on January 3rd, 1940.

On January 3rd—4th we had a very strange and rare aurora over southern Norway. From the beginning of darkness at about 17^h to about $19^h\,40^m$ MET the southern limitation of the aurora consisted of remarkable cloudlike forms in great irregular tongues towards the south. These forms had no ray structure and resembled clouds. They changed their form and situation very slowly. Their color was yellow green.

But at the same time a very different aurora occurred in NW. Very fine long *red* rays were seen which made a remarkable contrast to the yellow green cloudlike forms.[1] They were situated in the sunlit part of the atmosphere, from about 200 to more than 600 km over the earth, in contrast to the cloudlike froms which were in darkness and whose height was between 100 and 120 km. They lasted till about 18^h. (See Fig. 58.)

These cloudlike forms and sunlit rays were followed by common forms like homogeneous arcs and bands with ray structure in the north, which continued until about $2^h\,30^m$ when only a feeble glow remained. Later the sky was overcast.

As the occurrence of such long lasting and remarkable cloudlike aurora is exceedingly rare we give a list of all the photographs taken. We omit the photographs of the red rays and of other more ordinary ones, occurring later. The headings have the following meaning:

P. No. the number of the photograph.

St. Stations; if photographs were taken simultaneously from two or more stations, their letters are combined with dashes. The stations were Oslo (*C*), Oscarsborg (*O*), Askim (*Ak*), Lillehammer (*Li*), Tuddal (*Tu*), and Hokksund (*Hk*).

Those working at the stations were: *C*: Tveter, Herlofsen, Owren, Wischmann, and myself, *O*: Frank Johannesen, *Ak*: Bjordal, *Li*: Høstmælingen, *Hk*: Hassel, *Tu*: Tjønn. The stations *C*, *O*, *Ak*, and *Li* were in telephonic connection, *Hk* and *Tu* worked independently.

MET, mean time of Central Europe for the middle of the exposure.

Ex., exposure.

Ref. Const. The constellations or planets towards which the cameras were pointed.

Here is the list:

[1] See section 48 of the present paper.

Table 14.

Photographs of cloudlike Aurora on January 3rd, 1940.

P. No.	St.	MET	Ex.	Ref. Const.
2.2	*Hk*	17.08.53	10	Ori. Tau.
2.3	—	.09.45	15	Cet, ♃
2.4	—	.10.38	20	Per. Tau.
2.5	—	.11.33	20	Ori. Tau.
2.6	—	.12.13	20	Cet, ♃
3.1	—	.14.08	10	♃, ♂
3.2	—	.15.08	20	♃, ♂
3.3	—	.16.08	30	Ori. Tau.
3.4	—	.16.56	20	Tau.
3.5	—	.17.42	20	♄, ♃, ♂
3.6	—	.18.53	30	Ori. Tau.
4.1	—	.20.13	30	Ori. Tau.
4.2	—	.21.08	20	Per. Tau.
1.1	*Ak*	.25.08	15	Ori.
1.2	—	.26.29	15	Tau.
1.3	—	.27.22	15	♃, ♂
1.4	—	.31.42	15	UMa.
4.4	*Hk*	.32.53	50	Ori.
4.5	—	.33.58	30	♄, Cet.
4.6	—	.34.08	30	♀, Aql.
1.5	*Ak*	.34.27	15	Ori. Tau.
1.6	—	.35.42	15	Tau. Aur.
7.1	*Hk*	.38.08	60	Ori. Tau.
2.1	*Ak*	.39.22	15	♃, ♂
7.2	*Hk*	.40.18	60	♃, ♂
2.2	*Ak*	.41.08	15	Aql.
1	C	.41.14	16	Peg.
7.3	*Hk*	.41.38	60	♀, Aql.
4	*C*	.43.58	17	UMa.
5	—	.44.52	15	Aql. Psc.
7.4	*Hk*	.46.58	60	Aqr, ♀
7.5	—	.48.08	40	♄, ♃, ♂
7.6	—	.49.28	60	Tau.
10	*C—Ak*	.50.25	12	♃ ♂,
11	—	.51.19	13	Aqu. Peg.
9.2	*Hk*	.53.10	65	UMa.
13	*C—Ak*	.53.42	13	Aql.
14	—	.54.28	12	♃, ♂
18	*C—Ak—O—Li*	18.00.42	13	♂, Psc.
10.2	*Hk*	.02.03	60	♃, ♂
10.3	—	.03.15	45	Ori. Tau.
21	*C—Ak—O—Li*	.04.19	12	♃, ♂, Psc. Cet.
22	—	.05.36	12	Cap. Aqr.
10.5	*Hk*	.05.38	60	♃, Aql.
10.6	—	.06.36	40	♃, ♂
12.1	—	.08.40	64	♄, Cet.
25	*C—Ak—O—Li*	.10.46	12	♂, Cet. Psc
12.2	*Hk*	.11.28	60	Ori. Tau.
12.3	—	.12.08	50	Aur.
26	*C—Ak—O—Li*	13.08	10	♂, ♃, Cet. Aqr.
12.4	*Hk*	.13.08	50	UMi. Cep.
27	*C—Ak—O—Li*	.14.35	10	Aql. Del.
12.5	*Hk*	.14.46	56	♃, ♂, Peg. Aqr.
28	*C—Ak—O—Li*	.15.27	12	Aqr.
12.6	*Hk*	.16.15	105	Aql. Lyr.
30	*C—Ak—O—Li*	.17.05	12	Aqr.
31	—	.18.29	13	♄, Ari. Cet.
13.1	*Hk*	.19.58	60	Ori. Tau.
32	*Ak—O—Li*	.20.01	11	And.
33	*C—Ak—Li*	.21.00	13	Aqr. Peg.
13.2	*Hk*	.21.48	60	Per. Aur.
35	*C—Ak—O—Li*	.22.28	12	Aqr.
13.4	*Hk*	.24.18	60	Aql.
36	*C—Ak—O—Li*	.25.19	12	Aql. Cyg. Del.

Table 14 (continued).

P. No.	St.	MET	Ex.	Ref. Const.
13.6	*Hk*	18.27.08	80	Gem. Tau.
37	*C—Ak—O—Li*	.30.36	13	♀, ♂, And. Peg.
38	—	.31.25	13	Psc. Cet.
39	—	.32.22	12	Peg.
14.1	*Hk*	.32.23	80	Gem.
40	*C—Ak—O—Li*	.33.26	13	Aql Equ. Del.
41	—	.35.09	10	♀, ♂, Peg. Cet.
14.3	*Hk*	.35.28	80	♀, ♂, ♄
42	*C—Ak—O—Li*	.36.02	12	Ari. ♀, ♂
14.4	*Hk*	.37.23	60	UMi.
43	*C—Ak—O—Li*	.37.58	14	Aqr. Cet. Psc.
44	—	.38.45	12	Peg. Aqr. Psc.
45	—	.39.36	14	Peg.
14.5	*Hk*	.39.43	180	Aql.
46	*C—Ak—O—Li*	.40.26	13	Aql. Del. Sge.
47	—	.41.08	12	Lyr. Cyg.
14.6	*Hk*	.42.08	60	♀, ♂, Peg.
48	*C—Ak—O—Li*	.42.16	12	Cas.
49	*C, Ak, O, Li*	.45.24	12	Tau. Cas.
50	*C—O*	.46.10	12	Tau.
51	*O—Ak*	.48.15	13	Aqr.
52	*C—O—Ak*	.49.02	11	Aql. Del. Vul.
53	*O—Ak*	.49.53	13	Lyr. Cyg.
54	*C—O—Ak*	.50.54	17	Cyg. Sge.
15.1	*Hk*	.54.03	50	Ori. Gem.
15.2	—	.55.03	50	Gem.
15.3	—	.56.38	45	Tau.
15.4	—	.57.38	45	And. Ari.
15.5	—	.58.45	50	♀, ♂, Peg.
1*	*C—Li*	.59.18	16	♄, Cet.
15.6	*Hk*	.59.58	80	Aql.
2*	*C—Li*	19.00.18	10	♄, Cet.
3*	—	.01.31	8	Cet. Psc.
16.1	*Hk*	.02.03	90	Gem.
4*	*C—Li*	.02.09	11	Psc. Cet.
55	*C—O—Ak*	.02.34	10	Aql. Cyg. Del.
56	—	.03.17	15	Aqr. Peg.
16.2	*Hk*	.03.51	90	Ori. Tau.
57	*C—O—Ak*	.03.53	15	Peg. Cyg. Del.
5*	*C—Li*	.04.07	15	Tau Cet.
16.3	*Hk*	.05.33	70	Aur Gem.
58	*C—O—Ak*	.06.01	15	And. Peg.
59	—	.06.53	15	♀, ♂, Peg.
16.4	*Hk*	.07.43	70	Peg Psc.
60	*C—O—Ak*	.07.43	16	♄, Cet.
8*	*C—Li*	.08.43	18	Eri. Cet.
16.5	*Hk*	.09.18	90	Del.
9*	*C—Li*	.12.34	12	Cet. Psc.
10*	—	.13.11	11	Cet.
16 6	*Hk*	.13.53	80	♀, ♂, Peg.
11*	*C—Li*	.14.45	19	Cet.
17.4	*Hk*	.21.53	90	Del. Aql. Peg.
17.5	—	.24.15	45	UMa. Leo.
17.6	—	.25.16	62	Aql. Del Peg.
1**	*Tu*	.33.00	15	Aql. Del. Cyg.
62	*C—O—Ak*	.40.15	11	UMa. Lyr.

From this list we have first taken 4 characteristic sets for determination of a reasonable height of the phenomenon. The four sets were the following:

No. 35. $18^h\ 22^m\ 28^s$ MET.

Base line *Li—O*, 158.65 km.

P.	ε_2	*p*	*h*	*a*	*D*	*H*
1	33.3	13.5	9.6	40.0	551	116
2	33.3	13.2	7.8	40.6	566	105
3	30.7	12.1	6.5	44.3	638	105

No. 40. $18^h\ 33^m\ 26^s$ MET.

Same base line.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	3.3	21.0	11.7	62.6	425	104
2	1.9	20.1	10.9	65.0	447	103
3	0.4	19.2	10.7	67.5	466	105

No. 3.* $19^h\ 01^m\ 31^s$ MET.

Base line *C—Li*, 132.65 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	33.2	29.1	27.1	— 6.9	200	107
2	34.0	28.6	26.5	— 8.9	204	106
3	42.0	23.2	23.5	—11.2	227	104
4	41.2	23.6	23.1	—13.9	227	102

No. 4,* $19^h\ 02^m\ 09^s$ MET.

Same base line.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	44.4	20.8	23.0	—13.0	242	109
2	41.9	22.0	23.4	—16.2	234	109
3	38.6	23.7	23.9	—18.7	233	109

The sketches and pictures are seen on Plates 8, 9 24, and 25.

With the mean of these heights, 106 km, the geographical position of a series of points of single pictures was measured giving the outlines and situation of these cloudlike forms on a map of Scandinavia and adjacent countries. The following pictures were chosen:

Fig. 43:

Ak	4.4	17.32.53	MET
—	4.5	.33.58	—
Ak	2.1	.39.22	—
Hk	7.3	.41.38	—
C	4	.43.58	—
Hk	7.4	.46.58	—

Fig. 44:

Hk	12.2	18.11.28	MET
O	26	.13.08	—
O	27	.14.35	—

Fig. 45:

Hk	15.1	18.54.03	MET
—	16.1	19.02.03	—
Li	4*	.02.09	—
Ak	55	.02.34	—
O	55	.02.34	—

Fig. 46:

Li	11*	19.14.45	MET
Hk	17.5	.24.15	—
—	17.6	.25.16	—

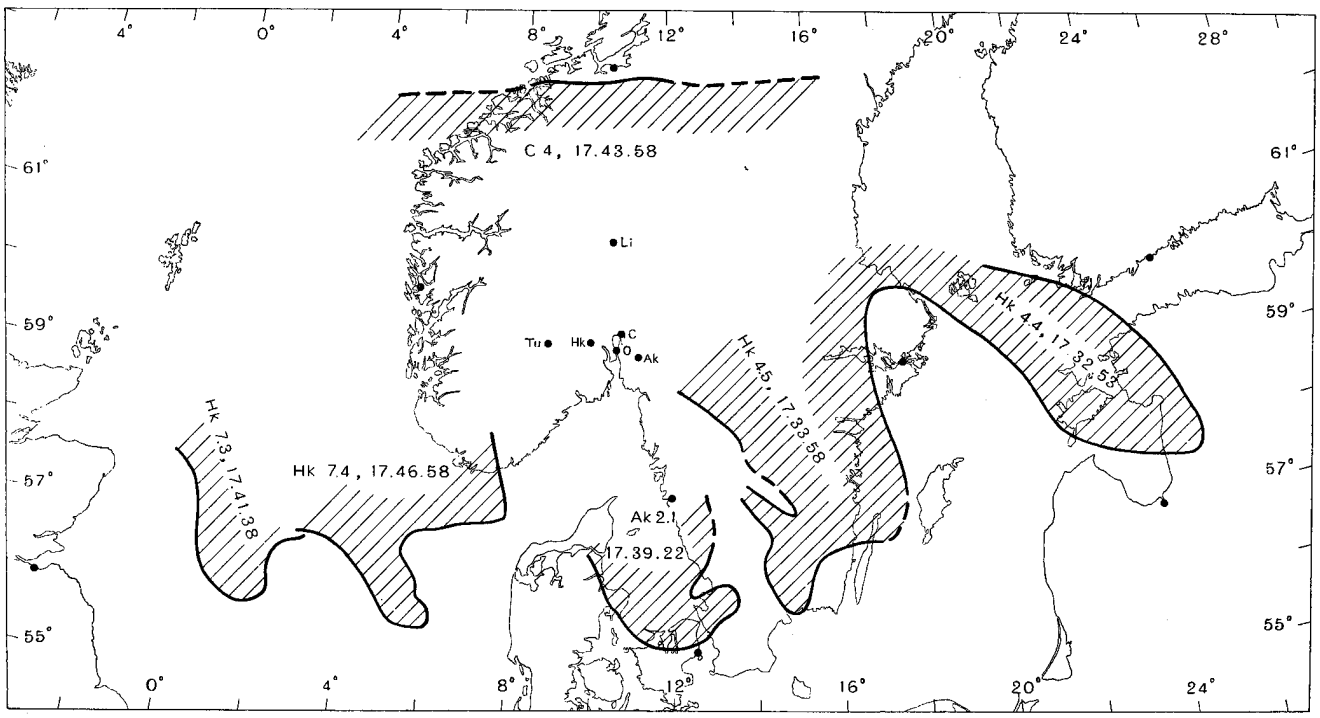

Fig. 43. Geographical outline of cloudlike aurora on January 3rd—4th, $17^h\,32^m$ to $17^h\,47^m$.

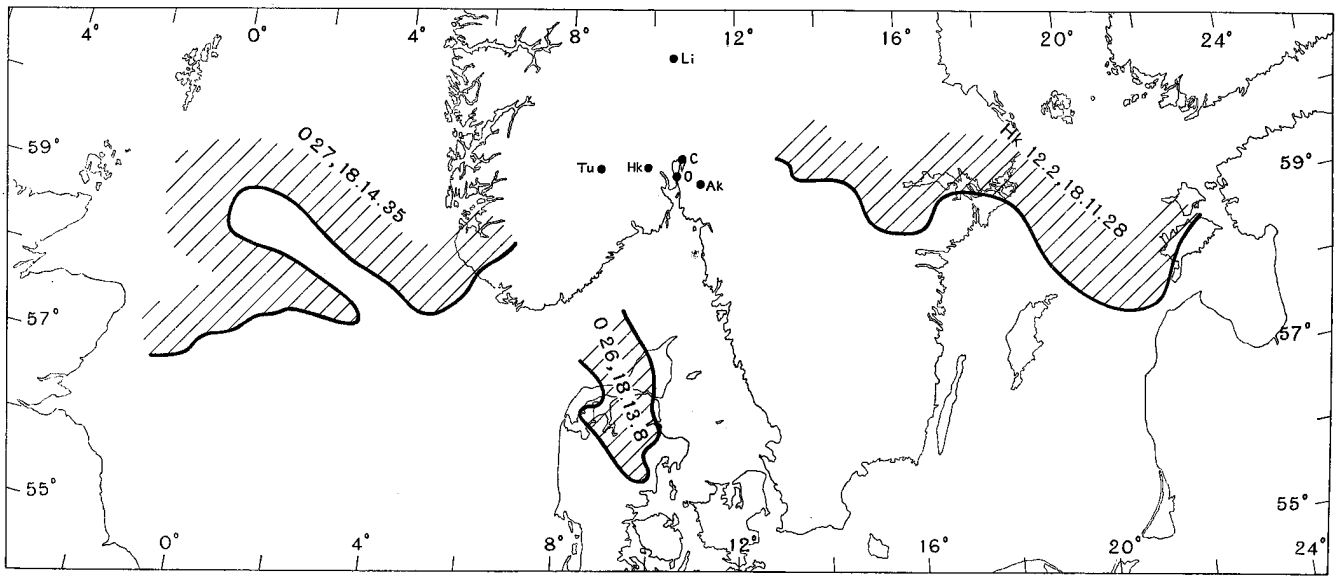

Fig. 44. The same from $18^h\,11^m$ to $18^h\,15^m$.

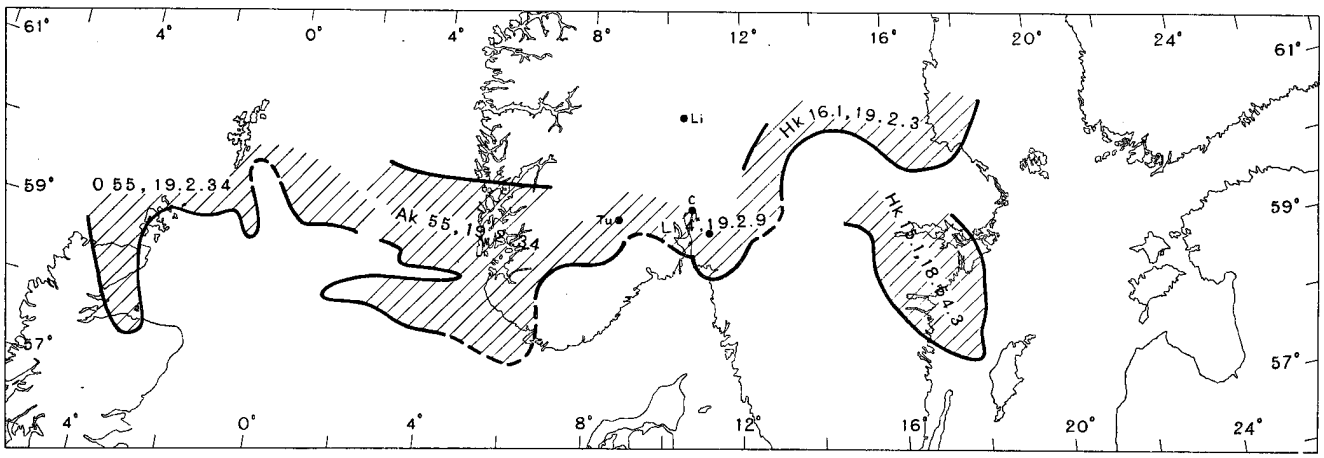

Fig. 45. The same from $18^h\,54^m$ to $19^h\,03^m$.

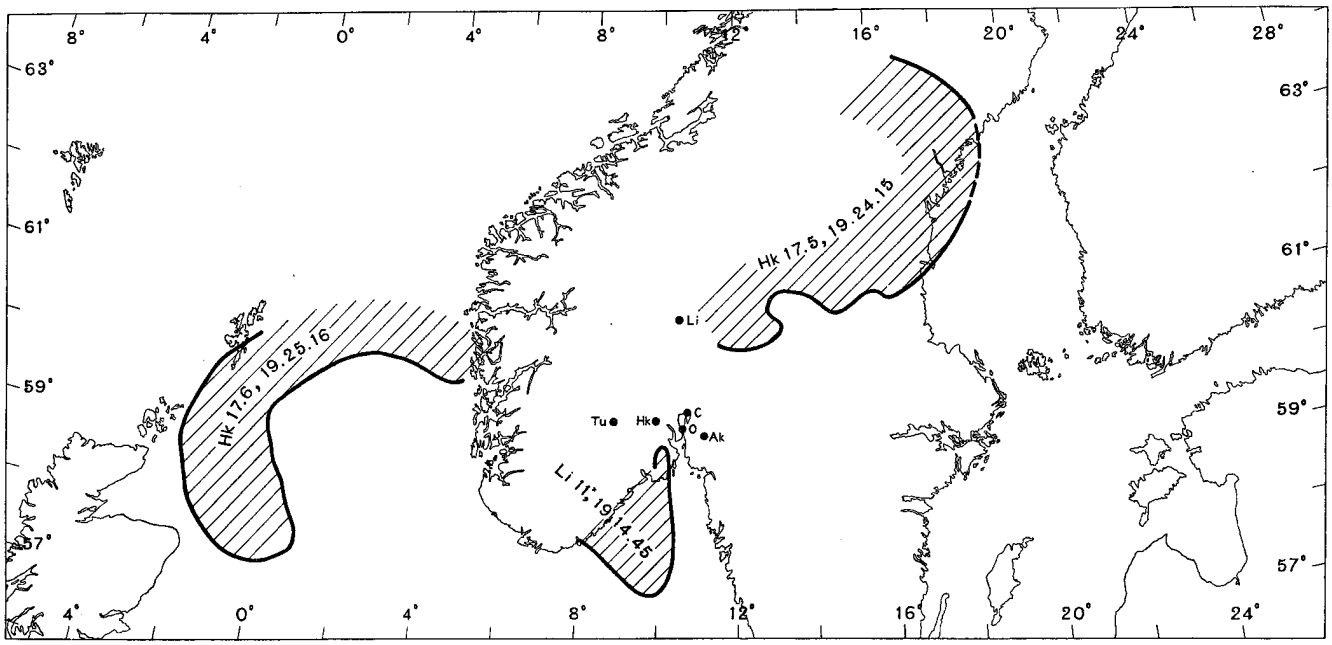

Fig. 46. The same from 19h 14m to 19h 26m.

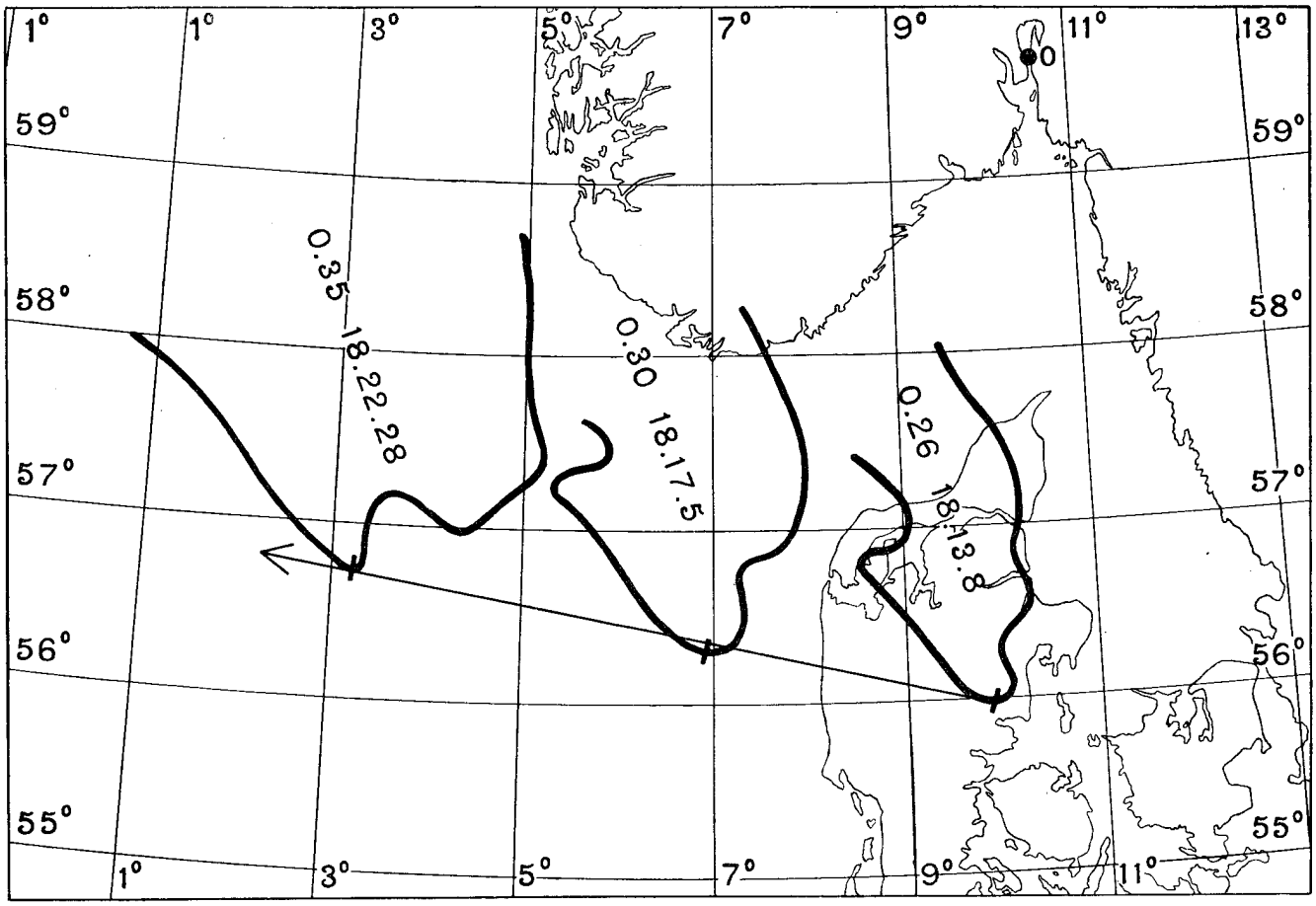

Fig. 47. Motion and deformation of a tongue of cloudlike aurora, January 3rd—4th, 1940.

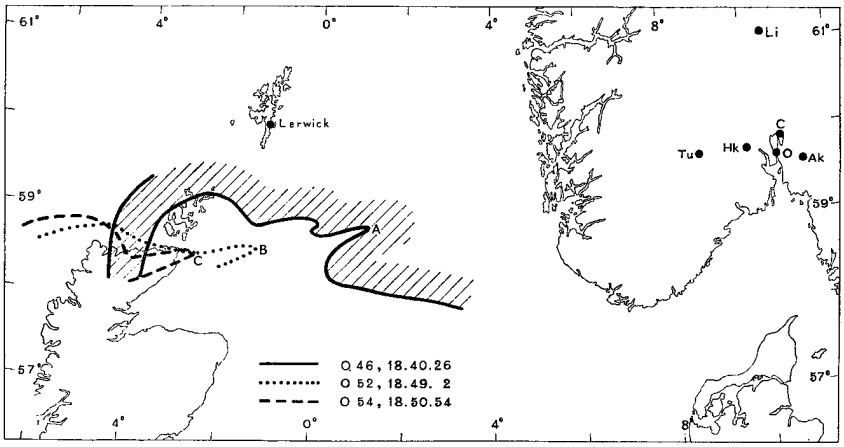

Fig. 48. The same for another part of the cloudlike aurora.

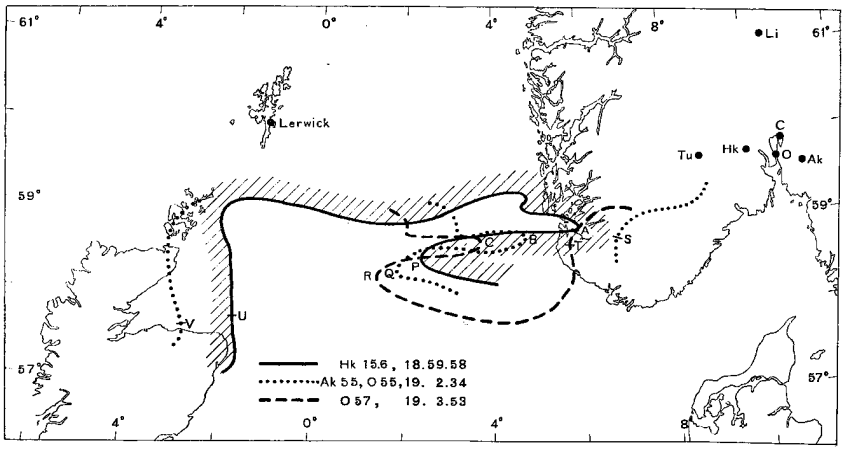

Fig. 49. The same for still another part of the same aurora.

Some of these are seen on Plates 25 and 26.

As seen from these maps the outline towards south was very irregular, changing slowly from minute to minute. The whole time the structure was cloudlike without any tendency to ray structure. As the height of the different points may have varied about ± 7 km from the mean, the outlines can only be considered as approximate, but at all events they give a fairly good idea of the remarkable limitation of the cloudlike aurora towards south. The northern limitation was, as seen on Fig. 43, regular, and farther north no aurora was seen. The great extent of this cloudlike aurora is remarkable as compared with its vertical thickness which hardly exceeded 10 to 20 km.

In some cases the same form can be recognized on successive pictures which give an idea of the velocity of displacement.

As a typical case we shall take the three pictures

O 26 $18^h\,13^m\,08^s$
O 30 $18^h\,17^m\,05^s$
and O 35 $18^h\,22^m\,28^s$

representing a very characteristic cloudformed tongue in S to SW. Assuming the height around the outline to be 106 km the geographical positions are seen on Fig. 47.

If we consider the displacement of the southern end A we get from O 26 to O 30 a velocity of 780 meters per second, from O 30 to O 35, 690 meters, and from O 26 to O 35, 730 meters. It moved in a westerly direction.

Some other cases might be mentioned:

The first one comprises the 3 pictures

O 46 $18^h\,40^m\,26^s$
O 52 $18^h\,49^m\,02^s$
and O 54 $18^h\,50^m\,54^s$

representing an irregular opening in the cloudlike aurora near the western horizon. Measuring the corresponding points A, B, and C we find that the velocity from A to B was 290 meters, and from B to C 850 meters per second. From A to C we find an average of 370 meters. This indicates a certain deformation of the outline of the aurora.

The second case is a similar opening developing anew and driving like the first one to the west:

Hk 15.6 $18^h\,59^m\,58^s$
O—Ak 55 $19^h\,02^m\,34^s$
O 57 $19^h\,03^m\,53^s$

For the velocity of different parts we find:

From A to B 435 meters per second
— B — C 710 — — —
— A — C 540 — — —
— P — Q 205 — — —
— Q — R 380 — — —
— P — R 260 — — —
— S — T 780 — — —
— U — V 420 — — —

In mean 470 m per second.

At all events the cloudlike aurora seems to have moved westwards with velocities varying between 200 and 800 meters per second.

40. Some Visual Observations of the Same Cloudlike Aurora.

In the notes accompanying *Olaf Hassel's* photographs from the station *Hk* he has given some visual observations of interest. He says:

"During the twilight: Cloudlike aurora in E and SE. The forms were brightest and their outlines sharpest towards south; towards north, however, they were feeble with diffuse outlines.

From $17^h\,14^m$ to $17^h\,19^m$: In E and SE indications of feeble pulsations.

At $18^h\,40^m$ the form of the aurora was as on Fig. 50.

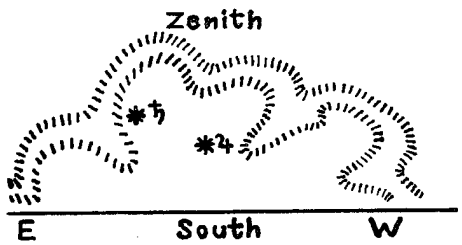

Fig. 50. Limitation of the same cloudlike aurora at $18^h\,40^m$ from Hokksund (Hassel).

At 19^h the northern limitation had the form of an arc.

From $19^h\,16^m$ to $19^h\,26^m$: The southern limitation moves northwards."

Among the numerous letters received only few are of general interest.

A. Grostøl writes from Stokke near Farsund (Latitude 58.1°, Longitude 6.8° E Gr.):

"I happened to be out at about 18^h MET and observed a remarkable aurora. It showed no rays, but

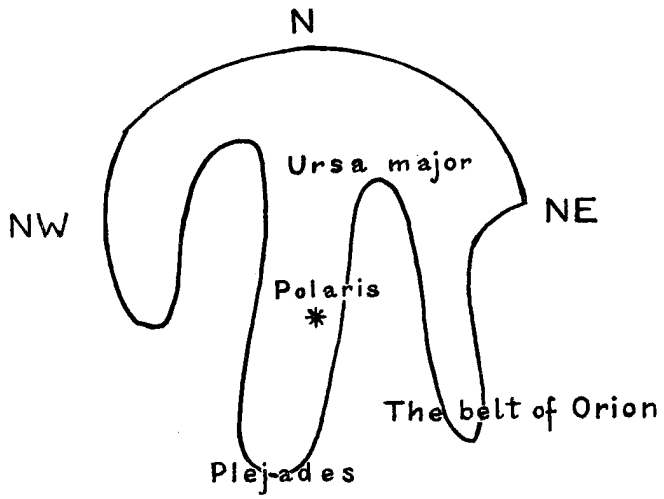

Fig. 51. Tongues southwards of the cloudlike aurora seen from Stokke (Grostøl).

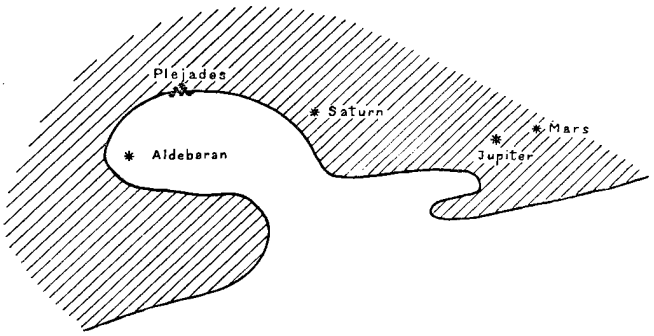

Fig. 52. Outline of the aurora seen from Røykenes at $19^h\,55^m$ (Kr. Kristensen).

consisted of a strange homogeneous surface of light on a clear sky. In NW a gray white tongue stretched towards SE. From NW to NE a feeble glow reached up to the Great Bear and another tongue stretched from NE southwards to the belt of Orion.

The aurora changed its form, but so slowly that the motion could not be seen; after 5 to 10 minutes, however, the change in form could easily be observed.

At 19^h, three great tongues could be seen, as on the following sketch (Fig. 51). At 20^h this cloudlike aurora had disappeared. Now it was only a common aurora in the north, without tongues."

Kr. Kristensen, district-physician in Førde, sent me the following sketch (Fig. 52) from Røykenes at Aalfjord, Vikebygd (Latitude 59.6°, Longitude 5.6° E Gr.). In the accompanying letter he says:

"When on a journey to Vikevik I arrived at Røykenes, I saw a fine aurora towards ESE during the twilight and tried to make a sketch of it. At the same time there were feeble rays in W round Vega and up towards the zenith.

The yellow green to white light in SE had a rather sharp boundary, as seen on the sketch, which is fairly correct, but the mutual distances of the stars are not reliable because I had no starmap with me. Within 10 minutes, however, this boundary had changed its form very considerably, moving westwards.

At $19^h\,55^m$ I also made a sketch of the two aurora arcs in the north . . ."

From engineer *A. Øverstad*, Sauda (Latitude 59.6°, Longitude 6.4° E Gr.) I got the following report:

"Regarding the aurora on January 3rd, 1940, I saw it the first time at $17^h\,48^m$. In the northern part of the sky from E to W I saw rays and tongues, but they were more quiet than usual. The western ones were red near the horizon. In the southern sky up to the zenith the aurora was quiet and woolly, like

a luminous haze or fog. It sometimes reached the horizon in SE.

About 18^h the woolly aurora had the form shown on the sketch, with Jupiter and Mars inside it." (Fig. 53.)

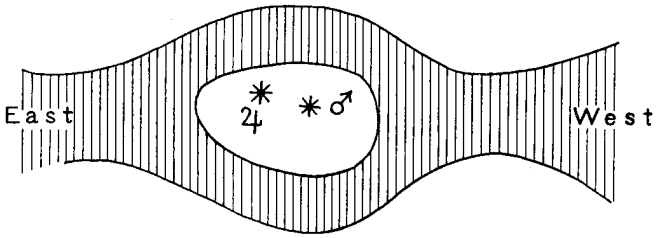

Fig. 53. The same seen from Sauda at 18^h.

From the meteorologist *Gunnar Peterson* at the station Malmslätt, Sweden (Latitude 58° 24.6′, Longitude 15° 31.3′ E Gr.), I got the following report:

"After sunset on January 3rd, 1940, an unusual aurora appeared. Just after sunset at $16^h\,50^m$ MET a big luminous cloudlike aurora from W to E was seen. In the west it was strongly red colored. At first I thought it to be high sunlit cirrus clouds. The aurora moved very slowly towards W. The southern boundary was strongly waved and the tongues reached so far south as β Aqr. and the bottoms between them were near Cassiopeia. After 17^h the waves resembled the picture No. 20 in the Photographic Atlas of Aurora Forms.[1]

Isolated rays appeared from time to time at different places.

At $17^h\,15^m$ I made a sketch on a starmap of a tongue of the aurora under Delphinus. This was at that time the most southern part of the aurora.

[1] Published by the International Geodetic and Geophysical Union, Oslo 1930.

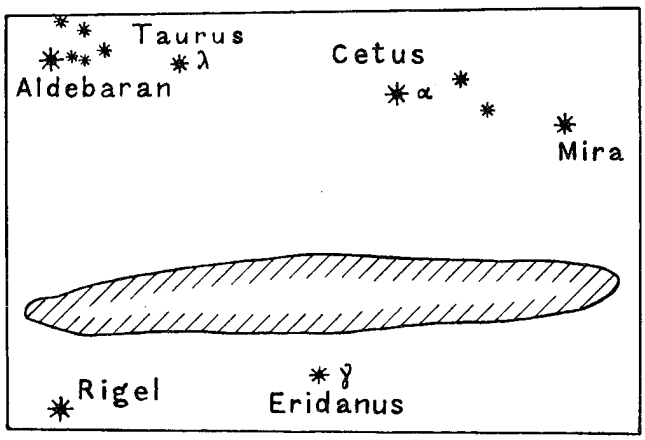

Fig. 54. Southern limit of aurora at $17^h\,20^m$ from Malmslätt (G. Peterson).

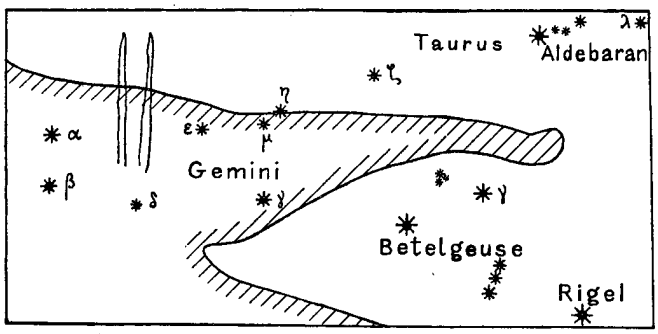

Fig. 55. Eastern part of the aurora at $17^h\,22^m$ (G. Peterson).

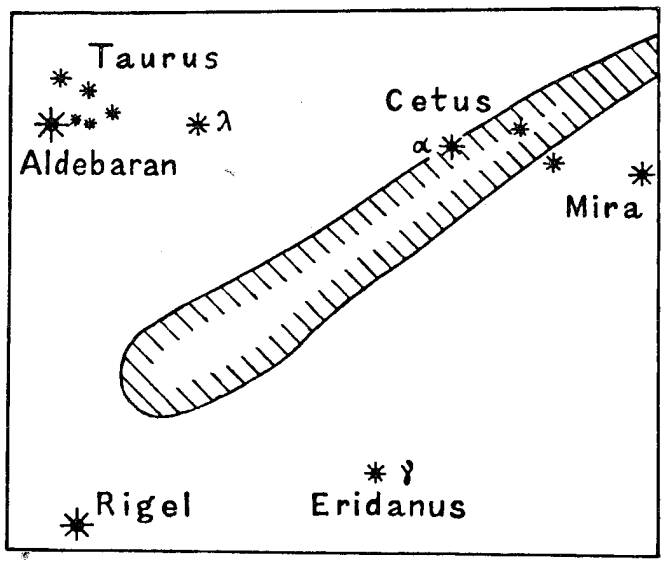

Fig. 56. The same at $17^h\,27^m$ (G. Peterson).

At $17^h\,20^m$ a luminous band was seen, parallel to the horizon in Eridanus. (See Fig. 54.) The southern boundary was again sketched at $17^h\,22^m$. A tongue over Orion with a luminous spot at the tip was drawn. (See Fig. 55.)

During half a minute ($17^h\,22^m$) some isolated rays were seen in Gemini.

At $17^h\,25^m$ a long luminous band was seen near the southern horizon; the left part towards Pegasus was drawn; this had also a luminous clump. During 15 seconds I also observed rays from Vega downwards. That part of the aurora was very red.

At $17^h\,27^m$ a similar band was seen from π Orionis, where it was most luminous, towards SE where it was hidden by clouds. The eastern part was drawn. (See Fig. 56.)

Each of these bands lasted only for 20 seconds.

At $17^h\,29^m$ I made a sketch of the southern boundary of the aurora which reached down to Mira Ceti. The hacks in Aries are not rays, but a more

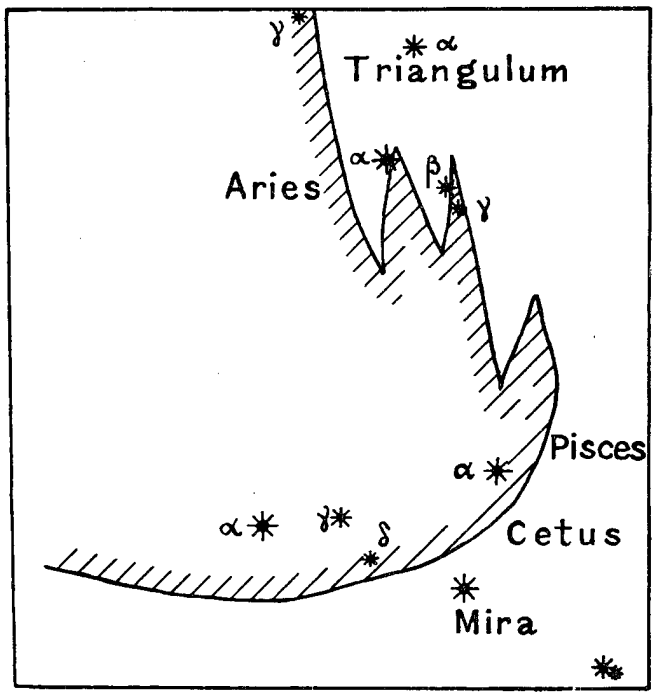

Fig. 57. Southern boundary at $17^h\,29^m$ (G. Peterson).

diffuse part with higher and more feeble parts in succession. (See Fig. 57.)

At this moment I was obliged to interrupt the observations until $19^h\,30^m$. At that time the sky was partly obscured by clouds. The aurora seemed to have withdrawn towards N and had now the form of an arc. Further observations were prevented by clouds."

We have found the geographical position of the aurora over Orion assuming the height to be 106 Km. From this it is probable that this tongue was the same as that which Hassel photographed at $17^h\,32^m\,53^s$, see Fig. 43. The eastern part of the cloudlike aurora stretched even to about 100 km east of Leningrad.

As to the western continuation of the aurora, the observations from *Lerwick* Observatory (Latitude 60° 8′, Longitude 1° 11′ W of Gr.) give interesting data. From a report received I quote:

"$18^h\,40^m$ MET: DS in shape of horse shoe about 10° radius centered 40° above S horizon. Inner edge sharp, outher edge diffuse. Appearence of a halo at times until formation of angles gave it hexagonal shape.

$18^h\,45^m$: DS moving to SW and loosing outline. Few pencils of R in NW passing up to zenith.

$18^h\,55^m$: Isolated R in NW to 30°. Extensive DS in southern half of sky.

$19^h\,15^m$: Cloud increasing, but DS through gaps.

$19^h\,40^m$: DS over northern half of sky extending 20° south of zenith."

The horseshoe-formed cloudlike aurora (DS) seen at $18^h\,40^m$ is the same as the aurora photographed from Oscarsborg (*O* 46) at $18^h\,40^m\,26^s$ which is evident from the geographical position seen on Fig. 48.

41. Other Remarks on the Cloudlike Aurora on January 3rd—4th, 1940. Spectra with the *Hβ*-line.

As the cloudlike aurora appeared soon after sunset it was interesting to see if any of the forms which had been photographed from 2 stations for height measuring, were lying in sunshine and showed the increased height observed for rays and arcs. The earliest set which could be used was *C—Ak* No. 11, at $17^h\,51^m\,19^s$ towards west. The set was not very good; for the best measured points we found a height of 104, 104, 104, 103 and some less good ones gave 81 and 95 km. The height of the earth's shadow over the point 1 (height 104 km) was 129 km, thus the aurora was in shadow and showed no height effect. I am sorry that no sets were taken giving the aurora clouds in sunshine.

My assistant Anders Nygaard tried to take some pictures in natural colors of the cloudlike aurora. He used the Agfa colour film. On the photographs the yellow green color was prominent, but the results were not as good as desired.[1]

Of special interest are some spectra taken of the cloudlike aurora. A small spectrograph was used, loaned from the Auroral Observatory at Tromsø, with camera lens F : 0.95, f = 55 mm and with a prism of dense flint glass giving good dispersion but absorbing strongly in the violet part of the spectrum. An Agfa Isopan ISS. plate was used. The spectra were taken by my assistant Herlofson.

The first spectrum was exposed from $18^h\,25^m$ to $18^h\,50^m$ towards a tongue of cloudlike aurora to the left of *α* Aquilae. The second one exposed from $18^h\,55^m$ to $19^h\,25^m$ at 45° in north towards a milky-white diffuse glow forming the northern part of the cloudlike aurora. The third one towards the same region from $19^h\,25^m$ to $19^h\,55^m$.

The first spectrum is seen together with a spectrum towards a homogeneous arc that same night at $21^h\,10^m$ to $22^h\,00^m$, on Plate 26.

It is of special interest that the hydrogen line *Hβ* has appeared on all spectra, together with the

[1] In 1931—32 the German scientist Dr. Bauer took a good picture in natural colours of a steady homogeneous arc at Tromsø. (Terr. Magn. December 1932, p. 476).

common lines and bands of oxygen and nitrogen (6363, 6300, 5577, 4708, and 4652). The occurrence of $H\beta$ was already indicated by Vegard on October 18th, 1939.[1]

I am sorry that no spectrum was taken of the high sunlit red rays in NW, it would have been of special interest to know if hydrogen lines were also visible at that great height, and if so, whether with increased strength or not.

42. An Earlier Observation of Aurorae like that of January 3rd—4th, 1940.

In his well known catalogue of aurora in Norway[2] Tromholt gives an interesting observation from February 3rd, 1869. The translation in English given here:

»*1869. February 3rd, Kristiania* (Oslo).

Unusually strong aurora. It began at $5^h\ 15^m$ before it had become dark (sunset at $4^h\ 20^m$) and lasted until long after midnight. Strongest between 6^h and 7^h; at that time it stretched far past zenith, and formed, especially on the southern hemisphere, irregular well rounded masses. A great tongue stretched even lower than Orion, down in Lepus, and another one went from West through Aquarius, Pisces and Cetus. The most southern part was from 12° to 15° over the southern horizon.

From 6^h strong rays with corona etc.«

The beginning of this aurora had thus a great resemblance to that of January 3rd, 1940.

43. Summary.

Among the frequent occurrences of cloudlike aurora some interesting cases are given. First the cloudlike aurora before dawn on March 24th—25th, 1933, which reached down to the unusual height of 70 to 80 km. It was situated WNW of Trondheim, and drifted towards ENE with a velocity of 200 meters per second.

The cloudlike aurora from January 27th—28th, 1935, which was measured with great exactitude reached down to about 88 km.

Of special interest was the cloudlike aurora on the evening of January 3rd, 1940. It had a mean height of about 106 km and formed a thin layer below the simultaneously occurring red sunlit rays in NW, which stretched from 200 to more than 600 km height. On account of a great number of photographs this cloudlike aurora could be carefully mapped, and its southern limitation was most irregular and remarkable. It drifted westwards with velocities ranging from 200 to 800 meters per second.

Its spectrum showed the hydrogen line $H\beta$ in addition to the common aurora lines.

[1] L. Vegard: On some recently detected important Variation within the Auroral Spectrum. Avhand. Det Norske Vid.-Akad. Oslo, Math. Naturv. kl. 1939, no. 8. Carl Størmer: Some Auroral Spectra from Southern Norway 1940, Astrophysica Norvegica Vol. III, No. 9. In this paper references to Vegard's papers are also given. L. Vegard and E. Tønsberg: Neue Ergebnisse betreffs des Auftretens von Atomlinien im Nordlicht. Gerl. Beträge zur Geophysik. 57, 289, 1941.

[2] Tromholt, Sophus: Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter, J. Dybwad, Kristiania (Oslo) 1902.

PART V. SOME REMARKABLE SUNLIT AURORA RAYS (VII)

44. Introduction.

As shown in a paper from 1929[1] the aurora rays in the sunlit part of the atmosphere show characteristics essentially different from those in the dark. In general the bases of these rays follow the boundary between the sunlit and the dark part of the atmosphere, and their summits can reach the enormous heights of 800 to 1100 km. It sometimes happens that they are divided, with one part in the sunlit and one part in the dark atmosphere. Their spectra show a very pronounced enhancement of the nitrogen bands near 4708 Å, 4278 Å, and 3914 Å, and of the red oxygen line 6300 Å, compared with the common aurora line 5577 Å.[1] The color of these sunlit rays is mostly gray to violet gray, but sometimes blue or red. Sometimes their light is ultraviolet and the rays are then invisible to the eye.[2]

I have gone through the extensive material of aurora photographs taken in southern Norway from 1917 to 1940 and have found the nights when sunlit aurora rays have been photographed. The list is given below.

[1] Carl Størmer: Sonnenbelichtete Nordlichtstrahlen, Zeitschr. f. Geophysik., Jahrg. 5, 177—194.

[1] Ibid. and further: Some Results Regarding Height and Spectra of Aurora Over Southern Norway During 1936, Geof. Publ. Vol. XII, Oslo 1938, and Blue Aurora Rays Situated in the Sunlit Part of the Atmosphere, Terr. Magn. Vol. 44, 1939.

[2] Über eine Nordlichtexpedition nach Trondheim in März 1933, Gerlands Beiträge, Vol. 41, 1934.

When these rays are photographed in the evening we add. e. to the date; for night or morning we add n. and m.

Table 15.

Occurrence of Sunlit Aurora Rays from 1917 to 1940.

1917.
August 21st—22nd, e.
1919.
October 4th—5th, e.
1920.
March 22nd—23rd, e. m.
1921.
May 13th, n.
1926.
January 26th—27th, e.
March 5th—6th, e.
March 9th—10th, e.
May 3rd—4th, n.
September 8th—9th, e.
September 14th—15th, e.
October 15th—16th, e.
1928.
March 11th—12th, e.
August 26th—27th, e. m.
September 7th—8th, e.
September 18th—19th, e.
1929.
March 15th—16th, e. m.
April 15th—16th, n.
April 16th—17th, n.
1930.
April 29th—30th, n.
August 21st—22nd, m.
September 3rd—4th, m.
September 18th—19th, m.
1931.
November 5th—6th, e.
1932.
August 29th—30th, e.
1933.
March 18th—19th, m.
March 19th—20th, e.
March 23rd—24th, m.
March 24th—25th, e.
April 15th—16th, m.
April 21st—22nd, n.
May 1st—2nd, n.
1934.
August 26th—27th, e.
August 27th—28th, e.
1935.
October 20th—21st, e.
October 21st—22nd, e.
1936.
April 20th—21st, n.
April 21st—22nd, n.
October 16th—17th, m.
November 3rd—4th, e.
1937.
March 30th—31st, e.
May 4th—5th, n.
September 10th—11th, m.
October 11th—12th, e.
1938.
January 22nd—23rd, e.
March 5th—6th, e.
March 21st—22nd, m.
March 22nd—23rd, m.
April 16th—17th, e.
April 22nd—23rd, e. m.
May 3rd—4th, n.
August 22nd—23rd, n.
September 14th—15th m.
September 15th—16th e. m.
Sept. 30th—Oct. 1st. e.
1939.
April 18th—19th, n.
April 24th—25th, n.
September 19th—20th, m.
October 7th—8th, e.
October 18th—19th, e.
1940.
January 3rd—4th, e.
March 29th—30th, e. m.
April 2nd—3rd, n.
April 3rd—4th, n.
April 25th—26th, e.
September 26th—27th, e.
September 28th—29th, e

From this it is seen that the frequency is greatest round the equinoxis and during the years of maximum frequency of aurora.

Sunlit rays may possibly have been photographed on other occasions, but only a determination of height and situation can decide this, and most of our material from 1923 to 1941 is still unmeasured.

45. Very High Sunlit Rays.

In 1928 I published an account[1] on a strange aurora of violet gray color occuring September 8th, 1926, and reaching the immense height of more than 1000 km. In a subsequent paper[2] on sunlit aurora rays, published in 1929, I showed that this high aurora, with a feeble ray structure and with the color of mauve violet to gray, was situated entirely in the sunlit part of the atmosphere.

The second time was on October 16th—17th, 1936[3]. The rays were red, but contained also blue and violet because they could be photographed on Sonja plates, which are insensible to red. The height was astonishing: base of rays at about 600 km near the borderline betweeen dark and sunlit atmosphere, and the summit up to 1100 km.

Sunlit rays reaching 800 to 900 km have been measured on some occasions, for instance on March 22nd—23rd, 1920, October 15th—16th, 1926[2], October 16th—17th, 1936[3], and on April 18th—19th, and 24th—25th, 1939[4]:

It seems that such very high sunlit rays only occur near maxima of auroral frequency.

46. Blue Sunlit Rays.

Sunlit rays of fine blue color have only been observed and measured twice, on the morning of March 23rd, 1920 and on the morning of September 15th, 1938. A monograph on these rays has been published in 1939,[5] where height, situation, and spectrum are given. We only reproduce here the interesting observation from September 15th, made by my assistant Egeberg:

"At $3^h\,10^m$ blue color was seen at the summit of a bundle of rays in NE.[6] Some minutes later the whole bundle had this characteristic color, except the bases of the rays. The color was deep blue violet, quite different from the feeble white violet colour often seen in sunlit aurora rays in the morning. The bundle moved slowly towards E. Successively there also appeared blue rays in the north, but here the green white color of the bases reached higher up along the

[1] Gerlands Beiträge zur Geophysik. Bd. XVII, p. 254—269.
[2] Sonnenbelichtete Nordlichtstrahlen, Zeitschrift für Geophysik, Vol. V. p. 177—194, Fig. 1.
[3] Geofysiske Publikasjoner, Vol. XII, no. 7, p. 15—17, 1938.
[4] Aurorae Photographed in Southern Norway 1939, The Sky Magazine, New York, December 1939.
[5] Blue Auroral Rays in the Sunlit Part of the Atmosphere, Terr. Magnetism etc. Washington, March 1939, p. 7—14.
[6] In the paper in Terr. Magn. Northwest was erroneously written instead of Northeast.

rays than in E. The border between the two colors was rather sharp. In W we had strong aurora curtains and rays, but of the common yellow green color. The blue rays became more and more numerous, and after a while they covered most of the northern sky, at last forming a great fan towards magnetic zenith, but not going so far as to form a whole corona. The blue color could now be seen all along the rays, except at the lowest parts of the rays in north, where the bases were still green white. The imposing fan of blue rays then faded, and only isolated long rays persisted, but of the same color. Even when the dawn had advanced so far that only the brightest stars were visible, some isolated blue rays could still be seen in NW, in the constellation Cygnus."

47. Red Sunlit Rays.

Red aurora rays in the *dark part of the atmosphere* have been observed at times during the years of maximum frequency of aurora. Around the last maximum 1938, such rays were seen and photographed on red sensitive plates for determination of height. In particular during the gorgeous aurora on January 25th —26th that year, the rays reached very great heights, up to 600 to 700 km, which is very rare for aurora rays in the dark atmosphere.[1] On September 13th the same year[2] similar fine red rays were also measured with summits up to 450 to 500 km.

As to *the red rays in the sunlit part of the atmosphere* they reach even higher, as for instance those already mentioned from October 16th—17th, whose summits reached more than 1000 km.

Such red sunlit rays have been photographed or observed on the following dates:

1936: October 17th, $1^h\,50^m$—$1^h\,55^m$ already mentioned in the section Very High Sunlit Rays.

1937: October 11th—12th, divided rays, see Part VI.

1938: February 6th, before sunrise. September 15th—16th, red violet.[3]

1939: April 24th—25th.[1]
September 17th—18th.
October 3rd—4th.

1940: January 3rd—4th.

In the following section we shall give observations and measurements of the red rays on January 3rd—4th, because this case was of particular interest.

48. The Red Sunlit Rays on the Afternoon of January 3rd, 1940.

These rays were of special interest, first because they occurred at a time of the year when sunlit rays are very rare, and secondly because they were associated with a very singular occurence of cloudlike aurora mentioned in the foregoing part of this paper. These two forms, the red rays and the cloudlike aurora, were the only forms of aurora which were seen between $17^h\,20^m$ and $18^h\,02^m$ that evening, and they were situated in two different layers of the atmosphere, the cloudlike aurora between 90 and 120 km and the rays between 200 and 650 km.

As to the photographs of the rays a list is given below. Here *P. No.* means the picture number, *St.* the stations, *M E T* the time etc. as in earlier lists. The plates used were Agfa Isopan ISS.

Table 16.

List of Photographs of Red Sunlit Aurora Rays on January 3rd, 1940.

P. No	St.	M E T	Ex.	Ref. Const.	Remarks
4.3	*Hk*	17.22.55	25	Lyr. Her.	
5	—	.25.03	50	Her.	Taken with Ernostar cam. and red filter
6	—	.36.13	50	Her.	Taken with Ernostar cam. and red filter
1	*C*	.41.14	16	Peg.	
2	—	.42.12	15	Peg.	
3	*C*	.42.59	12	Lyr. Her.	
8	*Hk*	.43.23	30	And.	
6	*C–Ak*	.45.54	10	Lyr. Her.	
9	—	.48.51	12	Cyg. Lyr.	
9.1	*Hk*	.51.13	50	Lyr. Her.	Western ray feebly red
9.5	—	.56.28	30	Lyr.	Western ray light red
9.6	—	.57.48	50	Lyr. Her.	Western red like fire
15	*C–Ak–O–Li*	.57.52	16	Lyr. Cyg. Sge.	Red
10.1	*Hk*	.59.53	50	Lyr.	Dark red
11	—	.59.53	60	—	The same taken with Ernostar and red filter
17	*C–Ak–O–Li*	.59.57	10	Lyr. Aql. Her.	
19	—	18.01.48	10	Lyr. Dra. Her.	Red and green

[1] Photographische Höhemessungen und Spektra des großen Nordlichtes vom 25-26 Januar 1938, Die Naturwissenschaften, September 1938.

[2] Auroral Work in Southern Norway, Terr. Magn. Washington 1939.

[3] Auroral Work in Southern Norway in the Year 1938, Terr. Magn. September 1939, p. 233–242.

[1] Aurorae Photographed in Southern Norway 1939, The Sky Magazine, New York, December 1939.

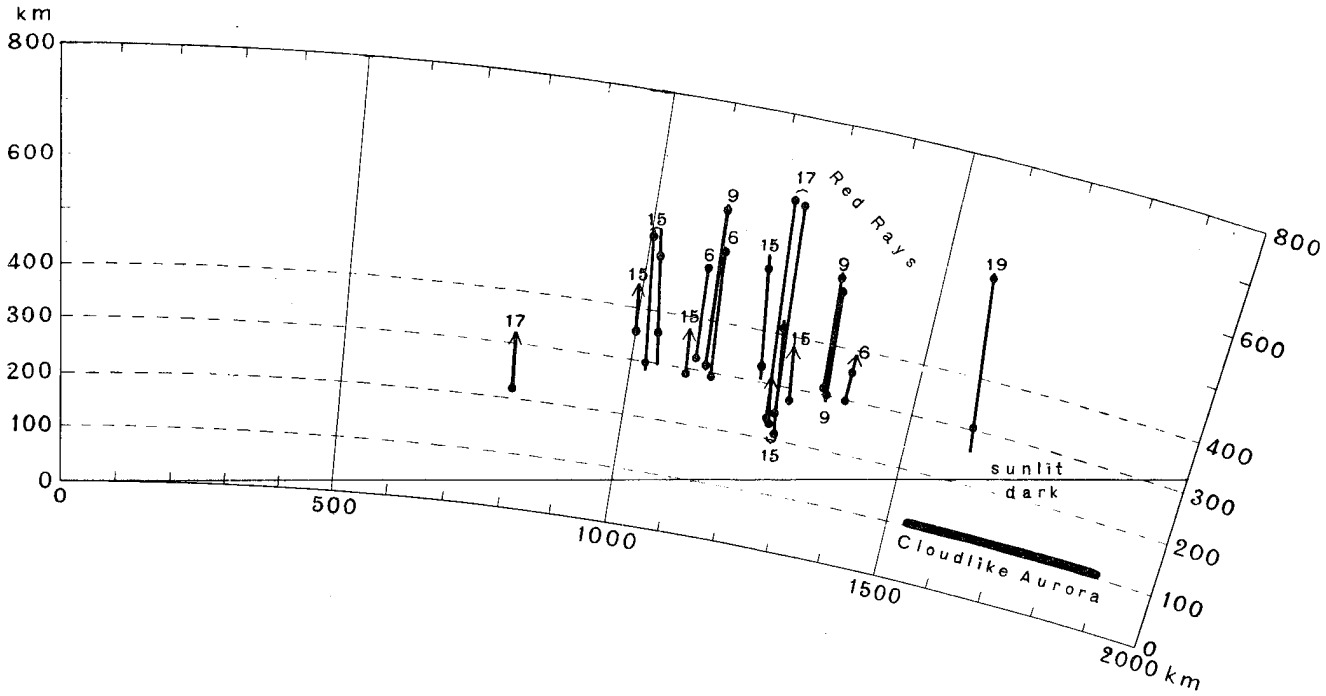

Fig. 58. Positions of cloudlike aurora and red aurora rays on January 3rd, 1940, in relation to the earth's shadow.

Rays were also seen and photographed simultaneously from several of my stations after $18^h\,02^m$, but their color was no longer red, only yellow green to gray. From $18^h\,03^m$ to $18^h\,05^m$ they even formed a fine corona.

The measurements of the red rays were rather difficult because the great masses of them caused overlapping of different rays which required great care.

Some typical cases are given here:

No. 15, $17^h\,57^m\,52^s$ M E T.

Base line *Li—C* 132.65 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—12.9	7.7	13.8	89.6	897	297
2	—14.9	7.5	17.1	92.0	892	357
3	—17.8	10.4	14.4	91.9	658	209
4	—17.2	9.2	20.9	92.9	706	324
5	— 8.3	6.9	25.1	85.7	904	533
6	—12.1	7.0	23.9	89.8	903	499
7	—12.2	9.4	28.0	87.4	660	411
8	—12.5	8.3	31.1	89.1	713	507

On the negatives the rays 1—5 mount even higher, at least up to 550 km. The rays were situated over and to the west of the Shetland Islands.

The sketches are seen on Plate 9, the pictures on Plate 27.

No. 17, $17^h\,59^m\,57^s$ M E T.

Base line *C—Ak* 44.75 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—52.4	1.9	12.8	108.8	775	232
2			36.7	100.0	736	646
3	—52.8	1.9	13.9	109.6	764	245
4			36.6	101.4	727	638

Here the parallaxes are small, but the pictures very good. The values of *H* and *D* for the points 2 and 4 have been found from the corresponding ones for points 1 and 3 by the method described in the paper: Resultats des mesures photogrammétriques[1] etc. § 3.

The situation of the rays was over the Shetland Islands. The sketches are seen on Plate 9, the pictures on Plate 27.

On Table 17 (next page) is a list of all the heights measured.

The positions of these red rays to the earth's shadow line are seen on Fig. 58, giving a vertical section of the earth's surface through the points where the sunrays touch this surface. The positions for each moment refer as usual to this shadow line. On the same figure is seen the position of the cloudlike aurora occuring simultaneously.

[1] Geofysiske Publikasjoner, Vol. IV, No. 7, Oslo 1926.

Table 17.
Heights of Red Sunlit Rays
on January 3rd, 1940.

No.	Time	Base	Heights near bases	Heights along rays	Heights near summits
6	17.45.54	*C—Ak*	292, 318, 297	353	533, 489
9	.48.51	*C—Ak*	302	404, 312, 472	499, 518, 597
15	.57.52	*Li—O*	290, 226, 346, 273		
15	.57.52	*Li—C*	297, 209	357, 324	533, 499, 411, 507
17	.59.57	*C—Ak*	232, 245		646, 638
17	.59.57	*Li—O*	217		
19	18.01.48	*C—O*	303	415	584

As seen from Table 16, Mr. Hassel also took pictures of the red rays through red filters, which show that the rays contained red light from base to summit.

49. Ultraviolet Sunlit Rays.

During the approximately 400 nights when aurorae have been photographed from our stations in southern Norway, it has happened, but very rarely, that, besides the aurora which we intended to photograph, we also got aurora rays on our plates that we had not seen at all. Probably these rays emitted only ultraviolet light invisible to the eye. This has happened on the following occasions:

February 28th, 1929.

On that occasion photographs were taken of an isolated pulsating arc and on the plates feeble rays were seen, which none of us had observed when we took the photographs. For details see Section 5 of the present paper, where the height measurements are given with position of the rays in relation to the earth's shadow.

March 19th, 1933.

This case has been published in the preliminary report on my expedition to Trondheim during the polar year[1]. During the photographic work the two stations Trondheim and Løkken pointed their cameras on an aurora which looked like a diffuse arc. None of us saw the rays which appeared on the plates, and the measurements showed that these rays were sunlit. Good pictures are published in the same report as Plate XI.

These two cases are interesting in so far as the rays were not observed visually. In some other cases invisible rays were photographed in red patches,[2] but it may be that they were hidden from direct view by the red colour.

50. Summary.

Among sunlit aurora rays, some of them are remarkable on occount of their great hight, as on September 8th, 1926, and October 16th—17th, 1937, where the summits reached heights up to 1100 km.

On a few occasions the sunlit rays can be blue, red or invisible to the eye, although appearing on the photographic plate, probably because they send out only ultraviolet light. Some similar cases are described.

[1] Über eine Nordlichtexpedition nach Trondheim im März 1933. Gerlands Beiträge zur Geophysik, Vol. 41, 1934, p. 382—386.

[2] See Part VII of the present paper.

PART VI. DIVIDED AURORA RAYS WITH ONE PART IN SUNSHINE AND ONE PART IN SHADOW (VIII)

51. Introduction.

The remarkable aurora form called *divided rays* was first described in some of my papers[1] published in 1929, and a fine set of pictures taken simultaneously from the 3 stations Oslo, Tømte, and Kongsberg was reproduced.

Some other cases were published in 1937,[2] 1938,[3] and 1939.[4]

Here is a list of the cases observed:

1920, March 22nd—23rd,
1926, September 8th—9th,
1928, September 18th—19th,
1929, March 15th—16th, April 15th—16th,
1936, October 16th—17th,

[1] New Evidence of the Action of Sunlight on Aurora Rays, Nature, June 8th, 1929, and: Sonnenbelichtete Nordlichtstrahlen, Zeitschrift für Geophysik, Jahrgang 5, p. 177—194, 1929.

[2] Divided Aurora Rays with One Part in the Sunshine and One Part in the Dark. Nature Vol. 140, p. 1095.

[3] Some Results Regarding Height and Spectra of Aurorae over Southern Norway during 1936, Geof. Publ. Vol. XII, No. 7, p. 17.

[4] Auroral Work in Southern Norway in the Year 1938, Terr. Magn. 1939, p. 238.

1937, October 11th—12th,

1938, March 21st—22nd.

Among these the cases in 1920 and 1926 are seen on Fig. 1 and 2 in my paper "Sonnenbelichtete Nordlichtstrahlen". The case in 1928 concerns only one single ray and is perhaps doubtful. The case March 15th—16th is found in my paper referred to above, and in the Note of June 8th, in Nature. Finally the case of October 16th—17th is published in Geof. Publ. referred to above.

In the following some of the most interesting cases will be treated in detail.

52. Divided Rays on March 15th—16th, 1929.

The sunlit aurora rays on this night have already been described in a paper from 1929.[1] Among these rays was a fine occurrence of the divided rays at $4^h\,16^m\,29^s$ M E T, reproduced as Fig. 7 in the paper in question.

We give here once more and with more details the results of measurements.

No. 95, $4^h\,16^m\,29^s$ M E T.

Base line Oslo—Tømte 46.68 km.

P	u_2	p	h	a	D	H
2	46.8	3.2	12.7	162.0	581	161
3	48.7	3.5	18.2	162.0	530	202
4	53.1	3.5	28.6	161.6	512	314
5	54.9	3.4	32.0	161.5	518	363

The same.

Base line Oslo—Kongsberg 65.70 km.

P	u_2	p	h	a	D	H
2	102.1	6.4	12.7	162.0	550	151
3	101.5	6.2	18.2	162.0	549	211
4	100.6	5.9	28.6	161.6	526	323
5	100.1	5.7	32.0	161.5	524	368

The same.

Base line Kongsberg—Tømte 105.15 km.

P	u_2	p	h	a	D	H
1	69.8	9.5	7.0	168.1	585	100
2	70.5	9.4	12.4	167.7	579	157
3	71.4	9.3	17.7	167.5	569	214
4	73.5	9.3	28.0	167.5	526	316
5	74.3	9.0	31.5	167.4	523	361
6	75.3	8.8	35.7	167.4	508	409

[1] Sonnenbelichtete Nordlichtstrahlen, Zeitschr. für Geoph., Jahrg. 5, p. 177—194, 1929.

The 3 measurements of the points 2, 3, 4, and 5 agree fairly well, but those with the largest base line are probably the best ones; they are adopted here.

The upper part of the ray goes down to about 296 km and the lower part up to about 223 km, and in the dark space between them the earth's shadow (disregarding the refraction) lies at about 275 km.

On the sketch Plate 9 the 3 positions are seen and the earth's shadow line is marked between the two parts of the ray, seen from Tømte.

The position in a vertical section of the earth and atmosphere is seen on Fig. 59 and the geographical situation on Fig. 60.

As to the pictures see the papers referred to.

The next set, No. 96, was taken 44^s later and shows the same phenomenon, but not so distinctly.

The results of the measurements were:

No. 96, $4^h\,17^m\,13^s$ M E T.

Base line Oslo—Tømte 46.68 km.

P	u_2	p	h	a	D	H
1	47.6	3.2	7.3	159.9		107
2	49.0	3.4	12.6	159.8		155
3	50.9	3.7	18.0	159.7		195
4	55.2	3.8	28.2	159.6		293
5	57.1	3.8	31.8	159.5		330

The same.

Base line Oslo—Kongsberg 65.70 km.

P	u_2	p	h	a	D	H
1	99.8	6.1	7.3	159.9		106
2	99.4	5.9	12.6	159.8		166
3	99.0	5.7	18.0	159.7		231
4	98.1	5.3	28.2	159.6		362
5	97.8	5.1	31.8	159.5		414

The same.

Base line Kongsberg—Tømte 105.15 km.

P	u_2	p	h	a	D	H
1	72.2	9.2	7.0	165.2	612	106
2	72.8	9.2	12.4	165.1	599	164
3	73.8	9.2	17.8	165.0	582	220
4	75.5	8.9	28.0	165.0	553	334
5	76.4	8.8	31.5	164.9	539	376

This is probably the best one and is adopted here. As on the foregoing set, the earth's shadow line is marked between the two parts of the ray seen from

Tømte (refraction disregarded). The sketch is seen on Plate 10 and the situation as before on Fig. 59 and 60.

On this night these two cases were the only ones observed and the rays were divided only for a short time.

53. Divided Rays on April 15th—16th, 1929.

One month later, on the night of April 15th—16th, divided rays were photographed again. From $1^h\,34^m$ to $1^h\,39^m$, 5 sets were taken from 4 stations simultaneously.

After closer inspection we have only measured one of them, No. 7, which gave the following results:

No. 7, $1^h\,38^m\,55^s$ M E T.

Base line Kongsberg—Tømte 105.15 km.

P	ε_2	p	h	a	D	H
1	37.2	7.5	25.7	−170.5	553	304
2	40.5	7.4	15.8	−171.4	582	198
3	41.2	7.2	12.5	−171.9	601	165
4	42.0	6.9	7.5	−172.5	635	118
5	35.6	7.9	25.7	−172.0	537	294
6	38.4	7.8	16.5	−173.1	565	199
7	39.1	7.7	12.9	−173.5	579	163
8	39.7	7.6	7.8	−174.0	597	112

The earth's shadow line goes between the upper and lower part of the ray as seen on the sketch Plate 10. The position is seen on Fig. 59 and Fig. 60.

54. Divided Rays on October 11th—12th, 1937.

On both the nights October 11th—12th and 12th—13th we had fine aurorae over Oslo. Most of my stations were in action and a great many photographs were taken from two, three, and four stations simultaneously.

On October 11th[1] the aurora began as a broad and diffuse arc in the north which lasted from sunset to about $20^h\,30^m$ without changing much. From time to time feeble sunlit rays were seen. At $20^h\,38^m$ fine red rays appeared in NE and they continued until about $20^h\,50^m$. Some measurements of them showed that they were lying in the earth's shadow, with bases about 130 km and summits only to 270—290 km.

[1] Carl Størmer: Divided Aurora Rays with One Part in the Sunlit and Another Part in the Dark Atmosphere, Nature Vol. 140, p. 1095.

At $20^h\,53^m$ the divided rays began in the north. Here is a log of the photographs taken of them. The signs for the stations are:

*C** and *C* Oslo
O Oscarsborg
K_4 Kongsberg
Li Lillehammer
Ak Askim
T Tømte
Tu Tuddal
Hk Hokksund

Table 18.

Divided Rays on October 11th, 1937.

P. No.	St.	M E T	Const.	Remarks
9*	*C*—Ak—K*	20.53.01	UMa.	The first divided rays
41	*Li*	.53.20	—	Divided rays
10*	*K—T*	.53.57	—	Divided rays, fine
42	*O—Li*	.54.13	—	Divided rays, feeble
124.6	*Hk*	.54.49	—	Divided rays, summits of upper rays red
43	*C—O—Li—Tu*	.54.55	—	Divided rays, lower parts very feeble compared with upper parts
11*	*C*—K—T—Ak*	.55.07	—	Divided rays, very fine
12*	—	.56.10	—	Divided rays, lower parts again feeble
44	*C—Li—Tu*	.56.15	—	Lower parts gone
45	*O—Li—Tu*	.57.02	—	Both parts visible
13*	*C*—K—T—Ak*	.57.09	—	Div. and undiv. rays
46	*O—Li*	.57.40	—	Div. and undiv. rays
14*	*C*—K*	.57.40	—	Div. and undiv. rays
47	*Li*	.58.05	—	Difficult to decide; very feeble
15*	*C*—K—Ak*	.58.28	—	Div. and undiv. rays
48	*C—Tu*	.59.08	—	Difficult to decide
16*	*C*—K—Ak*	.59.13	—	Div. and undiv. rays
125.2	*Hk*	.59.29	—	Summits red, feeble
49	*C—Tu*	.59.35	—	Only lower part, feeble
17*	*C*—K—Ak—T*	.59.53	—	Div. and undiv. rays
18*	—	21.00.26	—	Difficult to decide
125.3	*Hk*	.00.59	—	Difficult to decide
51	*C—Tu—Li*	.01.05	—	Difficult to decide
19*	*C*—K—Ak—T*	.01.15	—	Div. and undiv. rays
125.4	*Hk*	.01.29	—	Upper rays feeble, red
52	*C—Tu—Li*	.01.33	—	Difficult to decide
20*	*C*—K—Ak*	.01.53	—	Div. and undiv. rays
53	*C—Tu—Li*	.02.17	—	Upper parts
21*	*C*—K—Ak—T*	.02.55	—	Div. and undiv. rays
22*	*C*—K—Ak—T*	.03.47	—	Div. and undiv. rays
55	*C—O—Tu—Li*	.04.31	W of UMa.	Undivided
23*	*C—K—Ak*	.04.33	UMa.	Difficult to decide

Only a few pictures of this long series have been measured, because most of the pictures are feeble and difficult to measure in spite of the very long base lines. 8 more sets were taken and the last one, No. 28* at $21^h\,13^m\,57^s$, shows the last traces of the upper parts of the sunlit rays in NW; these were

lying about 400 km south west of the rays in No. 11*, their base points were also near the earth's shadow at about 400 km above the earth with summit up to 570 km. The lower part in shadow did not appear.

We only give the results[1] for the picture 11*, also mentioned in my Note in Nature.

*No. 11**, $20^h\ 55^m\ 07^s$ M E T.

Base line *T*—*K* 104.95 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*	H_1	T_1
1	—22.0	5.1	29.7	158.2	870	610	397	2195
2	—24.3	5.4	19.4	159.1	903	408	380	2150
3	—24.7	5.4	17.7	159.2	913	380	385	2165
4	—25.8	5.4	10.0	159.8	956	249	380	2150
5	—24.2	5.1	30.7	161.1	846	602	410	2230
6	—26.5	5.2	20.8	161.8	909	436	389	2175
7	—26.8	5.1	19.2	162.0	934	419	389	2175
8	—28.1	5.1	10.4	162.4	985	267	380	2150
9	—27.4	5.3	30.2	164.5	803	565	441	2310
10	—29.5	5.4	22.2	165.1	844	429	419	2250
11	—29.9	5.4	20.2	165.2	857	398	414	2240
12	—31.7	5.3	8.0	165.8	931	206	401	2210
13	—30.8	5.0	29.4	168.7	828	566	441	2310
14	—32.6	5.2	22.8	168.9	843	440	423	2265
15	—33.0	5.2	21.0	168.9	854	410	419	2250
16	—35.0	5.0	6.2	169.3	954	179	401	2210
17	—37.6	5.1	17.6	173.3	848	344	441	2310
18	—38.7	5.0	7.6	173.0	908	194	427	2275

On the sketches Plate 10 and on the two pictures reproduced, Plate 27, the space between the upper and lower parts of the rays 1—4, 5—8, 9—11, and 13—16 is clearly seen; the geographical situation and the position relative to the earth's shadow is seen on Fig. 60 and Fig. 59. The dark space between the upper and lower part of the ray 5—8 lies in sunshine, which is probably due to the difficulty in measuring exactly the feeble and diffuse rays in question.

A spectrum was taken of these rays on a panchromatic plate Agfa ISS. The plate was first exposed from $20^h\ 55^m$ to $20^h\ 58^m$ on the rays just under β and γ Ursa Majoris and then from $20^h\ 58^m$ to $21^h\ 15^m$ on similar rays to the left of η and ζ of the same constellation. In this spectrum the line 6300 Å is by far the strongest; next comes the line 5577 Å and the bands near 6550 Å. The spectrum, however, is not good enough to be reproduced or measured.

[1] The definition of H_1 and T_1 is given in Section 5.

55. Divided Rays on March 21st—22nd, 1938.

By far the best material of divided rays was obtained on the night of March 21st—22nd, 1938. On that night my assistant Olaf Hassel first observed the aurora from Fiskum (Latitude 59.7°, Longitude 9.8° E Gr.) near Kongsberg at 22^h and began to take pictures of it at $22^h\ 23^m$. He continued his work until $4^h\ 30^m$ in the morning.

My assistant Leif Owren observed the aurora from Bygdø, near Oslo, at $0^h\ 15^m$ as a glow in the north. From Oslo it was observed by my assistant Tveter at $0^h\ 40^m$ and the other aurora stations Askim (*Ak*), Kongsberg (*K*), and Tømte (*T*) were in telephonic connection with Oslo (*C*) at about 3^h. The work continued until 5^h. 90 single pictures were taken by Hassel and 72 sets simultaneously from my aurora stations *C*, *Ak*, *K*, and *T*, directed by Mr. Owren. Among these, long series were successful.

As to the development of the aurora the following may be of interest:

Before 22^h the sky was overcast. Clearing up successively.

22^h long feeble rays from the northern horizon and some minutes later a feeble arc about 5° over the northern horizon.

$22^h\ 35^m$—$22^h\ 43^m$ some rays in the north.

$23^h\ 48^m$ the arc again visible and rising slowly. A series of pictures of this arc was taken by Hassel. Continued rising until about $1^h\ 44^m$, when diffuse rays began to appear in the western part of the arc, and later in the eastern part. They soon disappeared again.

2^h. The arc was pulsating slowly. A long series of very fine pictures of the arc taken by Hassel.

$2^h\ 20^m$ feeble rays over the arc.

$2^h\ 55^m$ the arc sinking. Feeble rays from time to time.

$3^h\ 29^m$ the first divided ray.

From now on a series of rays, among which many divided ones, were photographed from my stations *C*, *T*, *Ak*, and *K*, but none from Fiskum. *Neither Hassel, nor any of the other observers really saw these divided rays; they only appeared on the plates.* This seems to indicate that the phenomenon of an upper and lower part separated by a dark space was either so feeble that it could not be seen by the eye, or that the emission of ultraviolet light from some parts and not from others made this strange effect on the plates.

The rest of the night until $4^h\,38^m$ only rays were photographed. A list of the photographs from $3^h\,29^m$ to $4^h\,39^m$ is given below; here *No.* is as usual the current number of the picture, *St.* the stations, *MET* Central European Time, *Ex.* exposure. All pictures on Sonja plates.

Table 19.

List of Simultaneous Photographs of Rays among Which Many Divided Ones.

No.	St.	MET	Ex.	Const.	Remarks
15	*K—Ak*	3.29.00	10	Cas.	Dark space not so pronounced
16	*C—Ak—K—T*	.29.47	28	Cas	Same remark
17	*C—Ak—K*	.30.46	15	Aur.	Upper part very feeble
18	*C—Ak—K—T*	.31.22	16	Cas.	Not divided
19	*C—Ak—K*	.32.12	26	Cas.	Not divided, sunlit ray from 192 to 416 km
20	*C—Ak—K*	.34.22	20	Cas., Per.	Div. and undiv. rays
21	*C—Ak—K—T*	.35.08	22	Aur., Per.	Broad, divided ray
22	*C—Ak—K—T*	.35.46	8	Cas., And.	Undiv. sunlit ray from 160 to 438 km
23	*C—Ak—K—T*	.36.28	7	Aur., Per.	Very fine div. ray
24	*C—Ak—K*	.37.14	21	Cas., And.	Undivided
25	*C—Ak—K*	.41.06(?)	19	Cas., And.	Undivided
26	*C—Ak—K*	.41.42(?)	25	Cas., And	Undivided
27	*C—Ak—K—T*	.44.48	25	Aur., Per.	Divided
28	*C—Ak—K—T*	.46.10	32	Aur., Per.	Only weakened in the middle
29	*C—Ak—K—T*	.47.13	42	Aur., Per.	Undivided
30	*C—Ak—K—T*	.48.15	31	Aur., Per.	Undivided
31	*C—Ak—K—T*	.49.23	35	Per.	Undivided
32	*C—Ak—K—T*	.50.16	30	Per.	Undivided
33	*C—Ak—K*	.51.14	24	Per.	Undivided
34	*C—Ak—K*	.52.03	22	Gem. Aur.	Divided, very fine
35	*C—Ak—K*	.53.01	37	Gem. Aur.	Only weakened in the middle
36	*C—Ak—K—T*	.54.27	36	Per., Cas.	Undivided
37	*C—Ak—K—T*	.55.21	26	Aur.	Undivided
38	*C—Ak—K—T*	.56.08	26	Aur.	Undivided
39	*C—Ak—K—T*	.56.55	21	Cas.	Undivided. Summit to 567 km. Sunlit
40	*C—Ak—K—T*	.57.51	22	Per., Cas.	Undivided
41	*C—Ak—K*	.58.35	22	Aur, Per.	Undivided, sunlit, summits up to 484 km
42	*C—Ak—K*	.59.15	28	Aur., Per.	Undivided, sunlit, summits up to 619 km

The rest of the pictures show no more divided rays, only feeble sunlit rays.

Of these sets the following numbers have been measured out: 15, 16, 19, 20, 21, 22, 23, 27, 34, 39, 41, 42, 67.

Among these the following sets of divided rays gave the results:

Table 20.

Divided Rays on March 21st—22nd, 1938.

P	ε_2	p	h	a	D	H	H_1	T_1
No. 15, $3^h\,29^m\,00^s$ MET. Base line $Ak—K_4$ 85.54 km.								
1	−3.5	8.1	30.5	−177.7	497	328	290	1890
2	−3.1	8.2	26.8	−178.1	512	292	288	1885
3	−2.7	8.4	21.8	−178.6	525	240	287	1880
4	−1.7	8.5	11.7	−179.2	557	142	282	1865
5	−2.1	8.2	30.5	−179.4	492	324	296	1910
6	−1.7	8.2	26.9	−179.7	512	293	292	1895
7	−1.2	8.3	21.6	−180.0	532	242	288	1885
8	−0.1	8.1	11.8	−179.4	582	151	280	1860
No. 16, $3^h\,29^m\,47^s$ MET. Same base line.								
1	−8.4	7.2	31.2	−171.2	546	374	267	1815
2	−8.2	7.6	21.2	−171.8	574	259	262	1800
3	−8.0	7.6	18.1	−172.0	587	228	259	1790
4	−7.7	7.7	11.7	−173.3	605	158	256	1780
No. 20, $3^h\,24^m\,22^s$ MET. Same base line.								
1	− 9.1	7.0	23.4	−170.5	607	305	238	1715
2	− 8.8	7.0	19.4	−170.8	628	263	234	1705
3	− 8.6	6.9	15.7	−171.0	659	226	229	1690
4	− 8.0	6.6	10.5	−171.2	704	174	220	1650
5	−18.9	5.1	23.2	−157.6	788	412	175	1475
6	−18.0	5.1	8.9	−159.4	878	205	160	1415
7	−20.9	5.1	21.6	−155.7	788	383	172	1465
8	−20.0	5.1	8.8	−157.3	869	200	157	1405
No. 21, $3^h\,35^m\,08^s$ MET. Base line $T—K_4$ 104.95 km.								
1	−26.5	8.1	33.0	160.9	527	386	306	1940
2	−27.1	8.1	29.1	160.8	548	347	304	1935
3	−27.8	8.0	23.5	160.6	586	294	300	1920
4	−28.4	7.9	13.5	160.3	636	189	296	1910
5	−23.0	9.6	33.7	155.0	458	338	329	2010
6	−23.4	9.7	31.2	155.1	467	313	328	2005
7	−24.3	9.8	25.0	155.2	490	257	325	2000
8	−25.2	9.6	14.3	155.4	539	164	321	1990
The same, base line $Ak—K_4$ 85.54 km.								
1	21.3	7.2	10.9	158 5	611	150	320	1980
2	20.3	7.5	22.3	157.3	550	260	330	2010
3	19.1	7.4	27.2	157.4	533	310	331	2015
4	18.1	7.4	33.0	156.7	502	365	337	2030
No. 23, $3^h\,36^m\,28^s$ MET Base line $C—K_4$ 65.5 km.								
1*			28.5	169.9	558	345	287	1880
2	−17.6	5.4	25.9	169.9	569	317	285	1875
3	−18.3	5.4	17.6	169.8	608	230	280	1860
4	−18.4	5.3	11.2	169.7	645	164	275	1845

Table 20 (continued).

P	ε_2	p	h	a	D	H	H_4	T_1
No. 27, $3^h\,44^m\,48^s$ MET. Base line $T—K_4$ 104.95 km.								
1	−27.4	8.0	32.0	161.9	537	379	273	1835
2	−29.5	8.1	22.2	162.1	577	272	268	1820
3	−30.0	8.0	18.5	162.2	598	236	267	1815
4	−30.5	7.9	14.5	162.3	620	196		
5			10.0	162.4	640	148	262	1800
No. 34, $3^h\,52^m\,03^s$ MET. Base line $C—K_4$ 65.5 km.								
1	10.2	4.2	31.4	139.3	697	502	342	2045
2	10.3	4.4	22.7	140.4	734	369	339	2035
3	10.1	4.5	17.9	140.9	748	298	337	2030
4	10.0	4.6	13.5	141.2	754	234	334	2020
5			9.1	141.7	765	174		
The same, base line $Ak—K_4$ 85.54 km.								
1	40.1	4.2	9.8	142.4	852	212	332	2015
2	39.1	4.4	16.8	141.5	793	303	336	2025
3	38.3	4.4	20.6	141.1	775	358	338	2030
4	33.4	4.8	33.8	139.0	657	512	343	2045

On Plates 10 and 11 corresponding sketches are seen. The position of the earth's shadow is indicated for each of the rays. Some of the pictures are reproduced on Plates 28 and 29.

56. Situation of the Divided Rays hitherto Measured.

On Fig. 59 we have drawn all the divided rays on a vertical section of the earth. The position of the rays relative to the earth's shadow line is seen, and the remarkable fact that this shadow line very nearly goes through the dark space between the two parts of the divided rays is clearly seen.

On Fig. 60 the geographical situation of each of the rays is given.

57. Spectra Taken during the Night of March 21st—22nd, 1938.

During the aurora that night my assistant Herlofson took two spectra, one of the arc and another of the sunlit rays, among which the divided ones occurred.

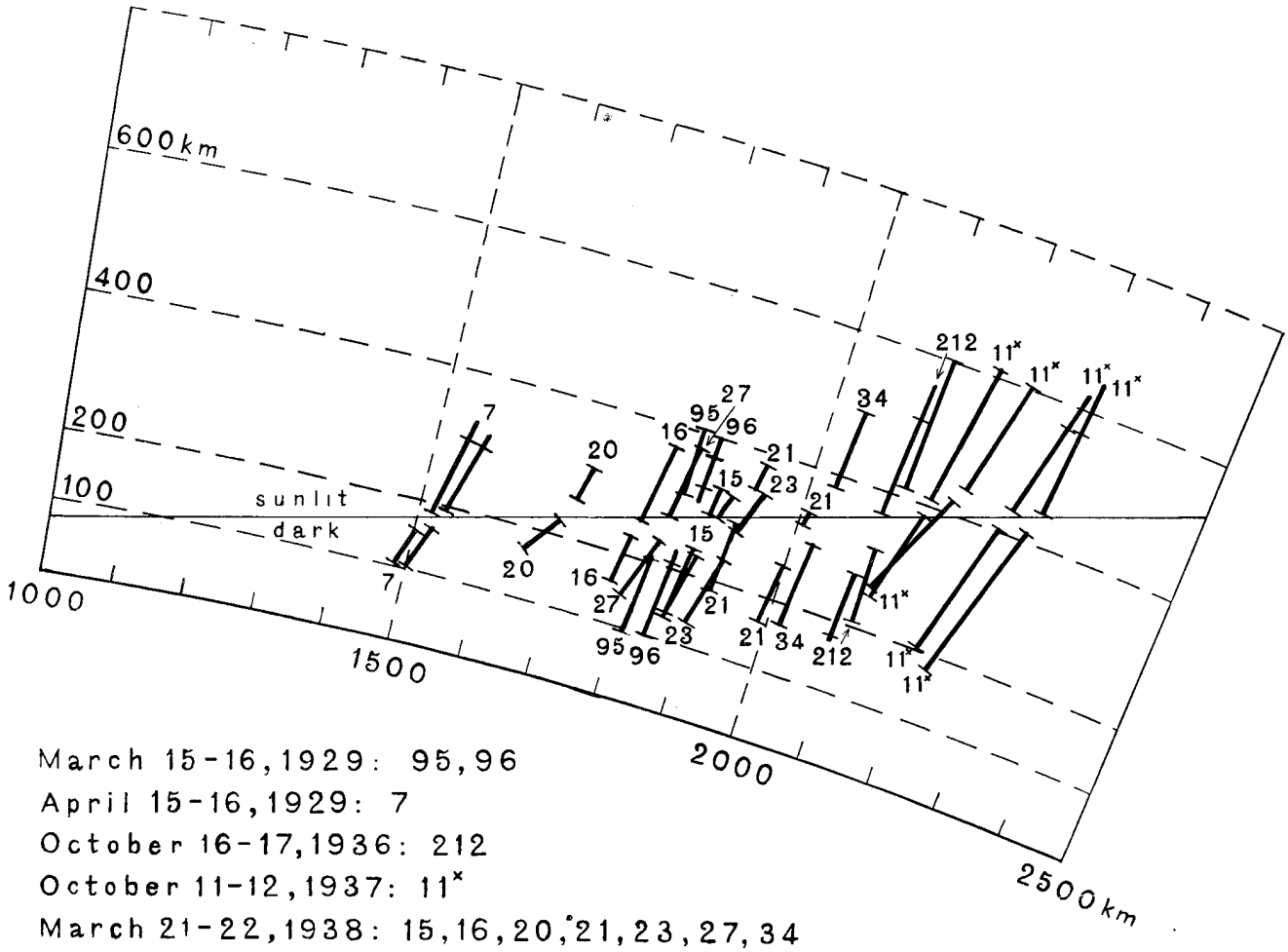

Fig. 59. The positions of the divided aurora rays in relation to the earth's shadow.

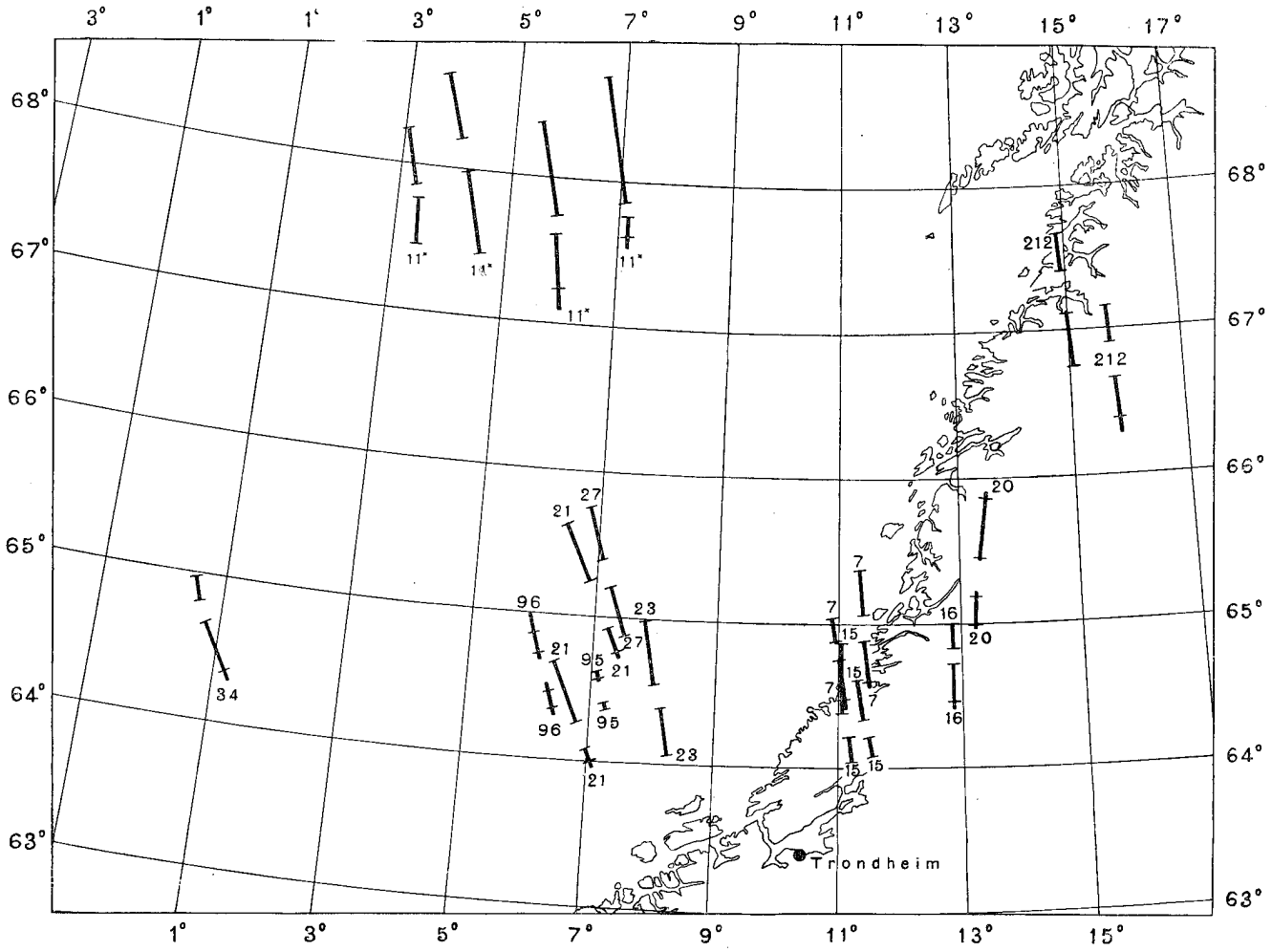

Fig. 60. Geographical situation of the same rays.

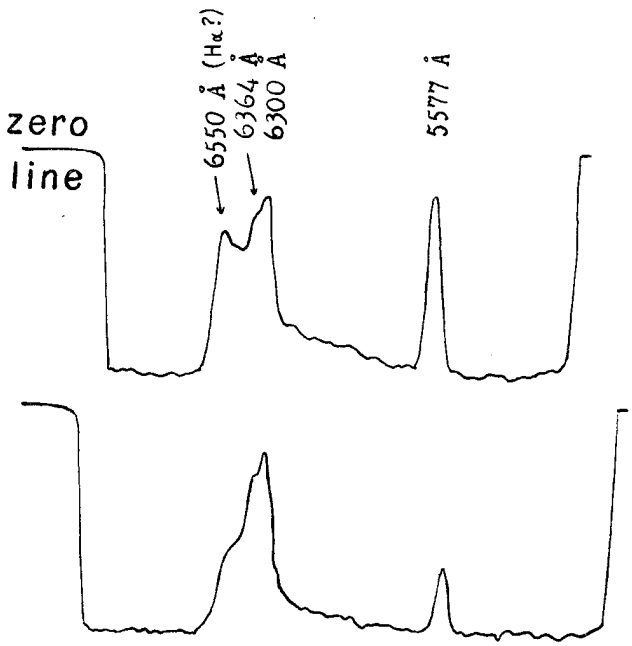

Fig. 61. Photometric registrams of auroral spectra of March 21st—22nd, 1938.
Homogeneous arc, exposed $1^h\,00^m$—$2^h\,50^m$ MET (upper picture) and sunlit rays, exposure $3^h\,30^m$ – $4^h\,15^m$ MET (lower picture).

He used a small flint glass spectrograph, loaned from the Auroral Observatory at Tromsø,[1] and the two spectra were taken on the same plate, Agfa Isopan ISS.

Both the reproductions of the spectra (Plate 29) and the photometric registrams (Fig. 61) confirm earlier observations[2] of the enhancement of the red oxygen lines λ 6300 and λ 6363 in sunlit rays. In the spectrum of the homogeneous arc there is some indication of a line close to $H\alpha$. But as the spectrum is too weak to show $H\beta$, it may be doubtful if the hydrogen lines observed in 1939 and 1940[3] have already appeared in March 1938.

[1] Carl Størmer. Astrophysical Norvegica III, 9, 1940.

[2] L. Vegard. Nature 137, 778, 1936. Carl Størmer. Geof. Publ. XII, 7, 1930.

I am indepted to Professor Vegard for the use of his Moll photometer for making the registrams on Fig. 61.

58. Summary.

Divided aurora rays with one part in sunshine and another in shadow have been observed on 8 nights from 1920—1940. 11 sets were measured out which confirmed earlier observations from 1929. Some spectra taken on March 21st—22nd, 1930, confirm earlier observations on the enhancement of the red oxygen line 6300 compared with the line 5577, for sunlit rays compared with auroral arcs in shadow.

[3] L. Vegard. Det Norske Videnskaps-Akademis Skrifter, Oslo, No. 8, 1939, Carl Størmer. Astrophysica Norvegica III, 9, 1940.

PART VII. RED PATCHES AND RED ARCS (IX)

59. Introduction.

From aurora observations during the last centuries it is a well known fact that red aurora forms in middle latitudes appear almost exclusively during years of maximum frequency of aurora. In his book on aurora,[1] Fritz says about this: "Eine weitere Eigentümlichkeit der Erscheinungen zur Zeit der Maxima ist die *rote* Farbe, welche bei Nord- und Südlichtern fast ausnahmslos an die Epoche größter Häufigkeit geknüpft ist, wie die Nordlichter 1830, 1837, 1860 und 1870 zeigten".

The same fact is shown from the aurora observations in Norway. We come back to this in a later section.

In the period from 1911 to the present, during which my aurora stations in southern Norway have been in action, red aurora forms have been observed several times, but simultaneous photographs of them for height measuring have only been successful in recent years.

Red aurora rays have been measured in 1936[2] and other red forms during the year of maximum frequency 1938 and later.

In the following, some of the most interesting of these forms, red patches and red arcs, will be dealt with in detail.

60. Red Patches on January 25th—26th, 1938.

The first reliable measurements of height and situation of red patches were made during the gorgeous aurora on January 25th—26th, 1938. In "Nature"[3] and in "Die Naturwissenschaften"[4] I have given preliminary accounts of our work that night. In the following we shall give a detailed description of two cases of red patches of very high altitude.

The first occurred at about $23^h\ 12^m$ MET. I conducted the work myself, from the east roof of the old observatory in Oslo (C) and was in telephonic connection with the 3 other stations Oscarsborg (O), Tømte (T) and Tuddal (Tu). The patch, mingled with some rays, was seen to the right of Orion and had, together with the rays, a fine red colour. We took two sets of pictures on Agfa ISS plates, the first one at $23^h\ 12^m\ 30^s$ MET simultaneously from O, T and Tu and the second one at $23^h\ 13^m\ 10^s$ from C, T and Tu. Exposure 10^s.

The base lines used had the following lengths:

O—Tu	101.50 km
T—O	73.75 »
C—Tu	108.81 »

The directions, however, were not very favourable for exact measurements and moreover the outlines of the red patch were very diffuse.

My assistant Olav Egeberg measured the plates in 1938 and a new control was made in 1940 by Herlofsen and myself. On Table 21 are seen the

[1] Hermann Fritz: Das Polarlicht, F. A. Brochhaus, Leipzig 1881, p. 135.

[2] Carl Størmer: Some Results regarding Height and Spectra of Aurora etc. p. 14. Geof. Publ. Vol. XII, No, 7. Oslo 1938.

[3] Photographic Measurements of the Great Aurora of January 25th—26th, 1938, l. c. Vol. 141, p. 955.

[4] Photographische Höhenbestimmungen und Spektra des großen Nordlichtes von 25. bis 26. Januar 1938, l. c. 26 Jahrg. Heft 39.

measurements made by Mr. Egeberg. Here the letters have the same significance as in the former sections. In particular p is the parallax in degrees and H the height in kilometers.

Table 21.

Height and Position of Red Patches on 25th—26th January, 1938, at $23^h\,12^m - 23^h\,14^m$ MET.

No.	MET	Base	P	ε_2	p	h	a	D	H
39*	23.12.30	$O-Tu$	1	16.8	5.1	38.3	33.3	708	730
—	—	—	2	19.8	5.7	32.2	35.5	749	563
—	—	—	3	27.5	7.0	27.7	40.0	639	389
—	—	$T-O$	1	50.0	3.7	34.0	31.7	670	529
—	—	—	2	54.8	2.9	28.8	34.3	686	444
			3	56.5	3.1	24.5	38.0	651	347
40*	23.13.10	$C-Tu$	1	25.0	5.7	38.1	30.9	707	657
			2	28.9	6.5	31.5	33.3	667	477
			3	32.2	7.5	26.6	36.0	598	345

Of these measurements those with the longest base lines O—Tu and C—Tu are the most reliable. Herlofson and I have measured anew some points on the middle of the left side of the spot where the most reliable results could be obtained, and found, with the base line O—Tu, heights from 340 to 550 km, of the same order as those found by Mr. Egeberg.

On Plates 11 and 12 are seen the sketches made from these negatives and on Plate 30, the pictures C 39*, T 39* and Tu 39*

The situation over the North Sea is shown in Fig. 62, at **a**. The aurora lay in the earth's shadow.

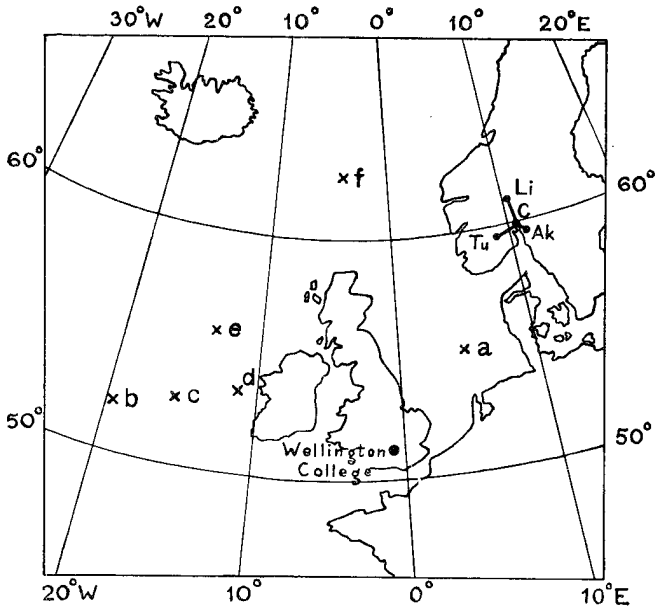

Fig. 62. Situation of red spots on January 25th—26th and another (f) on November 14th—15th, 1938.

It is interesting to note that the same spot was observed from Wellington College (51° 22′ Latitude 0° 48′ Longitude W of Greenwich) by Mr. M. Majondie and Mr. J. H. Gordon. In fact, in a letter to me they sent a list of observations, from which I quote:

$23^h\,05^m$ MET: Faint dull red patch left, by the Great Bear and very faint indications of red by Cassiopeia and W of the Pole Star. The rest of the red glow had gone.

$23^h\,07^m$ MET: Red glow almost imperceptible.

$23^h\,11^m$ MET: S. part of the sky normal up to an altitude of about 80°.

$23^h\,13^m$ MET: Red by the Great Bear increased slightly in brightness. One or two very minor streamers noticed.

$23^h\,14^m$ MET: Red fading out again, and very dim.

If we calculate the position of the Great Bear seen from Wellington and compare it with the geographical situation and height of the spot as measured by us, the position agrees quite well.

Later at $1^h\,35^m\,45^s$ the same night a new red spot was seen near the western horizon and photographed simultaneously from my 3 stations Oslo (C), Askim (Ak), and Lillehammer (Li). I myself led the work by telephone.

The bases Li—C and Li—Ak had the formidable length:

$Li-C$ 132.65 km
$Li-Ak$ 173.20 »

almost north—south.

The results of the measurements are seen on Table 22.

Table 22.

Height and Position of Red Spot on January 25th—26th, 1938 at $1^h\,35^m\,45^s$.

Base	P	ε_2	p	h	a	D	H
$Li-C$	1	5.0	4.4	15.5	74.7	1516	658
	2	2.4	4.9	10.7	77.1	1431	461
	3	0.9	5.2	6.8	78.5	1398	334
$Li-Ak$	1	—3.0	5.6	15.4	74.8	1558	688
	2	—5.5	6.0	10.6	77.2	1518	496
	3	—7.0	6.1	6.8	78.7	1529	384

Here 1, 2, 3 on the Li-picture are the same for the two base lines and were measured independently. Probably the last measurements with the longest base lines are the best ones.

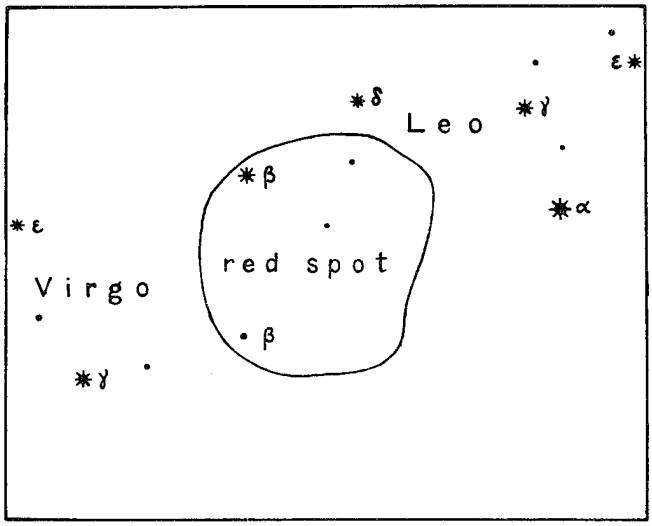

Fig. 63. Red spot at $22^h\ 36^m$ on January 25th—26th, 1938.

Once more we remark the great height from about 350 km up to near 700. The red spot lay in the earth's shadow.

On Plate 12 are seen the sketches, on Plate 30 the pictures from *Li*, *C*, and *Ak*.

The geographical position was NW of Ireland and is seen as letter *e* in Fig. 62.

61. Other Observations of Red Patches on January 25th—26th, 1938.

Of the great aurora of January 25th—26th I got a great many (about 250) visual observations both from Norway and from abroad. Among these are a series of most interesting descriptions of red patches. I give some of the best-ones, sent from Einar Schrøder in Holmestrand.

He says:

"During the evening of January 25th I observed a great many very beautiful red aurorae. I will try to indicate the situations of these red aurorae among the stars. The watch was compared with radio signals and the time is therefore rather correct.

$21^h\ 58^m$. Between β, δ, and ϑ Leonis. Simultaneously between γ Pegasi and α Arietis.

$22^h\ 14^m$. Red bundle of rays from α Arietis to ε Persei. Simultaneously between 43 and 43 Com. Ber. v Ursæ Majoris and δ Leonis. (Sketch followed.)

$22^h\ 19^m$. Between α Pisces and ε Arietis.

$22^h\ 36^m$. Between β, ϑ Leonis, β Sext., and β Virg. See sketch Fig. 63.

$22^h\ 40^m$. Between α Tauri, π Orionis and 10 Tauri. See Fig. 64.

$22^h\ 42^m$. Strong bloodred bundle from the region near α Ceti to between the Hyades and Pleiades. Simultaneously the eastern sky was almost covered by a reddish glow.

$22^h\ 44^m$. Strong red patch round β Canc. This patch moved slowly westwards and at $22^h\ 45^m\ 30^s$ it was lying around Procyon. See sketch Fig. 65.

$22^h\ 47^m\ 30^s$. On both sides of Orion.

$22^h\ 52^m$. Between Denebola, δ Leonis and α Can. Venat. See sketch Fig. 66.

$23^h\ 00^m$. Between α, β Arietis, γ Pegasi, and α Andromedæ. See sketch Fig. 67.

$23^h\ 06^m$. Strong and big red glow from Auriga to Gemini.

$23^h\ 08^m$. Between Denebola, δ Leonis, 15 Com. Ber. and γ Ursæ Majoris.

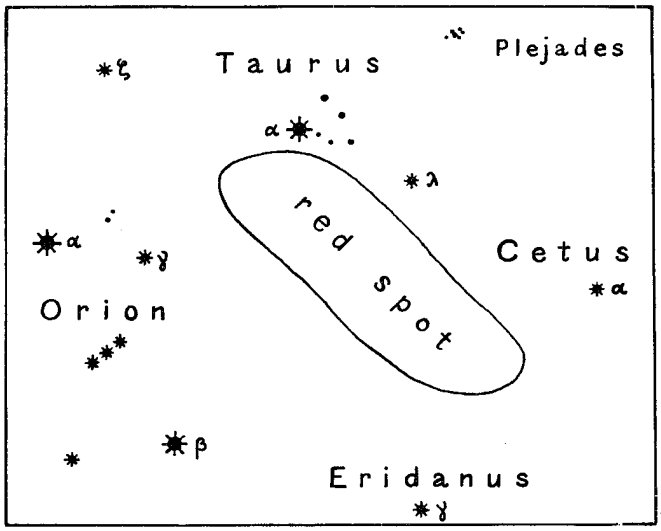

Fig. 64. Red spot at $22^h\ 40^m$ the same night.

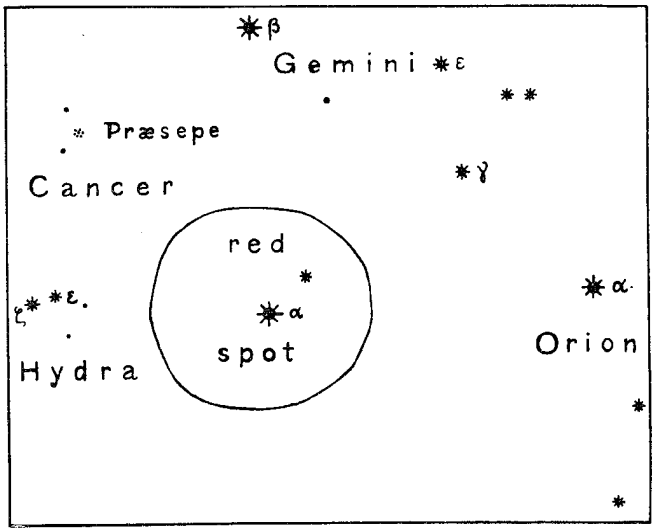

Fig. 65. Red spot at $22^h\ 45^m\ 30^s$ the same night.

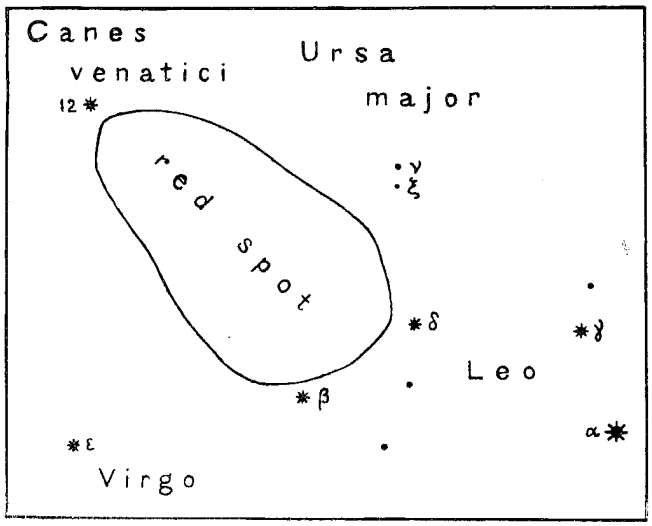

Fig. 66. Red spot at $22^h\,52^m$ the same night.

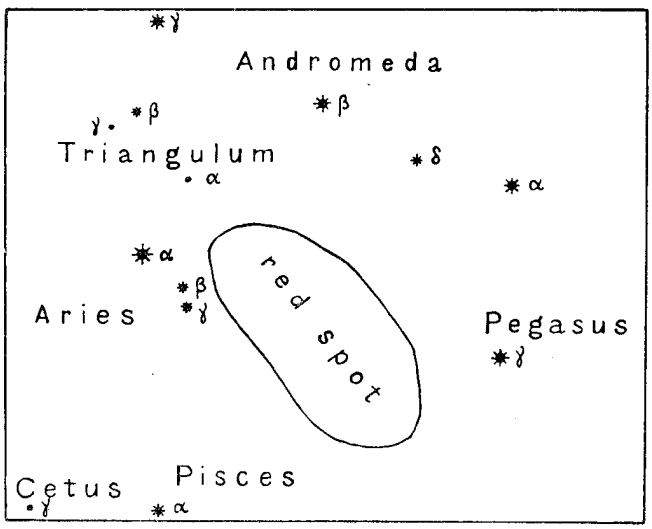

Fig. 67. Red spot at $23^h\,00^m$ the same night.

$23^h\,09^m$. Strong red bundle[1] through α, β, and γ Arietis. (Sketch followed.)

$23^h\,13^m$. Between α Tauri and ν Orionis.

A strange thing about these red aurorae was that in general two of them appeared simultaneously, one on the western and one on the eastern sky.

The northern sky was almost free from aurora, both the red ones and the white green ones."

[1] This happened to be photographed simultaneously from my stations Askim, Lillehammer, and Oslo, but the plates are not yet measured out.

In Oslo we made the same observation about the northern part of the sky. Later in the night the aurora went northwards.

62. Red Patch on November 14th—15th, 1938.

New measurements were successful on November 14th—15th the same year. At $23^h\,06^m$, when our stations were at work, a fine red patch mingled with some rays developed in W in the constellation Cygnus.

The patch was photographed at $23^h\,06^m\,40^s$ and at $23^h\,07^m\,13^s$ simultaneously from the stations Oslo (*C*), Askim (*Ak*) and Tømte (*T*), on panchromatic plates Agfa ISS. The longest base line was

T—*Ak* 80.05 km.

In spite of this long base line the measurements are not so good because the outline of the patch was very diffuse. By comparing the two pictures from *T* and *Ak* visually it is clear that the red patch developed in the neighbourhood of the red rays and had about the same height and position as these.

The results of the best measurements made by my assistant Herlofson were as follows.

Table 23.

Height and Position of Red Spot on November 14th—15th, 1938.

Base line *T*—*Ak* 80.05 km.

No.	MET	*P*	ε_2	*p*	*h*	*a*	*D*	*H*
66*	23.06.40	1	—34.0	4.7	16.5	116 6	745	277
		2	—25.1	4.1	33.6	111.3	770	613
		3	—32.3	4.5	16.4	114.8	790	296
		4	—24.3	4.0	32.0	110.0	809	610
		5	—27.8	3.8	16.9	110.9	967	308
		6	—26.2	4.0	20.7	109.5	903	435
		7	—24.4	4.2	24.7	108.2	842	478
67*	23.07.13	1	—32.5	3.9	20.8	116.8	872	419
		2	—27.5	4.4	32 3	113.3	722	542
		3	—31.4	4.1	19.8	115.2	846	384
		4	—26.2	4.4	31 8	111.5	735	542
		5	—26.5	4.0	19.0	110.0	912	402
		6	—24.0	4.3	25.6	107.8	8.8	480

Among these measurements, 66*, Nos. 1, 2, 3, 4 are the best ones, 5, 6, and 7 are doubtful; 67*, 5 and 6 are also doubtful.

At all events the red spot lay in the Earth's shadow from 300 to 400 km up to a height of 500

to 600 km over a region east of the Faeröe Islands, as marked on the map Fig. 62 (letter f).

For sketches and pictures see Plates 12 and 31.

The same red spot was observed by Mr. Søraas from Nestun (60° 16.5′, 5° 17.5′ E) near Bergen.

In fact he sent me a sketch of the spot observed at $23^h\,10^m$ MET.

At that time a picture was also taken from my station Askim. The sketch gives only an approximate position of the outlines of the spot, but it seemed interesting to get an independent verification of its height. The length (337 km) and situation of the base Askim—Nestun was calculated and the parallax, which was from 8 to 11 degrees, was measured for some points of the spot. The result was that the red spot was situated somewhere in the height interval 350 to 940 km, which confirmed its great height found before.

63. Successive Photographs of a Red Surface taken from the Station Hokksund by Olaf Hassel on Red Sensitive and on not Red Sensitive Plates.

During the gorgeous aurora of January 25th—26th, 1938, my assistant Olaf Hassel took, from his station Hokksund, a series of interesting photographs of a red surface coming from south-west. He always took pairs of photographs simultaneously, one on panchromatic plate Agfa ISS and one on plate Sonja EW not sensible to red. The pictures on the plates Agfa ISS were out of focus, but good enough for our purpose.

This red surface appeared at $0^h\,57^m$ in WSW and moved rapidly eastwards at the same time as a fine red drapery developed east of it, over Orion; a good set of pictures of this drapery was taken at $1^h\,06^m\,33^s$ and is reproduced in Die Naturwissenschaften 1938.[1] At $1^h\,09^m$ the aurora had reached Oslo and developed into a most imposing corona which at $1^h\,14^m$ reached its maximum. At that moment sound was heard at my station Tuddal by Mr. Tjønn and his assistant.[2]

The 3 sets taken by Olaf Hassel were the following:

First set at $0^h\,57^m\,42^s$ Spot very well seen on Agfa ISS. No spot seen on Sonja, only some faint rays to the left of the spot, also seen on the Agfa plate.

Second set at $1^h\,00^m\,46^s$ Same remarks. The spot has come higher and has divided in two, like summits of draperies.

Third set at $1^h\,03^m\,19^s$ Same remarks. The feeble rays on the Sonja plate are now covered by the red surface. A third summit of drapery to the right of the former ones has appeared.

Assumming the left summit of the red colouring at 700 km over the earth we have calculated the positions of the red spot at the 3 moments. The result is seen in Fig. 62, b, c, d.

The motion eastwards was in mean 1700 meters per second.

On Plate 31 are seen the pictures taken.

64. Feeble Rays Associated with the Red Spots.

Before we used panchromatic plates, the red color of the spots could not be photographed, but sometimes, as on Hassel's Sonja-pictures just mentioned, feeble rays containing blue, violet or ultraviolet light appeared on the plates.

The first case was a red patch photographed at $22^h\,19^m$ on December 16th, 1917, when a set of pictures was taken simultaneously from Oslo and Oscarsborg of a red spot near Jupiter.[1] The plates used were Lumière étiquette violette or Hauf Ultra rapid, both sensible to blue violet or ultraviolet, but not to yellow and red. On the plates no trace of the red spot was visible, only feeble rays which we had not observed visually. The height of the rays was found to be from 278 km to 522 km.

The next time was a case of red violet coloration at $0^h\,15^m$ on the night between October 18th—19th, 1919.[2] Visually no rays were seen in this red area, but on the plates,[3] however, they were seen. On account of the short base line Bygdø—Oscarsborg the parallax was so small (0.7° to 1.2°) that the height measurements were not very reliable. Three measures gave values between 400 and 550 km for the summits of the rays. The rays probably emitted ultraviolet light invisible to the eye.

Some invisible rays in red patches also occurred after sunset during the great aurora on January

[1] l. c. Jahrg. 26, p. 636.

[2] l. c., p. 637.

[1] *Geofysiske publikasjoner*, Vol. IV, No. 7, p. 22.

[2] The same, p. 32. See also *Die Naturwissenschaften*, 1923, p. 338.

[3] Lumière étiquette violette.

26th—27th, 1926. In a note from 1926[1] I have described this phenomenon. Here is a report: »From my station *B* (Bygdø near Oslo) I first observed the aurora at $17^h 40^m$ as a yellow green arc in the north. This arc soon disappeared, but now some strange red violet patches were seen in NW, which increased in extent and intensity. They were diffuse, and I could not see any rays in them. 6 photographs of these patches were taken from $17^h 54^m$ to 18^h, on plates Sonja EW (insensible to red). On the developed plates, however, a series of narrow rays could be seen, rays which probably were situated in the sunlit part of the atmosphere.

A similar phenomenon was observed by *Sophus Tromholt* in 1878. In a paper published in 1880[2] he describes an aurora which he observed from Bergen on the evening of October 18th, 1878. Here is a translation of his observation: "An aurora remarkable by its strange beginning! The sky was almost clear and the moon had not yet risen, and I therefore began to observe the northern sky already at $6^h 30^m$. In the first half hour nothing appeared. At 7^h I had just gone out and to my great surprise I saw a big red coloration developing under ε, ζ, and η Ursæ Majoris reaching up in Can. Venat. In this coloration exceedingly faint white rays were seen. At the same time a reddish coloration moved with great velocity from W to E along the northern horizon. But this lasted only a few seconds and then no trace of aurora was seen until $7^h 50^m$, when a feeble yellowish glow with dark segment appeared . . . .".

65. Dates when Red Spots or Surfaces have been Observed in Southern Norway since 1911.

I have looked through my photographs and the observations received regarding red spots and surfaces and have found the following dates for their occurrences:

Table 24.

Red Spots and Surfaces 1917—1940.

1917.
February 15th—16th.
December 16th—17th.

1919.
October 18th—19th.

1920.
March 22nd—23rd.

1926.
January 26th—27th.
October 14th—15th.
October 15th—16th.

1936.
January 24th—25th
October 16th—17th

1937.
January 7th—8th.
Sept. 30th—Oct. 1st.
October 11th—12th.
October 16th—17th.

1938.
January 21st—22nd.
January 25th—26th.
February 5th—6th.
February 6th—7th.
February 14th—15th.
May 11th—12th.
November 14th—15th.
December 16th—17th.
December 18th—19th.

1939.
March 30th—31st.
April 24th—25th.
September 3rd—4th.
October 3rd—4th.
October 7th—8th.

1940.
January 18th—19th.
March 24th—25th.
March 25th—26th.
March 29th—30th.
April 3rd—4th.
September 26th—27th.
October 26th—27th.
November 25th—26th.

From this it is seen that it is especially during years of maximum activity of the sun that such forms appear. This is still more characteristic if we make statistics of *all* red forms. This will be done in a later part of this paper.

66. Red Arcs.

The red auroral arcs are a still more infrequent form than the red patches. These red arcs must not be confused with arcs of common yellow green color but with red lower border. The arcs in question are red all over.

From 1911 until now red arcs have only been observed and photographed from my auroral stations on two occasions. The first time was on January 26th, 1926, when I saw it myself and got a photograph of it, but only from one station, and the second time was before sunrise on January 22nd, 1938, when my assistant Ole Høstmælingen secured some pictures, also from one station only.

During years of maximum solar activity such red arcs have been observed both in Norway and in middle Europe, for instance in the years 1870—72. We will come back to the Norwegian observations in section 69.

In spite of the fact that we have not succeeded in measuring the height of such red arcs photographically, we can make an estimate of their height from simultaneous visual observations.

67. The Red Arcs on January 26th, 1926.

In the foregoing sections we have already reported on some interesting aurora forms from this date, in particular on the remarkable red spots with invisible rays during the first phase of the aurora. These red spots successively developed to a red coloration

[1] *Die Naturwissenschaften*, Jahrg. 14, p. 632.

[2] Sophus Tromholt: Iagttagelser over Nordlys anstillede i Norge, Sverige og Danmark I, September 1878—April 1879, Christiania Videnskabsselskabs Forhandlinger 1880, No. 6.

towards W and then to a fine red arc passing near zenith from the eastern to the western horizon.

South of this arc was a yellow green one, and these two arcs were a sight of incomparable beauty. I am sorry that we did not succeed in getting simultaneous pictures of the red arc for height measuring. Only one interesting photograph from my station Bygdø near Oslo was obtained at $19^h 38^m$ MET. At that moment the red arc had dissolved in a series of long red rays. (See sketch Plate 12.)

But nevertheless an estimate of the relative height of these arcs can be obtained from the following interesting observation from A. Fock at the private Observatory *Orion* (Latitude 56°, Longitude 12° E. Gr.) in Denmark:

" . . . In NW high red rays reached an altitude of 60°. In north was a typical dark segment with a strong green arc over it . . . Over this was a dark space and over this again an imposing arc of deep red color from which a great number of red and very intense green rays reached up to 82°. This red arc began at a red region in NW and ended in a corresponding red region in NNE, as seen in Fig. 68."

I am sorry that no measurements were taken of the elevation of the lower borders of the two arcs over the horizon, but the fact that the red arc was situated over the green one combined with the observation from Oslo, which showed that it passed near zenith at the same time as the green one was on the southern sky, can only be interpreted in the manner that the height of the red one was much greater.

If we estimate the height of the green arc at 100 km and the feet of the rays in the red one at 150 or 250 km, the geographical situations can be seen in Fig. 69.

Some other visual observations of these two arcs are of interest:

Mr. Einar Wellerop sent me the following description from Porsgrund (Latitude 59.2° Longitude 9.6° E):

"A little before $19^h 30^m$ I saw, near zenith, a red coloration like the reflection of a fire. I went down to the river to find out what it was. I then saw a strong red coloration over the Solum hills in the west and thought it was a fire at Skotfos. But a little later some white yellow bundles of rays appeared at the northern border of the red coloration, and then I understood that it was an aurora. The red coloration increased successively and developed into an arc over

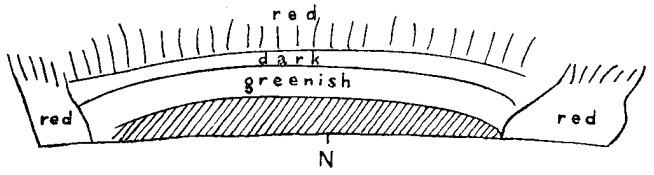

Fig. 68. Schematic sketch of red and green arcs on January 26th, 1926. seen from the Observatory Orion, Denmark.

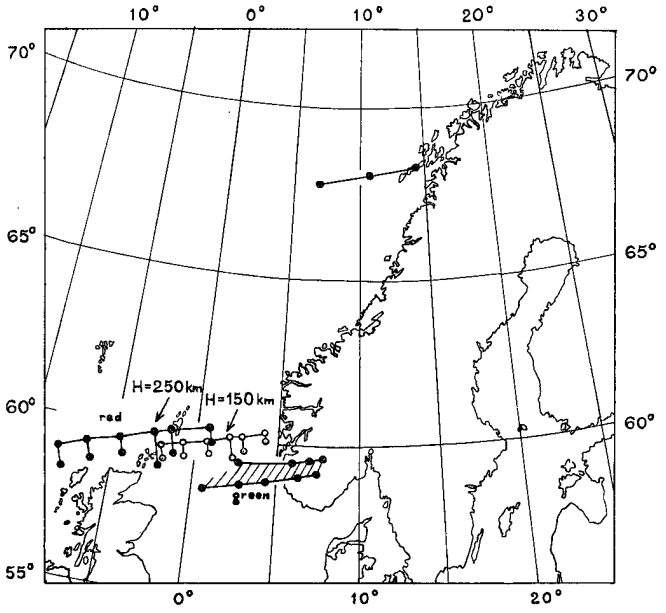

Fig. 69. Geographical situation of the same arcs, and of the red arc on January 22nd, 1938.

zenith from west to east, somewhat bent towards north east . . . To the south of this red arc and on the other side of the moon was another arc, like a rainbow of cold ice green color . . ."

Mr. Ottar Andersen writes from Hylleraasen, Engerdal (Latitude 61.5°, Longitude 12° E) as follows:

"Following the request sent out from the Oslo broadcasting station I send you some observations of the aurora on the evening of January 26th, 1926. The observations are taken without instruments and are only approximate.

The place of observation is Hylleraasen, on the east side of Engersjøen in Engerdal. The time was controlled by radio."

7.15 p. m. ($19^h 15^m$ MET): "The *red band* was 5.5 cm broad, measured at a distance of 60 cm from the eye (5.5°). The lowest part of the band nearly due west. The inclination of the band about 60° with the horizon. The *green band* in south west 10.5 cm (9.5°) broad with inclination of about 40° with the horizon. Less prominent aurora in the north." See Fig. 70.

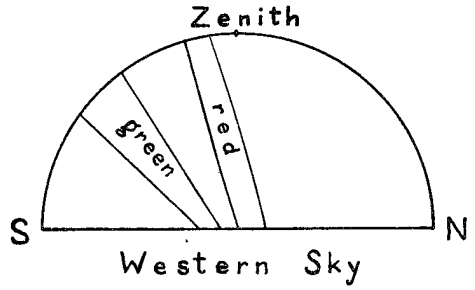

Fig. 70. The same arcs seen from Hylleraasen Engerdal.

8 p. m. (20^h MET): "The red band has moved a little to the south and now stretches across the whole heaven. It is about 15° broad and the upper border passes near the moon."

A faint red band also across the northern sky.

8.15 p. m. (20^h 15^m MET): "The aurora over the greater part of the western sky, but no prominent colors."

8.30 p. m. (20^h 30^m MET): "Very little change from 8.15. A red band slightly colored, about 45° over the northern horizon and across the northern sky. A slight red coloration on the western sky, near zenith."

8.45 p. m. (20^h 45^m MET): "The aurora insignificant. The aurora had the finest colors between 7.45 and 8."

68. The Red Arc on January 22nd, 1938.

The second time we obtained photographs of a red arc was before sunrise on January 22nd, 1938.

On the night of January 21st—22nd we had a fine aurora in the northern sky and most of our stations were in operation. 71 good sets were taken simultaneously from 2, 3 or 4 stations. At about 4^h 15^m however, the aurora had almost gone, only a feeble glow near the northern horizon remained and therefore we resolved to suspend the work. But unfortunately it was too early to stop. Some hours later the activity augmented considerably with big red rays and a remarkable red arc in the north.

Fortunately the red arc was seen by my assistant Mr. Ole Høstmælingen in Lillehammer, and he immediately took out his camera and secured 10 photographs of it. The first 4 were taken on Sonja plates; they were overexposed and show no lower border. The 6 following were taken from 7^h 27^m to 7^h 31^m on panchromatic plates Agfa ISS, each with 20^s exposure. These were also overexposed, but on the third one, taken about 7^h 28^m the lower border of the red arc can be seen together with Capella and α and β Persei.

Hoping to get visual observations from northern Norway I sent a note to the newspapers, which resulted in a series of reports. Among these was one from Mrs. Caroline Bordewich[1] in Lyngvær, Lofoten (68.3° N, 14.2° E Grw) which could be used for height determination. She writes: "I saw the aurora between 7^h 30^m and 8^h in the morning. It had the form of a red belt from NE to SW and was not flaming like a common aurora, but quiet."

Asking for more details she answered: "Most of the red arc was situated north of zenith. One sixth of its breadth was south of zenith, five—sixths north of it".

Combining this with the photograph from Lillehammer at 7^h 28^m my assistant Herlofson found the minimum height of its lower border to be about 250 km and its upper part about 450 km or more. It lay in the sunlit part of the atmosphere. Its geographical position is seen in Fig. 69.

Among the other observations the following might be of interest: Mr. *Einar Bøe* writes from Stockmarknes (Latitude 68.6°, Longitude 14.9°): "The 22nd January 1938 at 8^h I saw a light phenomenon from Stockmarknes. It stretched from horizon to horizon SW to NE and lasted about 10 minutes. The clouds were at a height of 800—900 m and had several breaks through which I could see the light, it shone, however, through the clouds even where these were thickest. The phenomenon resembled an aurora arc, but had a red purple colour. It pulsated slowly, and the stars could be seen even through the most shining parts of it". Asking him for more details he added:

"I was on a trip in a motorboat and had just left Stockmarknes, when I observed the aurora which lasted about 10 minutes . . . . I can not give more details. It stretched like a broad belt from NE to SW from horizon to horizon and passed through zenith. It first faded away in east and later in W. What I have reported is quite correct; in fact I found that the phenomenon was so strange that I wrote down my observations immediately after the disappearence of the arc".

I got about 50 letters with observations of this arc. Many of the observers were persuaded that it was a reflection of a great fire. In addition to the observations already given, the following may be of interest:

[1] In my paper in Terr. Magn. I have erroneously written Borchgrevink instead of Bordewich.

Miss *Kari Tangen* writes from Vang, Hedmark (Latitude 60.8° Longitude 11.1° E. Gr.): "Together with two other persons I saw the aurora at $6^h\,35^m$ on January 22nd, 1938. At that moment the whole northern sky was as red as blood. In this glow some common yellow green rays appeared. From 6.45 to 7.15 the red glow moved to the north-eastern part of the sky. At about 7.50 it had removed to north-west and now formed an arc from NW—NE but the color faded as the dawn advanced."

Mr. *Petter Husa* from Sørskogbygda (Latitude 61.0° Longitude 11.8° E. Gr.) sent me the following observation: "I saw this beautiful red aurora at 7 o'clock in the morning as a broad red belt under and around the Great Bear. It shone so intensely that the snow was coloured red".

Mr. *Otto Garthus* sent from Garthus, Aurdal (Latitude 60.7°, Longitude 9.7° E Gr.), the following description: "From about $7^h\,30^m$, or perhaps a little earlier, I saw the aurora till it faded in the dawn. It looked like a bloodred arc across the northern sky from the western to the eastern horizon (the valley runs almost straight south-north and is rather narrow. The astronomical horizon is therefore much lower than the visual one). This bloodred arc did not quite reach the nothern horizon; in fact under the arc was a darker horizontal belt (dark segment). The aurora was quiet, no flames or rays, but it seemed to me that it was slowly increasing and decreasing (pulsating) sometimes at one place and sometimes at another."

69. Old Observations of Red Arcs in Norway.

Going through the extensive catalogue of aurorae in Norway by Sophus Tromholt[1], I have found the following observations of red arcs:

1826. December 26th. Vadsø (70° 04′, 29° 41′) "reddish flaming arcs".

1846. September 22nd, Oslo. . . "Already at 19^h, one could see, during strong twilight, rays and flames in N. Successively several irregular arcs appeared, some of them on the northern sky. Many of them had a feeble dirty-red colour and did not show any motion."

1859. February 24th, Oslo. . . . "Later in the night the aurora was gorgeous with a high arc, shining with an intense red colour."

[1] Sophus Tromholt: Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter, Kristiania 1902.

1869. November 9th, Reine (67° 56′ N, 13° 09′ E) "18^h arc; moves from northern to the southern sky. The aurora gorgeous, in all the colours of the rainbow, corona in Cygnus for about 15 minutes. At the same time a red arc in north with color like fire . . ."

1870. January 1st, Reine (67° 56′ N, 13° 09′ E) ". . . at 22^h an arc SW—zenith—NE. At $23^h\,35^m$ to $23^h\,50^m$ red as blood, across the sky as a broad belt SW—zenith—NE."

1870. October 14th, Skagerak (57° 43′ N, 9° 57′ E). "From 19^h—$19^h\,45^m$ a feebly flaming red arc whose lower border in N was 21°. It cut the horizon at ENE½E and WNW½W. Under this red arc was a common aurora in the form of a quiet arc. When the red arc disappeared the second one grew more shining. From $22^h\,15^m$—23^h the red arc appeared anew, and reached, together with the other one, a height of 58°. Then they both disappeared."

1870. November 8th, Oslo. "A complete arc going through zenith or perhaps a little more south, had a strong blood red color . . ."

1870. December 17th, Oslo. ". . . At $19^h\,30^m$ a narrow deep red arc in N, with blood red rays . . ."

1872. February 4th, Værø (67° 39′ N, 12° 46′ E) "Remarkable strong red arc SW—E, rather steady."

From this list it is evident that red arcs very rarely occur, and only during years of great solar activity.

70. Summary.

The first reliable measurements of red spots were made in 1938, on the nights of January 25th—26th and November 14th—15th. They showed that the spots observed lay in the height interval from about 300 to about 700 km in the earth's shadow.

Interesting pictures taken on plates sensible to and not sensible to red revealed faint rays in the red patches not seen visually.

A patch moving eastwards over the Atlantic on January 25th—26th, 1938, had a velocity of about 1700 m per second.

Statistics on the occurrence of red patches show that they are most frequent around years of maximum activity of the sun.

Red arcs which are still more infrequent have only been measured approximately, showing a lower border at about 250 km over the earth. From 1911—1941, only two cases are recorded. Earlier observations collected by Sophus Tromholt are referred to.

PART VIII. SOME STATITICS ON RED AURORAE IN NORWAY

71. Sophus Tromholts' Statistics.

Already in the section 59 it was pointed out that the red aurora was associated with years of maximum solar activity. Also for Norway this fact appears clearly when we examine the observations until 1878, collected by Sophus Tromholt.[1]

I have gone through his large catalogue and noticed the following dates of red aurora:

Table 25.

Dates of Red Aurora in Norway 1734—1878.

1734	1787	March 24th
November	April 2nd	April 5th
1737	September 7th	April 6th
December 16th	1797	November 12th
1747	December 1st	November 14th
December	1804	November 15th
1761	March 30th	December 18th
December 27th	1811	December 19th
1768	November 9th	1838
December 5th	1817	February 4th
1770	February 8th	March 6th
January 18th	1818	1839
February	February 5th	January 10th
March 22nd	February 8th	October 21st
1777	1825	October 23rd
April 1st	February 11th	1840
November 3rd	1826	January 3rd
November 27th	December 26th	September 21st
December 28th	1827	1841
1778	January 20th	November 18th
January 18th	1830	1846
February 25th	December 13th	September 22nd
March 26th	1831	1847
October 22nd	January 7th	September 24th
1779	1835	October 24th
November 9th	November 17th	November 22nd
1780	1837	December 17th
February 29th	January 25th	1848
September 22nd	January 26th	February 21st
1786	February 18th	October 18th
March 19th		October 23rd
		November 17th
		November 26th
		December 17th

1849	1862	March 28th
January 23rd	October 3rd	April 1st
February 18th	1868	April 9th
February 20th	December 5th	April 10th
February 22nd	1869	April 13th
March 18th	February 3rd	April 17th
October 22nd	May 13th	April 18th
1850	September 16th	April 19th
January 12th	September 25th	August 21st
February 22nd	November 9th	October 12th
October 1st	1870	October 14th
1851	January 1st	November 2nd
September 4th	January 3rd	November 5th
December 28th	February 11th	November 9th
1852	March 8th	November 10th
January 20th	March 13th	November 19th
February 11th	March 24th	1872
November 11th	March 25th	February 4th
1854	March 28th	February 5th
March 16th	April 18th	April 16th
April 11th	September 3rd	August 14th
1855	September 15th	August 16th
October 18th	September 23rd	October 17th
1857	September 24th	November 5th
December 16th	October 14th	December 21st
December 17th	October 20th	1873
1858	October 21st	January 5th
March 1st	October 23rd	January 21st
December 24th	October 24th	January 22nd
1859	October 25th	February 3rd
February 24th	October 26th	March 5th
April 21st	October 27th	March 9th
August 28th	October 28th	March 21st
October 12th	November 8th	March 22nd
October 17th	November 17th	August 15th
October 31st	November 19th	October 22nd
1860	November 20th	1874
March 12th	November 23rd	April 13th
1861	November 24th	November 10th
January 6th	November 27th	1876
February 27th	December 16th	March 25th
March 9th	December 17th	November 10th
December 19th	December 19th	1877
	1871	April 22nd
	January 13th	September 15th
	January 14th	September 22nd
	February 11th	December 4th
	March 27th	

This frequency of red aurora is compared with the sunspot curve[1] in Fig. 71. The frequency is indicated for each year by a vertical line, whose height is proportional to the number of cases. As mentioned before the red aurorae occur principally during years with many sunspots, in particular during the high maximum 1870—72.

[1] See the *citation* in section 9.

[1] A. Wolfer: Observed Sunspot Relative Numbers, Terr. Magn. 1925, and later supplements.

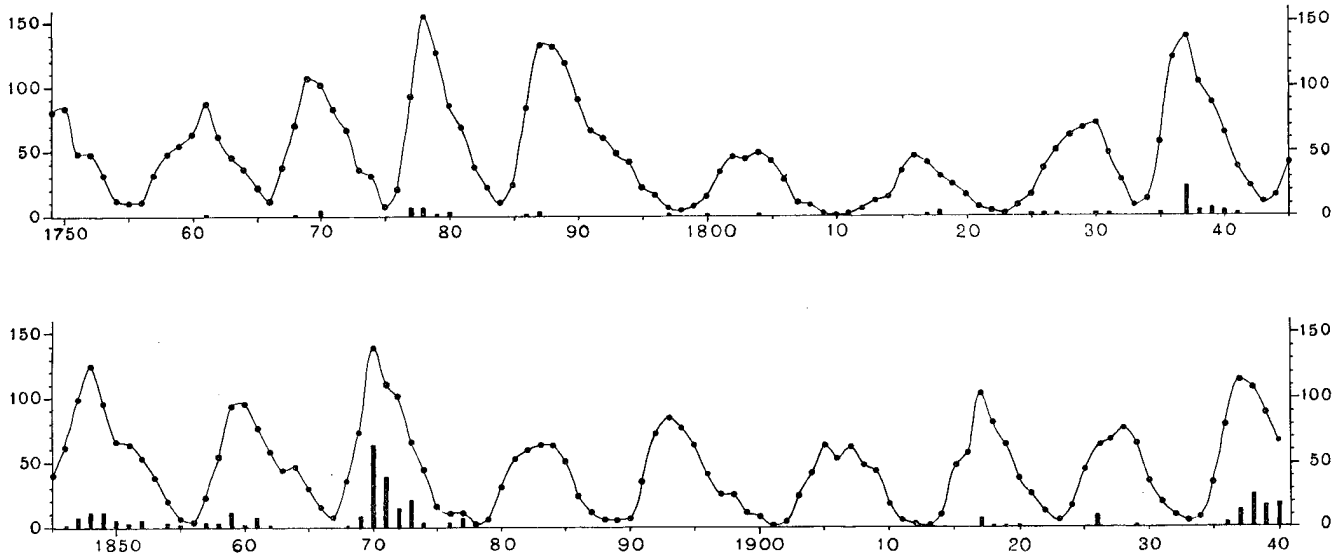

Fig. 71. Frequency of red aurora from 1734—1877 and from 1911—1940 as dark streaks compared with the sunspot curve.

72. Red Aurorae from 1911—1940.

During the interval 1878—1911 no statistics of aurora have yet been worked out for Norway. From 1911 to the present the photographs and observations from my stations in southern Norway together with observations sent me from other places in southern Norway may give a usable list.

As the aurora forms were also noticed we shall use the following abreviations taken from the International Photographic Atlas:

HA homogeneous arc
HB homogeneous band
DS diffuse luminous surface
G feeble glow
RA arc with ray structure
RB band with ray structure
D drapery
R ray
C corona
F flames

Red aurora was observed:

Table 26.

Dates of red Aurora Forms in Southern Norway 1911—1940.

1917.
February 15th—16th, *DS*
April 17th—18th, *R*
August 21st—22nd, *R*
December 16th—17th, *DS*, *R*, *C*, *F*

1918.
March 7th—8th, *R*

1919.
October 18th—19th, *DS*

1920.
March 22nd—23rd, *DS*, *R*, *C*

1926.
January 21st—22nd, *R*
January 26th—27th, *HA*, *RA*, *DS*, *R*, *C*
March 5th—6th, *R*, *C*
October 14th—15th, *R*, *DS*
October 15th—16th, *RB*, *DS*, *R*, *C*

1929.
February 27th—28th, *RB*, *R*

1936.
January 24th—25th, *DS*
October 16th—17th, *RB*, *DS*, *R*, *D*

1937.
January 7th—8th, *RB*
February 3rd—4th, *R*
April 24th—25th, *R*
September 10th—11th, *RA*, *R*
Sept. 30th—Oct. 1st, *DS*, *R*
October 11th—12th, *DS*, *R*
October 16th—17th, *DS*, R

1938.
January 21st—22nd, *Ha*, *DS*, *R*
January 25th—26th, *DS*, *RB*, *R*, *D*, *C*
February 5th—6th, *DS*, *R*
February 6th—7th, *DS*
February 14th—15th, *DS*
March 11th—12th, *R*
May 11th—12th, *DS*
September 13th—14th, *R*
September 15th—16th, *R*
Sept. 30th—Oct. 1st, *R*
November 14th—15th, *DS*, *R*
December 2nd—3rd, *R*, *D*
December 16th—17th, *DS*
December 18th—19th, *DS*, *R*

1939.
February 24th—25th, *R*
March 30th—31st, *DS*
April 24th—25th, *R*, *DS*
September 3rd—4th, *DS*
September 17th—18th, R
September 19th—20th, *R*
October 3rd—4th, *R*, *DS*
October 7th—8th, *DS*
October 17th—18th, *R*

1940.
January 3rd—4th, *RA*, *R*, *C*
January 18th—19th, *DS*, *R*
March 24th—25th, *DS*
March 25th—26th, *DS*, *RA*, *R*
March 29th—30th, *DS*, *R*
April 2nd—3rd, *D*, *R*
April 3rd—4th, *DS*
September 26th—27th, *DS*, *D*
October 26th—27th, *DS*, *R*
November 25th—26th, *DS*, *R*, *D*

On Fig. 71 is seen the corresponding frequency, which has its maximum in the years 1937—1940.

PART IX. SOME NEW CASES OF HIGH HOMOGENEOUS ARCS AND OF REMARKABLE BANDS

73. High Homogeneous Arcs Observed in 1938 and 1940.

Before ending these monographs it might be of interest to mention some cases of high homogeneous arcs and remarkable bands observed since the corresponding monographs (Nos. I and II) were published in 1935 and 1938.

The first case of high arcs was on the night of February 6th—7th, 1938, and is described in a report on the auroral work in southern Norway in 1938.[1] The arc as seen from Oslo appeared at $20^h\,30^m$ and lasted to about $20^h\,46^m$ as a faint arc near the belt of Orion in the south. The mean of 24 heights was 159 km, ranging from 138 and 181 km. The arc lay in the earth's shadow.

[1] Terrestrial Magnetism and Atmospheric Electricity, Vol. 44, No. 3, Washington 1939, p. 233—242.

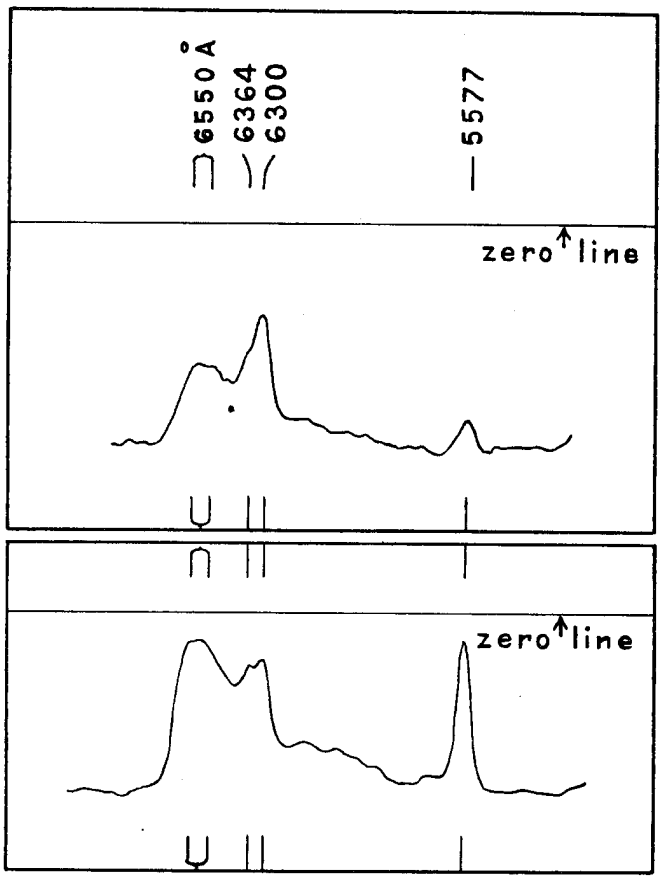

Fig. 72. Registrams of spectra of high homogeneous arcs, height 170—190 km (upper picture) and common arc in 100—120 km, (lower picture) taken on the same panchromatic plate.

The next case occurred 27 days later, on March 5th—6th, and is described in the same paper. The arc, or more exactly the arcs, were in the south, in Orion and Taurus, and the mean of 7 heights was 183 km, ranging from 172 to 195 km. The arcs were situated in the earth's shadow. Of special interest was a spectrum of these arcs taken on a panchromatic ultra rapid-red plate, compared with the spectrum of a common arc taken on the same plate. The spectra are reproduced in the paper referred to. My assistant Herlofson has taken a registram which illustrates better than words the behaviour of the lines and bands 6550, 6363, 6300, and 5577 (See Fig. 72).

The last case of high arcs occurred on December 20th—21st, 1940, from $18^h\,09^m$ to $18^h\,44^m$. A most interesting collection of about 24 sets of pictures from Oslo, Askim, and Lillehammer was taken, but only a few of them have been measured and calculated. The heights found are spread around 200 km. In particular the beginning and end of this case is interesting. But as similar arcs are so well described in the first communication we do not enter in to details here.

74. Some Remarkable Bands on January 7th—8th, 1937.

In the second of these monographs, published in 1937[1], I have described some interesting arcs and bands of ray structure from 1936.

Since that time new remarkable cases have occurred and in the following we shall give an account of some of them.

The first one is from *January 7th—8th, 1937.* As mentioned before (p. 26) a most splendid aurora was seen that night over southern Norway. It lasted the whole night and in Oslo it stretched sometimes even to the southern horizon. Rare forms occurred which I have seen neither before nor later.

I had all my aurora stations[2] at work, and more than 750 successful photographs were taken, among

[1] Remarkable Aurora Forms from Southern Norway, II, Some Arcs and Bands with Ray Structure, Geofysiske Publikasjoner, Vol. XI, No. 12, Oslo 1937.

[2] Oslo (*O*), Oscarsborg (*O*), Tømte (*T*), Kongsberg (*K*), Lillehammer (*Li*), Trondheim (*N*), Summit of the Gausta mountain (*G*), and Hokksund (*Hk*).

which a fine collection of about 190 sets from 2, 3, or 4 stations simultaneously.

The general development of the aurora was as follows:

The aurora, as observed from Oslo, was first seen at about 18^h MET, as an arc in the north. The arc rose higher and at about $19^h\,15^m$ it passed through the Great Bear. At about $20^h\,12^m$ the intensity increased and rays and curtain began to develop. The intensity was increasing steadily at the same time as the motion. At $20^h\,21^m$ some very luminous bands were photographed in NW, and in spite of the short exposure of 2^s the plates were almost overexposed. We come back to these bands later on. — The aurora had now spread over to the southern sky where an arc was seen as a limitation of the whole display towards south. A series of pictures was taken of some remarkable *quiet* yellow-green bands. These bands, which will be mentioned later, were seen all over the heaven, from about $20^h\,30^m$ to $21^h\,40^m$.

After a period of feeble aurora remains, a new arc developed at about 22^h and the rest of the night more diffuse forms were prominent, with broad arcs, cloudlike forms, and pulsating patches.

Some of the remarkable bands occurring at $20^h\,21^m$ have been measured out from pictures taken simultaneously from Oscarsborg and Lillehammer, giving the formidable base line of 158.65 km. The exposure was only 2 seconds, but in spite of their feeble impression on the plate a series of stars has been identified on all pictures.

The first set, No. 98, was taken at $20^h\,21^m\,02^s$ MET from Oslo, Tømte, Oscarsborg, and Lillehammer towards northwest of an accumulation of homogeneous bands of a remarkable form. It was of interest to measure out this set carefully and not less than 56 points were chosen. For some of them the geographical situation was found assuming a reasonable value for the height. They are omitted in the table.

Here are the results: (See next column.)

The geographical situation of the points Nos. 10, 14, 15, 16 is found supposing $H = 106$ km, of Nos. 29 and 30 supposing $H = 110$ km, and of No. 42 and of Nos. 48 to 56 supposing $H = 108.5$ km.

The mean of all the heights is 108.5 km. The sketches are seen on Plate 13, the pictures on Plate 32, and the geographical situation on Fig. 73 together with the position of the auroral stations Lillehammer and Oscarsborg:

See Fig. 73 on the next page.

No. 98, at $20^h\,21^m\,02^s$ MET.

Base line Lillehammer—Oscarsborg, 158.65 km.

P	ε_2	p	h	a	D	H
1	—71.7	16.1	34.5	171.6	146	103
2	—71.3	15.6	33.7	167.9	155	106
3	—70.9	15.6	32.8	164.0	160	106
4	—70.4	15.8	31.8	160.0	164	105
5	—69.6	15.9	30.6	156.0	171	104
6	—69.0	14.8	27.8	153.3	193	106
7	—69.9	11.3	23.2	155.2	253	114
8	—71.1	9.8	19.1	155.4	283	106
9	—73.9	7.1	16.2	160.3	335	107
11	—75.8	5.8	13.7	162.2	368	102
12	—73.4	6.5	13.8	158.4	383	107
13	—72.0	7.4	13.6	155.4	365	100
17	—68.2	13.9	27.1	152.6	215	115
18	—69.6	12.0	23.2	153.7	241	109
19	—70.2	11.1	21.4	154.2	256	108
20	—69.6	11.9	22.3	153.0	245	106
21	—68.1	14.0	26.4	151.6	216	111
22	—66.6	15.8	30.3	150.7	184	112
23	—66.1	22.5	41.0	152.6	125	112
24	—66.0	21.3	38.5	150.4	137	112
25	—65.6	20.3	36.1	148.3	150	113
26	—66.3	17.6	31.8	148.8	177	113
27	—67.5	14.6	27.1	150.5	212	113
28	—69.0	12.5	23.0	151.8	239	108
31	—68.4	10.4	17.6	150.0	303	106
32	—68.0	11.3	20.2	149.9	280	110
33	—67.8	13.0	23.2	149.7	241	109
34	—66.7	16.0	27.6	147.7	200	109
35	—64.9	18.5	32.3	145.9	176	115
36	—67.6	12.9	22.3	148.9	247	108
37	—65.5	18.8	29.5	145.0	175	103
38	—66.7	13.5	23.1	147.5	244	110
39	—65.7	13.7	23.8	146.4	247	115
40	—64.9	15.7	24.4	143.8	223	107
41	—63.2	19.7	30.7	140.2	179	111
43	—65.7	13.8	21.7	144.8	251	107
44	—65.2	12.9	19.2	144.1	277	104
45	—63.6	12.7	17.5	141.6	301	105
46	—68.0	17.7	34.9	156.0	158	113
47	—68.8	17.5	36.3	161.8	151	114

It is remarkable that its *vertical extension* was only about 10 to 15 km, compared with its horizontal extension which was over 340×180 km^2.

The aurora changed its aspect very quickly. In fact, the next set, No. 99, had no resemblance to No. 98. It was taken at $20^h\,21^m\,28^s$ simultaneously from the same 4 stations, and had a form well adapted to fantastic interpretations from people in the street: it resembled a running gnome or a fantastic aeroplane, as one can judge from the Lillehammer picture on Plate 32. The color was yellow green. The measurements gave the following results: See p. 70, second column.

Mean height for all points 108 km.

From this it is seen that the aurora was at the same mean height over the earth as the foregoing set. The points Nos. 27 and 28 at the "hind leg",

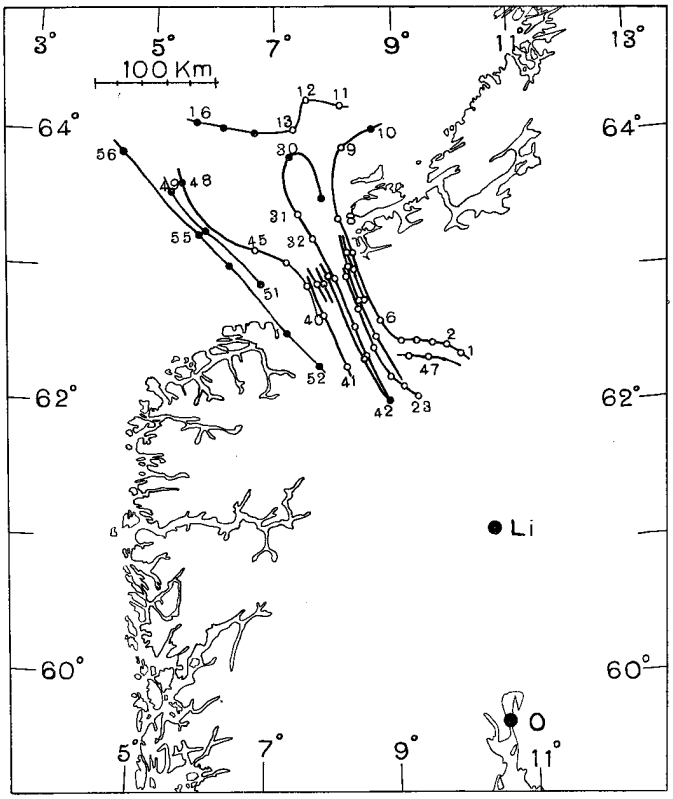

Fig. 73. Geographical situation of aurora bands on January 7th—8th, 1937, at $20^h\ 21^m\ 02^s$.

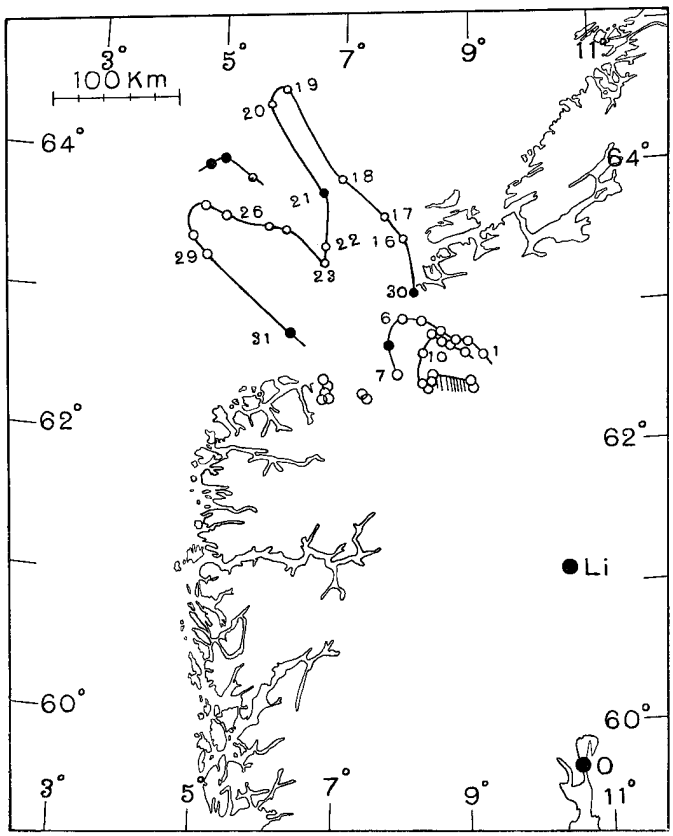

Fig. 74. The same bands as on Fig. 73, at $20^h\ 21^m\ 28^s$.

Remarkable Bands at $20^h\ 21^m\ 28^s$ MET, January 7th—8th, 1937.

Base line Lillehammer—Oscarsborg 158.65 km.

P	ε_2	p	h	a	D	H
1	—70.9	14.1	29.1	159.3	182	106
2	—70.5	13.7	27.6	157.2	195	106
3	—70.2	13.7	26.3	155.1	200	103
4	—69.5	13.6	25.1	152.9	212	105
5	—68.4	13.6	24.0	150.3	227	102
7	—63.1	18.1	27.1	139.7	203	108
8	—64.8	18.3	28.8	142.7	185	106
9	—64.6	18.8	30.2	142.9	179	108
10	—67.0	15.7	26.1	147.2	203	104
11	—68.0	14.3	26.5	151.0	212	110
12	—68.9	14.5	27.8	153.4	199	109
13	—69.4	14.8	29.3	155.1	188	110
14	—69.6	15.2	31.8	158.8	175	113
Mean height for Nos. 1—7 = 105 km, for Nos. 8—14 = 109 km.						
16	—71.0	9.6	18.3	154.7	290	104
17	—70.7	9.1	16.6	153.7	312	103
18	—69.0	8.8	14.7	151.2	354	105
19	—68.8	7.3	10.7	150.9	438	99
20	—67.3	8.0	11.3	148.8	424	100
22	—65.1	11.5	16.4	144.3	317	103
23	—63.7	12.2	18.3	142.8	307	110
24	—63.1	11.4	14.7	141.6	347	102
25	—62·0	11.5	13.8	140.1	358	99
26	—59.5	11.5	13.3	137.3	388	106
27	—58.9	11.3	11.5	136.5	405	96
28	—56.3	12.4	12.0	132.9	396	97
29	—55.8	13.0	14.5	132.2	378	111
32	—62.9	10.1	13.3	142.4	395	107
35	—57.9	20.6	29.2	131.1	207	120
36	—58.3	20.2	27.4	131.2	212	115
37	—56.5	19.1	23.2	128.7	243	110
38	—55.4	19.5	26.7	128.3	238	126
39	—54.5	20.4	27.3	126.3	231	125
40	—55.7	19.9	23.5	127.0	237	108
41	—53.7	20.4	26.8	125.3	236	126
42	—66.6	17.1	27.9	146.3	186	102
43	—65.1	18.0	30.7	145.0	182	113
44	—69.5	16.6	30.2	153.7	166	99
45	—67.7	17.9	34.0	153.5	160	111

however, went down to 96 and 97 km, and the "right arm", Nos. 1—14, had a mean height for its lower part of 106 km, for its upper part 109 km. The upper part of some small rays reached a height of about 126 km. The whole display had, like the former one, a small vertical extension (of about 30 km) compared with its horizontal extension, length more than 280 km and breadth more than 150 km. The geographical situation is seen on Fig. 74 together with the position of the auroral stations; for the points Nos. 21, 30 and 31 the height was assumed to be 102 km, for the points 6, 33 and 34, 106 km. The sketches are seen on Plate 13 and the pictures from Lillehammer and Oscarsborg on Plate 32.

It is remarkable how quickly the aurora has changed its form in the 26 seconds between the pictures Nos. 98 and 99.

The next set of pictures was taken on the same night from the same 4 stations simultaneously at $21^h\ 10^m\ 10^s$ of the remarkable *quiet and isolated bands* mentioned above. We have measured out the two pictures from Lillehammer and Tømte, base line 94.50 km. As the parallaxe was very great, from 29 to 45 degrees, we had some difficulty in identifying the different parts of the band; in fact it looked very different from two stations as seen on Plate 32.

The results of the measurements were:

Remarkable quiet and isolated band at $21^h\ 10^m\ 10^s$ MET on January 7th—8th, 1937.

Base line Lillehammer—Tømte, 94.50 km.

P	ε_2	*p*	*h*	*a*	*D*	*H*
1	—37.1	37.3	48.4	69.7	82	93
2	—33.6	34.3	52.3	65.5	84	112
3	—38.4	39.0	53.5	68.6	66	91
4	—35.2	37.6	56.3	65.4	68	113
5	—36.2	39.7	46.4	63.5	82	87
6	—31.4	37.4	52.0	60.3	82	105
7	—25.0	29.9	32.2	64.7	143	93
8	—22.4	28.6	36.0	62.6	146	110
9	—27.5	29.1	33.9	69.5	142	96
10	—25.2	28.2	37.7	66.5	143	113
11	—32.2	31.2	36.6	71.7	123	94
12	—29.6	30.3	40.5	69.4	124	109
13	—33.4	32.1	40.5	72.0	113	97
14	—30.7	31.7	44.5	68.9	110	110

The mean height of the lowest points was 93 and of the highest 111 km.

The sketches are seen on Plate 13, the pictures on Plate 32 and the geographical situation on Fig. 75.

Table 27.

Height of Quiet Aurora Bands, January 7th—8th, 1937.

No.	Base	MET	Near lower border	Near upper border
132	*C—O*	20.55.38	92, 97, 97, 97, 96	111, 109, 116
133	*C—O*	.56.24	96, 85, 92, 94, 91, 93	123, 111, 143, 120, 111, 121
137	*T—O*	21.10.10	94, 95, 95, 95	108, 109, 111, 112
137	*T—C*	.10.10	93, 90, 98, 97, 96,	106, 105, 111, 110, 111
138	*Li—T*	.11.20	94	
138	*C—O*	.11.20	88, 95, 85, 90	119, 117, 111, 109
139	*C—O*	.12.44	93, 95, 88	114, 110, 97
139	*T—O*	.12.44	93, 97, 91	118, 121
140	*O—T*	.16.38	92, 93, 85	119, 113
140	*T—O*	.16.38	91, 89	
			Mean 93 km	Mean 113 km

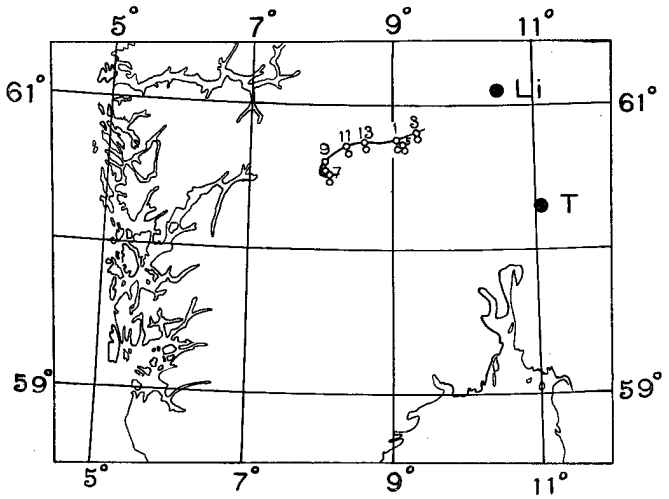

Fig. 75. Geographical situation of the quiet band on January 7th—8th, 1937, at $21^h\ 10^m\ 10^s$.

We have also measured the rest of the pictures of this aurora form and with the following result: (See Table 27.)

The mean heights of the upper and lower parts are thus practically the same as for the picture 137.

75. Fine Band on September 18th—19th, 1941.

The next case worth mentioning was a most beautiful band on the evening of September 18th, 1941, when a gorgeous aurora was seen all over Europe and even from the Azores. (See section 7.) In Oslo clouds made photography impossible, but I had telephonic connection with my stations Lillehammer and Kongsberg and I was then able to lead the photographic work and exposures at these stations. At $20^h\ 25^m\ 46^s$ simultaneous pictures were taken of a very fine band towards west. The Lillehammer picture which resembled very much the two finest photographs from my Bossekop expedition in 1910, Plates 67 and 73 in the report on the expedition,[1] has been reproduced on Plate 33. As the Kongsberg picture was also very fine, we have measured out these two pictures. With the long base line of about 167 km, the parallaxes are very great, from 26 to 54 degrees, which give very exact results. For the lower border of the most luminous part we found the heights

94, 94, 94, 93, 97, 98 km,

[1] Bericht über eine Expedition nach Bossekop zwecks photographischer Aufnahmen und Hohenmessungen von Nordlichtern, Videnskabsselskabets Skrifter, Math.-Naturv. Klasse No. 17, Oslo 1911.

mean 95 km. The vertical extension of the most luminous part was about 14 km. The color was yellow green. The band visible on Plate 33 stretched from Bergen towards the Faeröe Islands.

76. Similar Band on October 31st—November 1st, the Same Year.

As a last case we have chosen a fine band with ray structure observed on the night of October 31st to November 1st, 1941. That night a very fine aurora occurred after midnight. It was first observed as a diffuse arc in the north which later changed into curtains and rays. We had the two stations Holmestrand (*Hs*) and Oslo Meteorological Institute (*M*) in action and a long series of interesting pictures was taken until dawn. At $0^h\ 30^m$ MET a very fine band with ray structure stretched from the western horizon over to north and a series of sets was taken. From one of these (see Plate 33) the height of the lower border was found to be about 96 km. The band was very similar to that just mentioned and to the band photographed from Trondheim on March 24th—25th, 1936, reproduced in my paper: "*Remarkable Aurora Forms from Southern Norway. II. Some Arcs and Bands with Ray Structure*[1], Plate VI—X. Its geograpical situation measured from the photographs was from the north of Scotland to Bergen, then towards north east and north over Dombaas and Trondheim, and westwards again over the sea west of Namsos; the visible part had a length of about 1500 km.

[1] Geofysiske Publikasjoner Vol. XI, No. 12.

The band had a very intense yellow green color and was well adapted for cinematographic exposures.

I was prevented from working at my station personally, as was Mr. Nygaard, who generally was in charge of the cinematographic work; this work was therefore taken over by another of my assistants, Mr. Østvold, who succeeded in taking a fine series of the northern part of the band. Each second a new picture was taken and the time was regulated by a metronome giving the seconds. From the intensity of the band it is evident that a much shorter exposure would have been sufficient, but as it was his first attempt, Mr. Østvold did not realize exactly the intensity of the band.

At all events, the moving picture series was so interesting that it has been reproduced on Plate 34. It was taken about $0^h\ 30^m$ MET.

Later in the night, after 2^h, red rays were seen in NE and before dawn my assistant Hassel, who at that time was alone at the station *M*, photographed fine sunlit rays in the northeast and north.

77. Summary.

In this part some new cases of two of the aurora forms earlier published are described, namely homogeneous arcs of great altitude and remarkable aurora bands. Typical cases of the first form occurred on February 6th—7th and March 5th—6th, 1938, and on December 20th—21st, 1940.

The bands described are from January 7th—8th, 1937, and from September 18th—19th and October 31st—November 1st, 1941. On the last night a moving picture strip was taken, reproduced on Plate 34.

PART X. THE AURORAL WORK SINCE 1922

78. Some Statistics on the Auroral Work since 1922.

In the preceding monographs most of the remarkable forms observed in southern Norway have been described. There are, however, still certain forms which deserve description, but the material is so scanty that it is better to await more observations. It is in fact remarkable how varied the big aurorae over Oslo can be. In almost every new case something remarkable occurs. The trained observer who watches the aurora the whole night very often discovers rare forms, even such as have not occured before, and these ever changing displays are the principal cause of the great thrill of this work, which let him forget uncomfortable conditions in the cold winter nights.

It might be of interest to give a list of the number of successful photographs taken since 1922. This is made in Table 28.

To these statistics we may add the following remarks: Under heading I the number of single photographs is given for each night. II, III, and IV show the number of sets of photographs taken simultaneously from 2, 3, or 4 stations. The heading "Sets" gives the total number of sets of simultaneous pictures, that is the sum II+III+IV.

The heading Σ gives the total number of pictures, that is the sum

$$\Sigma = I + 2 \cdot II + 3 \cdot III + 4 \cdot IV.$$

As seen from the next two columns the number of measured sets is very different for the different years. For the years 1923 to 1926 inclusive, most of the plates have been measured; in fact this work was begun but not continued, on account of other occupations. Also most of the materiel from the polar year 1932—1933 has been evaluated, but not yet published. For certain years, like 1931, 1934, and 1935 almost nothing has been done, and for the remaining years only aurorae of special interest have been measured out.

Table 28.

Auroral Work in Southern Norway in the Years from 1923 to 1941 Inclusive.

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1923	October 16th—17th	19	31	5		36	96	36	188		*B, C, D, H, K, O*
1924	November 24th—25th		6			6	12	6	19		*B, K*
	December 20th—21st	3					3				*B*
1925	January 16th—17th	3					3				*B*
	— 19th—20th	11	10	2		12	37	12	50		*B, D, H, K*
	February 19th—20th	5					5				*B*
	October 9th—10th	1					1				*B, K, O*
	November 8th—9th	16	7			7	30	7	65		*B, T*
	— 10th—11th	18	25			25	68	25	102		*B, C, D, K, T*
1926	January 26th—27th	15	24			24	63	24	91		*B, C, O, T*
	March 3rd—4th	2					2				*B, T*
	— 5th—6th	18	29	7		36	97	24	98		*B, C, D, K, O, T*
	— 9th—10th	6	3			3	12	1	8		*B, C, K, T*
	— 13th—14th	4					4				*B, T*
	— 19th—20th		11			11	22	11	61		*B, D*
	May 3rd—4th	3					3				*B*
	September 7th—8th	2					2				*B*
	— 8th—9th	1	14			14	29	14	84		*B, C, K, O*
	— 14th—15th	5	3			3	11				*B, C, D, K, O, T*
	— 15th—16th	26	14	1		15	57	1	4		*B, C, K, O*
	— 16th—17th		4			4	8				*B, T*
	October 15th—16th	88	59	7		66	227	46	233		*B, C, K, O, T*
	November 28th—29th	17	24	11		35	98	1	2		*B, C, K, O, T*
	Deeember 23rd—24th	3					3				*T*
1927	November 29th—30th	2					2				*C, K, T*
	December 13th—14th	24	44	3		47	121	46	260		*B, C, D, K, O, T*
1928	March 11th—12th	3	9			9	21	5	17		*C, K, T*
	— 13th—14th	2	31			31	64	2	6		*C, D, K, T*
	May 11th—12th	6					6				*C*
	August 26th—27th	5	24	32		56	149	37	183		*C, K, O, T*
	September 7th—8th	5	7			7	19	6	20		*C, K, O*
	— 18th—19th	19	6	26	5	37	129	32	183		*C, K, O, T*
	October 13th—14th	4					4				*B, C, K, T*
	— 25th—26th	8	5	7		12	39				*C, K, O*
	November 2nd—3rd	46	12			12	70				*C, K, O*
	— 6th—7th	13	3	2	2	7	33				*B, C, K, O, T*
	— 13th—14th	45	1	1		2	50				*C, K, O*
1929	January 5th—6th		1	2		3	8				*C, K, T*
	February 26th—27th	6	37			37	80	6	14		*C, K*
	— 27th—28th	23	43			43	109				*C, K, O*
	— 28th—March 1st	13	16	4		20	57	13	99		*C, K, O*
	March 15th—16th	9	15	37	13	65	202	51	293	2	*C, K, O, T*
	April 15th—16th			3	8	11	41	2	29		*C, K, O, T*
	— 16th—17th	12	2	13	45	60	235	60	263	1	*C, K, O, T*
	September 9th—10th	3					3				*C, K*
	October 7th—8th	7	15			15	37				*C, O*
	— 30th—31st	1	7	9		16	42				*C, K, T*
	November 3rd—4th	2	6	13	3	22	65				*C, K, O, T*
	— 16th—17th		2	5		7	19				*C, K, O, T*
	December 3rd—4th	2					2				*K*
	— 16th—17th	11	14	14	11	39	125	1	2		*C, K, O, T*

Table 28 (continued).

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1930	January 4th—5th	1	1			1	3				*C, K, O, T*
	— 6th—7th	4	8	7	1	16	45				*C, K, O, T*
	— 20th—21st	22	10	15	5	30	107				*C, K, O, T*
	April 29th—30th		7	8		15	38				*C, K, O*
	August 21st—22nd	5	9	6		15	41				*C, K, O*
	September 1st—2nd		15			15	30				*C, K*
	— 3rd—4th	4	10			10	24				*C, K*
	— 18th—19th	23	37	29		66	184	3	10		*C, K, O, T*
	— 29th—30th	1	9	2		11	25	11	105		*C, K, O, T*
	October 3rd—4th	1	12	15		27	70	1	3		*C, K, O*
	— 14th—15th	10	6			6	22				*C, O*
	— 17th—18th	33					33				*K*
	— 26th—27th		38	3		41	85				*C, K, O*
	November 24th—25th	2					2				*C, K, O*
1931	September 20th—21st	42	22	24		46	158				*C, D, K, O, T*
	October 2nd—3rd	1					1				*C, K, T*
	— 29th—30th	11	6			6	23				*C, O, T*
	— 30th—31st	22	24	4	2	30	90	1	5		*C, K, O, T*
	— 31st—Nov. 1st	4	1			1	6	1	3		*C, K, O, T*
	November 5th—6th	2	3	7	2	12	37	1	2		*C, D, K, O, T*
	— 16th—17th	10	10	4		14	42				*C, D, K, T*
1932	March 10th—11th	17	19	12		31	91	18	128		*C, K, O*
	April 13th—14th	6					6				*C, K, T*
	August 29th—30th	3	2	7	8	17	60	12	48		*C, Li, O, T*
	September 23rd—24th	2					2				*C, Li, O*
	October 23rd—24th	4					4				*C, Li, T*
1933	February 18th—19th	4					4				*Lø*
	— 22nd—23rd	4					4				*Lø*
	March 18th—19th	54	55			55	164	27	143		*C, Da, Li, Lø, K, N, O*
	— 19th—20th	4	12			12	28	12	64		*Lø, N*
	— 21st—22nd	10	5			5	20	2	5		*C, K, Li, O, T*
	— 23rd—24th	42	65	2		67	178	53	254		*Li, Lø, N*
	— 24th—25th	38	72			72	182	50	176		*Lø, N*
	April 15th—16th	22	19	8		27	84	25	123		*C, Da, K, Li, Lø, O, U*
	— 18th—19th	17					17				*Lø*
	— 21st—22nd	1		4		4	13	4	32		*C, Da, K, T*
	May 1st—2nd	52	31	38		69	228	61	432		*C, Da, K, Li, Lø, T*
	September 14th—15th	41	20	21	6	47	168				*C, K, Li, Lø, O, T*
	— 15th—16th	2					2				*Lø*
	— 17th—18th	7					7				*Li, Lø*
	— 25th—26th	25					25				*Lø*
	— 27th—28th	11					11				*Lø*
	— 28th—29th	5					5				*Lø*
	November 6th—7th	1	7	12	1	20	55				*C, K, Li, T*
	— 7th—8th		4	4		8	20				*C, K, Li*
	— 11th—12th	31					31				*Lø*
	December 9th—10th	12	43	14		57	140	8	59		*C, K, Li, T*
	— 10th—11th	18	14	5		19	61				*C, K, Li, T*
1934	January 14th—15th	24					24				*Lø*
	February 16th—17th	17	6	1		7	32				*C, K, O, T*
	— 17th—18th		3			3	6				*K, T*
	March 7th—8th	2					2				*Da*
	— 22nd—23rd	25					25				*Lø*
	— 25th—26th	7	8	11		19	56				*C, Da, Li, O*
	August 26th—27th	3					3				*Da*
	— 27th—28th	18	19	16		35	104	1	8		*C, Da, K, Li, Lø, T*
	September 25th—26th	15	2	9	5	16	66				*C. K, Li, O*
	— 27th—28th	1	1			1	3				*C, K, T*
	October 15th—16th	47	24	43	4	71	240				*C, Da, K, Li, O*
	— 25th—26th	5					5				*C, Lø*
	November 7th—8th	24					24				*Lø*
1935	January 23rd—24th	13	18	33		51	148	1	2		*C, Da, K, T*
	— 27th—28th	127	97	28	27	152	513	7	52		*C, Da, Li, K, O, T*
	February 1st—2nd	90	8	8		16	130				*C, Da, Li, K, O, T*
	— 24th—25th	66	7	9	10	26	147				*C, Da, Li, K, O, T*
	March 1st—2nd	2					2				*Li*
	— 14th—15th	14	23			23	60				*C, Da, Li, K, O, T*

Table 28 (continued).

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1935	September 16th—17th	3					3				*Da*
	— 24th—25th	6					6				*N*
	— 29th—30th	7					7				*C, Li, N*
	October 20th—21st	12					12				*C, K, Li, T*
	— 21st—22nd	71	54	14	2	70	229	1	11		*C, Da, K, Li, O, T*
	— 25th—26th	32					32				*N*
	— 27th—28th	7					7				*N*
	— 28th—29th	18	4			4	26				*C, Da, K, Li, T*
	November 14th—15th	6					6				*C, Da, Li, T*
	— 27th—28th	4	5			5	14				*C, Da, K, Li, T*
	— 30th—Dec. 1st	7					7				*N*
1936	January 18th—19th	27					27				*Da*
	— 24th—25th	86	66	15	5	86	283	2	27		*C, Da, K, Li, O*
	February 2nd—3rd	4					4				*N*
	— 26th—27th	2					2				*N*
	March 18th—19th	6					6				*Da*
	— 22nd—23rd	3					3				*G*
	— 24th—25th	56					56				*N*
	— 27th—28th	31	15	41	5	61	204	1	3		*C, G, K, Li, T*
	April 20th—21st	38	38	63	4	105	319	10	57		*C, K, Li, O, T, V*
	— 21st—22nd	14	40	7	1	48	119	14	49	2	*C, K, N, O, T, V*
	September 12th—13th	10					10				*Å*
	— 26th—27th	2	24			24	50				*C. K, Li, T*
	October 5th—6th	38					38				*Å*
	— 7th—8th	5					5				*Å*
	— 8th—9th	1					1				*Å*
	— 15th—16th	23					23				*V*
	— 16th—17th	186	90	91	19	200	715	39	267	16	*C, K, Li, O, T, V*
	— 20th—21st	29					29				*C, G, V*
	— 24th—25th	32	31	10		41	124	1	25	1	*C, K, Li, N*
	November 3rd—4th	73	30	16	10	56	221	2	7		*Å, C, Li, O, T*
	— 10th—11th	68					68				*Å, G*
	— 11th—12th	25					25				*G*
1937	January 7th—8th	209	63	82	44	189	757	17	249		*C, G, Hk, K, Li, N, O, T*
	— 10th—11th	5					5				*N*
	March 30th—31st	2					2				*Hk*
	— 31st—April 1st	29	3			3	35				*Ak, C, K, Li, Tu*
	April 1st—2nd	38					38				*Ak*
	— 2nd—3rd	4					4				*Ak*
	— 28th—29th	2					2				*Ak, C, Li*
	— 29th—30th	5					5				*Hk*
	May 4th—5th	22	26	12	7	45	138	4	24		*Ak, C, Hk, K, Li, T*
	September 10th—11th	30					30				*Ak, C, Hk, Tu*
	— 23rd—24th	5					5				*Hk*
	— 30th—Oct. 1st	69	24	1		25	120				*Ak, C, Hk, K, N, O*
	October 9th—10th	11					11				*Ak, C, Hk, K, Li, T*
	— 11th—12th	52	43	34	9	86	276	5	43	2	*Ak, C, Hk, K, Li, O, T, Tu*
	— 12th—13th	77	29	20	21	70	279				*Ak, C, Hk, K, Li, T*
	— 15th—16th	15					15				*Hk*
	November 27th—28th	37					37				*Ak, C, Hk, K*
1938	January 17th—18th	2	2	2		4	12				*Ak, C, Li, O, Tu*
	— 18th—19th	28	14	17	2	33	115				*Ak, C, Hk, K, Li, O, T*
	— 21st—22nd	5	21	49	1	71	198	4	24		*Ak, C, Hk, K, Li*
	— 22nd—23rd	3	21			21	45				*C, Hk, K, Li, T*
	— 23rd—24th	1	3	9	2	14	42	2	11		*Ak, C, Hk, K, Li*
	— 25th—26th	477	123	70	21	214	1017	50	335	15	*Ak, C, Hk, K, Li, O, T, Tu*
	— 27th—28th	9					9				*Hk*
	— 30th—31st	2					2				*Hk*
	February 5th—6th	1					1				*Hk*
	— 6th—7th	144	74	43		117	421	6	24	3	*C, Hk, K, Li*
	— 10th—11th	32					32				*Hk*
	— 14th—15th	1					1				*Hk*
	— 23rd—24th	5					5				*Hk*
	March 1st—2nd	34	13	3		16	69			3	*Ak, C, Hk, Li*
	— 4th—5th	58		1		1	61			1	*Ak, C, Fi, Li*
	— 5th—6th	130	43	30		73	306	14	58		*Ak, C, Fi, Li, O, T*
	— 6th—7th	103					103				*Fi*

Table 28 (continued).

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1938	March 21st—22nd	93	6	22	32	60	299	13	75	5	*Ak, C, Fi, K, T*
	— 22nd—23rd	148	40	38	17	95	410			10	*Ak, C, Fi, K, Li, O, T*
	— 29th—30th	31					31				*Hk*
	April 6th—7th	87	1	4	1	6	105	1	9	3	*Ak, C, Hk, K, T*
	— 16th—17th	40	9	1	2	12	69	3	14	4	*Ak, C, Hk, K, Tu*
	— 17th—18th	22					22				*Hk*
	— 18th—19th	38					38			1	*Ak, Hk*
	— 22nd—23rd	93	31	41	4	76	294	2	8	8	*Ak, C, Hk, Li, Tu*
	— 23rd—24th	6					6				*C, Hk*
	May 3rd—4th	105	11	12	5	28	183			1	*Ak, C, Hk, K, T*
	— 4th—5th	17	2			2	21			2	*Ak, C, Hk*
	August 1st—2nd	5					5				*C*
	— 22nd—23rd	75	16	1		17	110				*Ak, C, Hk, K, Li*
	— 24th—25th	4	15	10		25	64				*Ak, C, K*
	September 13th—14th	119	14	29	30	73	354	4	17	8	*Ak, C, Hk, K, Li, O, T*
	— 14th—15th	184	125	21	3	149	509	10	80	17	*Ak, C, Hk, K, Li, O, T*
	— 15th—16th	80	21	4	6	31	158	3	13	8	*Ak, C, Hk, K, Li*
	— 30th—Oct. 1st	52	30	11	5	46	165	3	14	8	*Ak, C, Hk, K, Li, T*
	November 8th—9th	10	43	80	20	143	416	2	10	10	*Ak, C, Hk, Li, O, T, Tu, W*
	— 14th—15th	142	57	42	3	102	394	5	22		*Ak, C, Hk, Li, O, T*
	— 24th—25th	6					6				*Hk*
	December 2nd—3rd	17					17				*Hk*
	— 3rd—4th	25					25				*Hk*
	— 17th—18th	11					11				*Hk*
	— 18th—19th	41					41				*Hk*
1939	February 1st—2nd	89					89				*Hk*
	— 6th—7th	25	8	2		10	47	1	2		*Ak, C, Hk, Li, O, W*
	— 13th—14th	6					6				*Hk*
	— 16th—17th	8					8				*Hk*
	March 10th—11th	25					25				*Hk*
	— 11th—12th	47					47				*Hk*
	— 14th—15th	10					10				*Hk*
	— 15th—16th	58					58				*Hk*
	— 19th—20th	12					12				*Hk*
	— 28th—29th	8					8				*Li*
	— 29th—30th	36	26	6		32	106	1	4		*C, Hk, Li, W*
	— 30th—31st	120	2			2	124				*C, Hk, Li*
	April 18th—19th	82	30	50	3	83	304	7	50	3	*Ak, C, Hk, Li, O, T, Tu*
	— 20th—21st	71					71				*Ak, C, Hk, O*
	— 21st—22nd	6					6				*Hk*
	— 23rd—24th	4					4				*Hk*
	— 24th—25th	94	60	4		64	226	8	48	7	*Ak, C, Hk, Li, O, T, Tu, W*
	— 25th—26th	61					61				*Hk*
	— 27th—28th	36					36				*Hk*
	— 28th—29th	14					14				*Hk*
	May 5th—6th	9					9				*Hk*
	August 12th—13th	39					39				*Hk*
	— 13th—14th	16					16				*Hk*
	September 9th—10th	63					63				*Hk*
	— 12th—13th	4					4				*Hk*
	— 19th—20th	117	24	8		32	189	3	51	12	*C, Hk, O, Tu, W*
	— 30th—Oct. 1st	2	8	6		14	36				*Ak, C, Li, W*
	October 3rd—4th		2			2	4			2	*Ak, C, Li*
	— 5th—6th	7					7				*Hk*
	— 7th—8th	23	18	2		20	65	1	4	2	*Ak, C, Hk, O*
	— 16th—17th	5					5				*Hk*
	— 17th—18th	61	8	12	5	25	133	4	16		*Ak, C, Hk, Li, O, Tu, W*
	— 18th—19th	87	52	11		63	224	1	4		*Ak, C, Hk, Li, O, W*
	— 21st—22nd	39					39				*Hk*
	November 12th—13th	87					87				*Ak, Hk*
	— 17th—18th	1					1				*Hk*
	December 6th—7th	116					116				*Hk*
	— 7th—8th	23	16			16	55				*C, Li, Tu*
	— 16th—17th	18					18				*Hk*
1940	January 2nd—3rd	7					7				*Hk*
	— 3rd—4th	186	30	15	10	55	331	16	66	7	*Ak, C, Hk, Li, O, Tu*
	— 24th—25th	3					3				*Hk*

Table 28 (continued).

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1940	January 29th—30th	93	21	3		24	144			2	*C, Hk, Li, O*
	February 6th—7th	22					22				*Hk*
	— 25th—26th	6					6				*Hs*
	March 9th—10th	16					16				*Hk, Hs*
	— 16th—17th	42					42				*Hk, Hs*
	— 28th—29th	1					1				*Hs*
	— 23th—30th	359	49	30		79	547	3	9	14	*Ak, C, Hk, Hs, K, O*
	— 30th—31st	59					59				*Hs*
	April 2nd—3rd	156	32	32		64	316	1	6		*Ak, C, Hk, Hs, K*
	— 3rd—4th	107	4	1		5	118				*Ak, C, Hk, Hs, K*
	— 25th—26th	67					67				*Hk*
	August 26th—27th	12					12				*Hs*
	September 2nd—3rd	53					53				*Hs*
	— 3rd—4th	56					56				*Hs*
	— 7th—8th	22					22				*Hs*
	— 26th—27th		4			4	8			1	*Ak, Li, M*
	— 28th—29th	46					46				*Ak, Hs, Li, M, T*
	— 30th—Oct. 1st	5					5				*Hs*
	October 2nd—3rd	6					6				*Hs*
	— 8th—9th	150	62	13	12	87	361	1	6	4	*Ak, Hk, Hs, Li, M, T*
	— 11th—12th	51					51				*Hk, Hs*
	— 25th—26th	56					56				*Hk, Hs*
	— 26th—27th	42	2			2	46	2	12		*Hk, Hs*
	— 27th—28th	99					99				*Hk, Hs*
	— 28th—29th	6					6				*Hk*
	November 21st—22nd	28					28				*Hk*
	— 22nd—23rd	106	4			4	114				*Ak, Hk, Hs, Li*
	— 25th—26th	3					3				*Hk*
	— 29th—30th	100	9	4		13	130				*Ak, Hk, Hs, K, Li, M*
	December 2nd—3rd	18					18				*Hk*
	— 20th—21st	93	46	40	6	92	329	8	59	2	*Ak, Hk, Hs, K, Li, M*
	— 21st—22nd	37					37				*Hk, Hs*
	— 22nd—23rd	5					5				*Hk*
	— 26th—27th	10					10				*Hk*
	— 29th—30th	4					4				*Hk*
	— 31st—Jan. 1st	129					129				*Ak, Hk, Hs*
1941	January 1st—2nd	4					4				*Hs*
	— 7th—8th	12					12				*Hk*
	— 18th—19th	81					81				*Hk, Hs*
	— 25th—26th	17					17				*Hk*
	February 13th—14th	21					21				*Hk*
	— 25th—26th	83					83				*Hk, Hs*
	March 1st—2nd	17					17				*Hs*
	— 11th—12th		9	28		37	102				*Ak, K, Li, M*
	— 13th—14th	63	22	32	5	59	223				*Ak, Hs, Li, K, M*
	— 19th—20th	18					18				*Hs*
	— 23rd—24th	13					13				*Hs*
	— 30th—31st	172	9	10		19	220	3	8	10	*Ak, Hk, Hs, K, M*
	April 7th—8th	59					59				*Hs, M*
	— 18th—19th	6					6				*Hs*
	— 24th—25th	262	73	30		103	498	4	32	9	*Ak, Hs, Li, M*
	May 3rd—4th	11					11				*Hs*
	August 25th—26th	142					142				*Hs, M*
	— 27th—28th	72					72				*Hs*
	September 14th—15th	59					59				*Hs, M*
	— 18th—19th	87	5			5	97	2	10		*Ak, Hs, K, Li, M*
	— 19th—20th	85	21	2		23	133			1	*Ak, Hs, Li, M*
	— 20th—21st	5					5				*M*
	— 21st—22nd	202	134			134	470	57	293	7	*Ak, Hs, M*
	— 22nd—23rd	20	4			4	28	1	3		*Hs, M*
	— 25th—26th	35					35				*Hs*
	October 10th—11th	94					94				*Hs, M*
	— 11th—12th	194	21	11		32	269			2	*Ak, Hs, Li, M*
	— 12th—13th	6					6				*Hs*
	— 22nd—23rd	121	35	27	16	78	336	2	7	4	*Ak, Hs, Li, K, M*
	— 23rd—24th	81					81				*Hs, M*
	— 24th—25th	61	4	1		5	72				*Ak, Hs, M*

Table 28 (continued).

Year	Date	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1941	October 26th—27th	33	18	46	25	89	307			4	*Ak, Hs, Li, M*
	— 31st—Nov. 1st	182	67			67	316	1	5	12	*Hs, M*
	November 1st—2nd	3					3				*Hs, K, M*
	December 1st—2nd		17			17	34				*Hs, Li*
	— 13th—14th	40	6			6	52			1	*Ak, Hs, M*

As to the spectra only a few have been taken before 1936. Since that time Mr. Hetland and in particular Mr. Herlofson have taken a good deal, but very few of them have been studied in detail.

As to stations in action their situations are seen on the two maps Figs. 76 and 77. The meaning of the letters is seen from the following list where the number in parentheses means the height in meters over sea level:

Å, *Aas*, near Oslo, Latitude 59° 39′ 57″, Longitude 10° 46′ 17″ E Gr. (94), for some time, in 1936, used by my assistant Olaf Hassel. Worked without telephone.

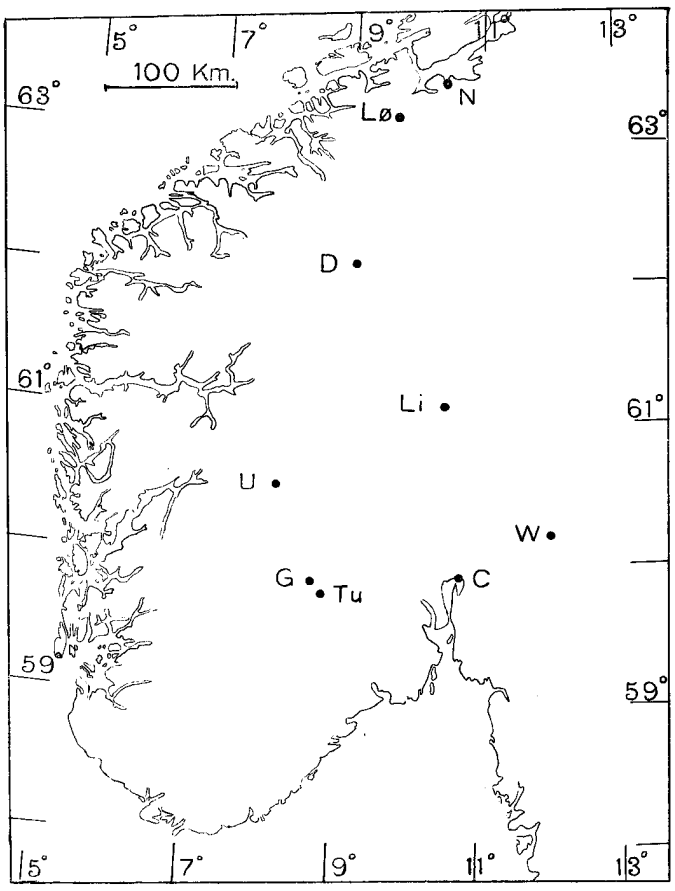

Fig. 76. Photographic auroral stations used since 1922; more distant stations.

Ak, *Askim*, to the south east of Oslo, Latitude 59° 34′ 40″, Longitude 11° 09′ 48″ E Gr. (134), used by my assistant Bjordal since 1937.

B, *Bygdø*, Latitude 59° 54′ 12″, Longitude 10° 41′ 32″ E Gr. (19), former head station used by myself, but not used since 1928.

C, *Oslo Observatory*, Latitude 59° 54′ 44″, Longitude 10° 43′ 24″ E Gr. (33), head station till the autumn of 1940, when it was transferred to station *M*. Most of the pictures have been taken at the station *C*. A great many of them were taken by myself and later by my assistants Tveter, Wesøe, Anda, Egeberg, Herlofson, and Owren.

In all not less than 35 helpers have done their work at this station, up to 8 assistants at the same time.

D, *Dombaas*, Latitude 62° 05′ 30″, Longitude 9° 05′ 54″ E Gr. (550), for some years used by the astronomer Sigurd Einbu as my assistant.

Da, *Darbu*, Latitude 59° 41′ 56″, Longitude 9° 48′ 17″ E Gr. (55), for some years used by Hassel. Worked without telephone.

Fi, *Fiskum*, Latitude 59° 41′ 37″, Longitude 9° 49′ 34″ E Gr. (ca. 60), also used by Hassel, in 1938. Worked without telephone.

G, *Gaustatoppen*, Latitude 59° 51′ 00″, Longitude 8° 39′ 36″ E Gr. (1845), near the summit of the mountain Gausta, used for some time, but later transferred to the station *Tu*, on account of unsteady weather. The station *G* was used by Hans Johnsen Tjønn with his daughter.

H, *Horten*, Latitude 59° 24′ 02″, Longitude 10° 29′ 12″ E Gr. (2), south of Oslo, used by Mr. Glimme.

Hk, *Hokksund*, Latitude 59° 45′ 40″, Longitude 9° 54′ 02″ E Gr. (20), not far from Kongsberg, used by Hassel until he moved to Oslo as assistant at the Norwegian Meteorological Institute. Worked without telephone.

Hs, *Holmestrand*, Latitude 59° 29′ 11″, Longitude 10° 19′ 39″ E Gr. (4), south of Oslo, used by

Einar Schrøder. Worked without telephone until 1941, later with telephone.

K, *Kongsberg*,[1] Latitude 59° 40′, Longitude 9° 39′ (cr. 175), west of Oslo, for many years used by Petter O. Busengdal and after his death by his two sons Odleiv and Ragnar; for some years also by Beggerud, Jørgensen, and Vanberg.

Li, *Lillehammer*, Latitude 61° 05′ 47″, Longitude 10° 30′ 11″ E Gr. (350), used by Ole Høstmælingen and his brother.

Lø, *Løkken Verk*, Latitude 63° 07′ 45″, Longitude 9° 41′ 24″ E Gr. (284), south west of Trondheim, used by Herstad during the polar year and some years later. After his death transferred to the station *N*.

M, *Det Norske Meteorologiske Institutt, near Oslo*, Latitude: 59° 56′ 26″, Longitude 10° 43′ 33″ E Gr. (115). Now head station after station *C*. The photographs were taken by Tveter, Herlofson, Olsen, Owren, and myself. From the same station Hassel now takes his pictures (since the spring of 1941. He works alone because he is deaf and dumb.)

N, *The Physical Institute of Norges tekniske Høgskole, Trondheim*, Latitude 63° 25′ 01″, Longitude 10° 24′ 32″ E Gr. (70), used during the polar year and some years afterwards. Photographs were taken by myself and later by Westin.

O, *Oscarsborg*, Latitude 59° 40′ 22″, Longitude 10° 36′ 49″ E Gr. (25), south of Oslo, used successively by Hafnor, Larsen, Bakøy, and Frank Johannesen until April 1940, when it was destroyed by war action.

T, *Tømte*, Latitude 60° 17′ 39″, Longitude 11° 04′ 07″ E Gr. (290), north east of Oslo, during many years used first by Carsten Borchgrevink, later by Albert Tømte and his brothers, until 1941, when the station was transferred to station *Hs*.

Tu, *Tuddal*, Latitude 59° 44′ 12″, Longitude 8° 48′ 49″ E Gr. (733), south of station *G*, used for some years by T. Tjønn.

U, *Ustaoset*, Latitude 60° 30′, Longitude 8° 02′ 42″ E Gr. (990), where I stayed in the Easter of 1933 and took some picturcs. Worked without telephone.

V, *Vestfossen*, Latitude 59° 43′ 44″, Longitude 9° 53′ 05″ E Gr. (30), east of Kongsberg, used for some time by Olaf Hassel. Worked without telephone.

[1] From 1922 to 1942 the station *K* has moved in Kongsberg 7 times, the latitude varying from 59° 39′ 45″ to 59° 40′ 18″ and the longitude from 9° 38′ 29″ to 9° 40′ 13″.

W, *Kongsvinger*, Latitude 60° 11′ 57″, Longitude 12° 01′ 03″ E Gr. (240), used for some years by Hoch Nielsen.

On the next table (Table 29 page 80) the work for each year is summarized.[1] The great number of days when aurorae were photographed since 1938 is partly due to the work of the single stations *Hk* and *Hs*.

To work out statistics of aurora from Table 29 would not give reliable results because many other factors, as weather, zeal of different assistants, and number of stations in action have played too great a part in the result.

Only for the month frequency is the result more reliable. *The greatest frequency is shown by October, next come September and March.* During June and July the nights are so bright that no aurora have been photographed. That the month October shows a maximum agrees with the statistics of aurorae for

[1] In my article: Auroral Work in Southern Norway in the year 1938 I had given a too great number of sets for aurora pictures from 1922 to 1937, due to a misunderstanding of one of my assistants.

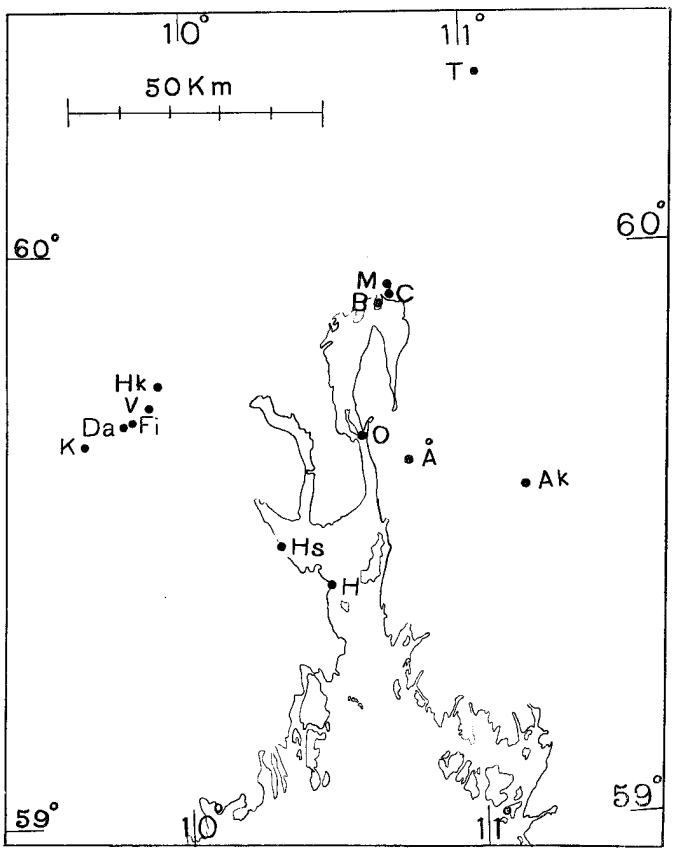

Fig. 77. Photographic auroral stations used since 1922; nearer stations.

Table 29.

Total for Each Year.

Year	Nights	I	II	III	IV	Sets	Σ	Sets measured	Heights	Spectra	Photographic stations in action
1923	1	19	31	5		36	96	36	188		*B, C, D, H, K, O*
1924	2	3	6			6	15	6	19		*B, K*
1925	6	54	42	2		44	144	44	217		*B, C, D, H, K, O, T*
1926	15	190	185	26		211	638	122	581		*B, C, D, K, O, T*
1927	2	26	44	3		47	123	46	260		*B, C, D, K, O, T*
1928	11	156	98	68	7	173	584	82	409		*B, C, D, K, O, T*
1929	14	89	158	100	80	338	1025	133	700	3	*C, K, O, T*
1930	14	106	162	85	6	253	709	15	118		*C, K, O, T*
1931	7	92	66	39	4	109	357	3	10		*C, D, K, O, T*
1932	5	32	21	19	8	48	163	30	176		*C, K, Li, O, T*
1933	22	401	347	108	7	462	1447	242	1288		*C, Da, K, Li, Lø, N, O, T, U*
1934	13	188	63	80	9	152	590	1	8		*C, Da, K, Li, Lø, O, T*
1935	17	485	216	92	39	347	1349	9	65		*C, Da, K, Li, N, O, T*
1936	22	759	334	243	44	621	2332	69	435	19	*Å, C, Da, G, K, Li, N, O, T, V*
1937	17	612	188	149	81	418	1759	26	316	2	*Ak, G, Hk, K, Li, N, O, T, Tu*
1938	42	2486	735	540	154	1429	6192	122	714	107	*Ak, C, Fi, Hk, K, Li, O, T, Tu, W*
1939	39	1529	254	101	8	363	2372	26	179	26	*Ak, C, Hk, Li, O, T, Tu, W*
1940	39	2261	263	138	28	429	3313	31	158	30	*Ak, C, Hk, Hs, Li, K, M, O, T, Tu*
1941	36	2361	445	187	46	678	3996	70	348	50	*Ak, Hk, Hs, Li, K, M*
Total	324	11149	3658	1985	521	6164	27204	1113	6189	237	

the whole of Norway resulting from Sophus Tromholdt's catalogue.[1]

In this report of our work we may add some words on our attempts to take moving pictures of aurorae. Since my first attempt on my auroral expedition to Bossekop in 1913[2] new systematic work has been done from time to time since 1938. Several meters of good pictures were taken first by myself,[3] then by my assistants Herlofson, Nygaard, and Østvold, and in showing these films on a screen one gets a rather good impression of the phenomenon in spite of the drawback that the aurora on the screen moves up to 10 times as fast as the aurora itself.

Regarding the more detailed reports of the aurora work, a great aurora log for the years 1923 to 1937 has been worked out, but not published. In this log the following data for each picture have been noted: Number of picture, station, time, exposure, auroral form, stars, number of points measured and general remarks.

As to visual observations a similar log has been made and since 1927 annual reports have been published in Camille Flammarion's Annuaire.[1]

Many things remain to be worked our from the immense material collected and a part of this program may possibly be completed in the coming years, at least the report from the polar year 1932–33, because most of the material from this year has already been measured out and calculated.

79. Acknowledgements.

I want to conclude this paper by expressing my deep gratitude to the following persons and institutions:

— To all my assistans at the stations, who have not feared darkness and cold to assist me even from sunset to sunrise.

— To the assistants who have helped me in measuring and calculating the plates and in drawing the figures and diagrams, in particular to Herlofson, Egeberg, Wasiutyński, and Østvold, specially in charge for this paper.

— To the Department of Education which has given a yearly grant to cover the expenses of having the aurora stations in action.

[1] Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter, Kristiania 1902, p. 420.

[2] On an Auroral Expedition to Bossekop in the spring of 1913. The Astrophysical Journal, Vol. XXXVIII, p. 311—314, 1913.

[3] Auroral Work in Southern Norway in the Year 1938, Terr, Magn. Vol. 44, p. 241.

[1] Annuaire astronomique et météorologique, Camille Flammarion, publié par l'Observatoire de Juvisy, années 1929—1941.

— To the foundations Nansenfondet and Forskningsfondet who have given grants for measuring and calculating the material.

— To the administration of telephone and telegraph who have allowed me to use the state telephone lines between the aurora stations without any expenses. In particular to the women chief operators of the state telephone who have always done their best to get telephonic connections in order as quickly as possible.

— To my colleague professor Rosseland who has given me excellent working accomodations at the Institute of Theoretical Astrophysics, Blindern, Oslo.

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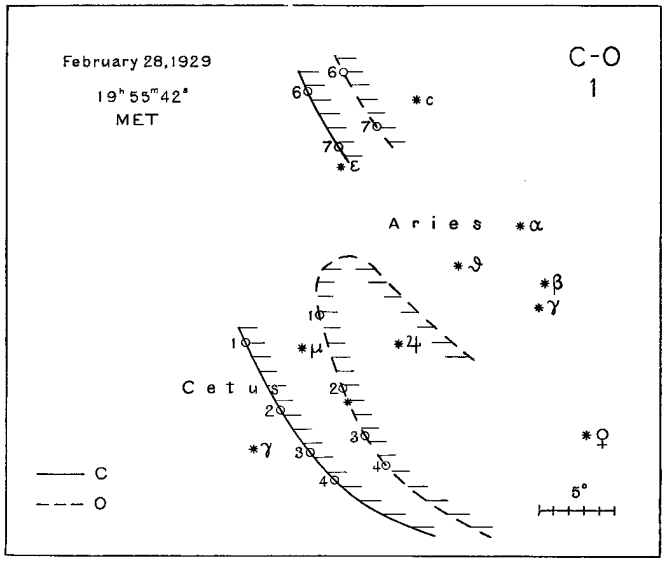
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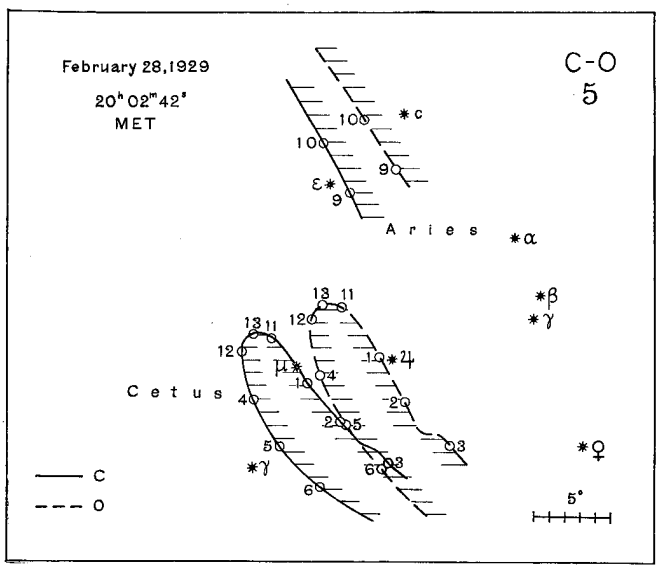
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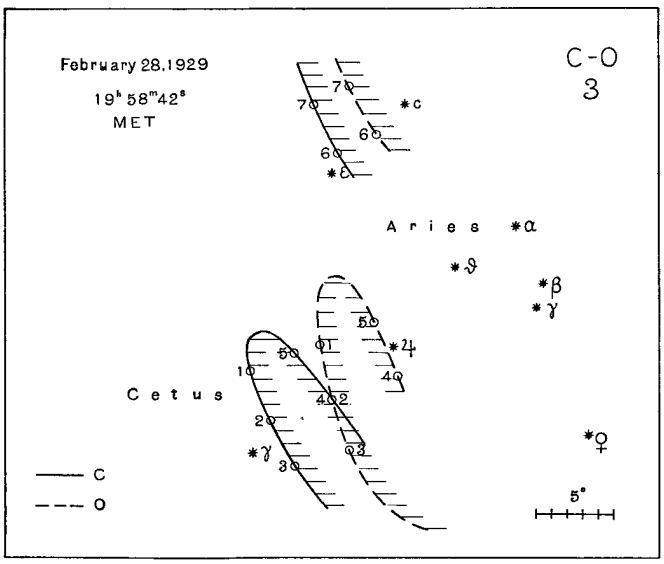
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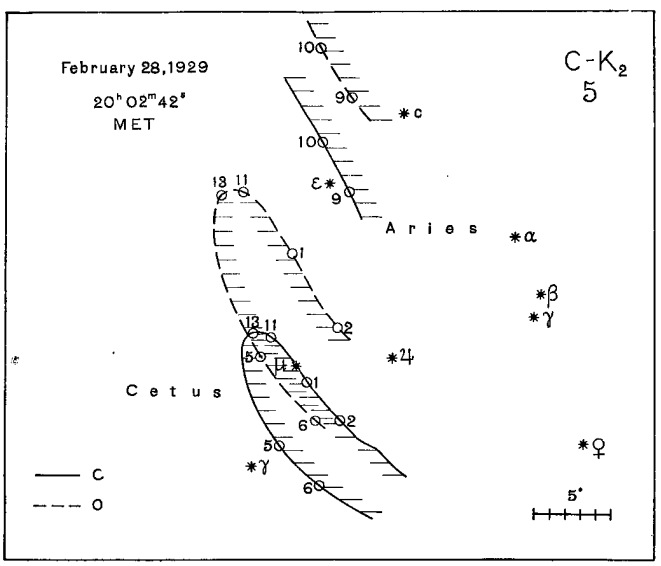
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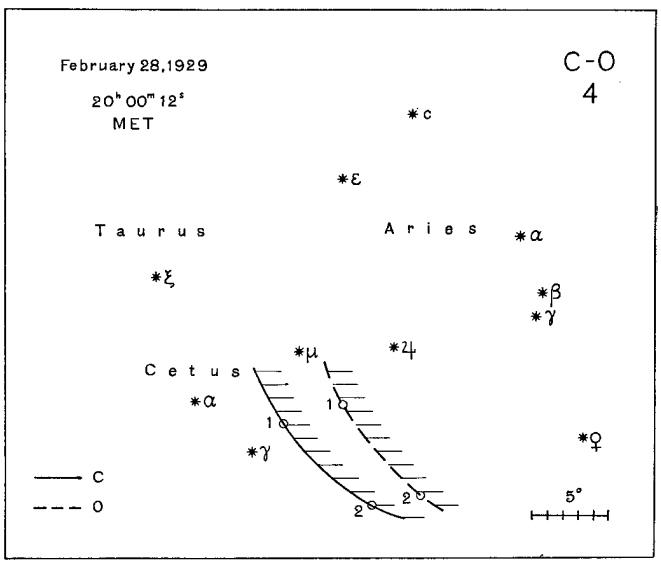
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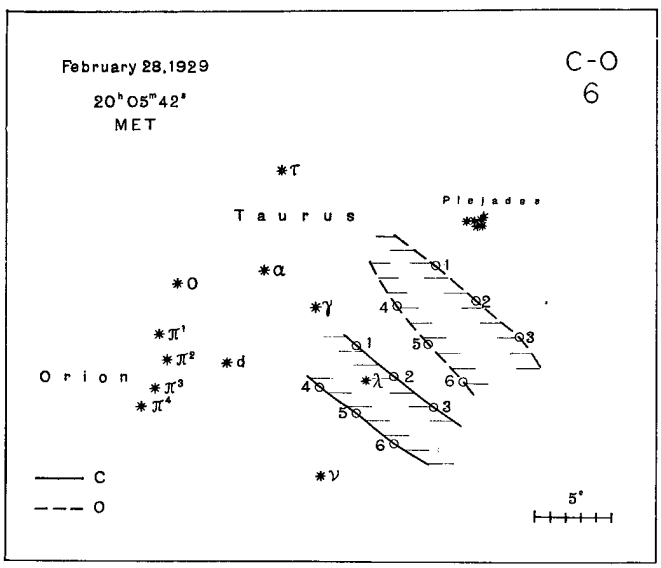
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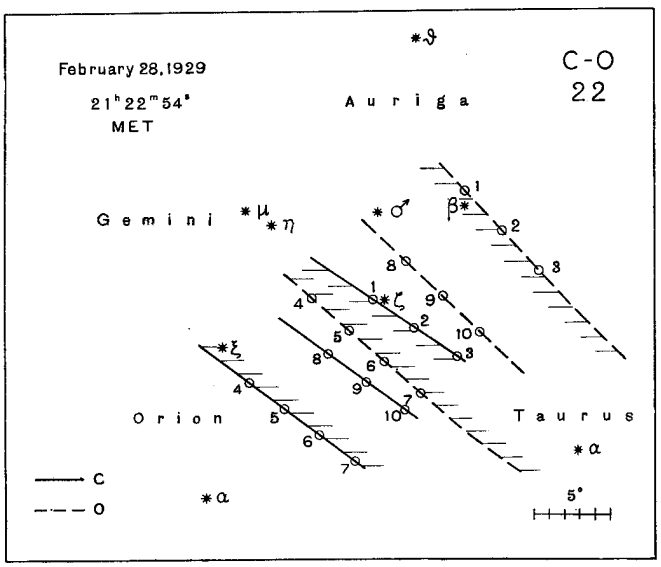
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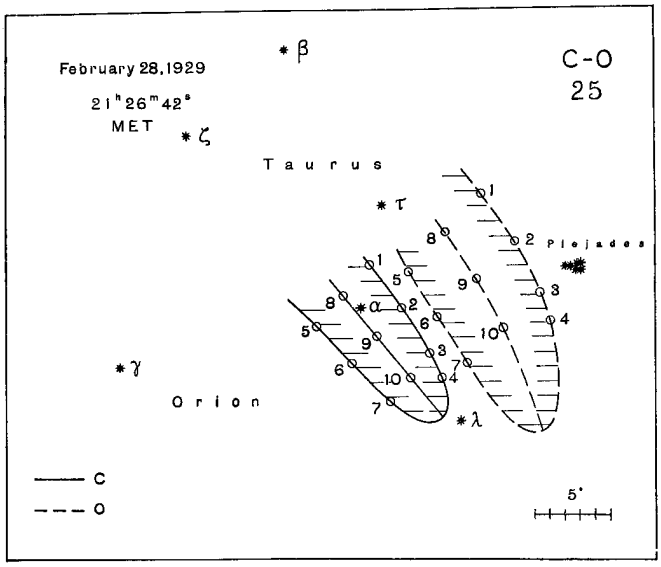
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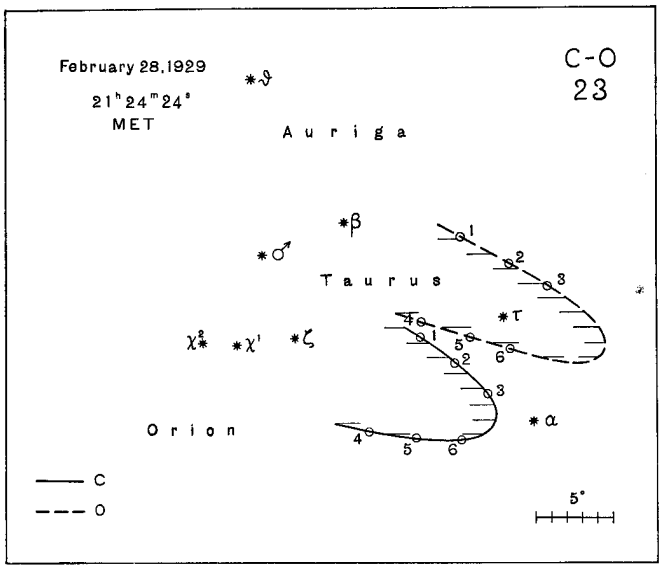
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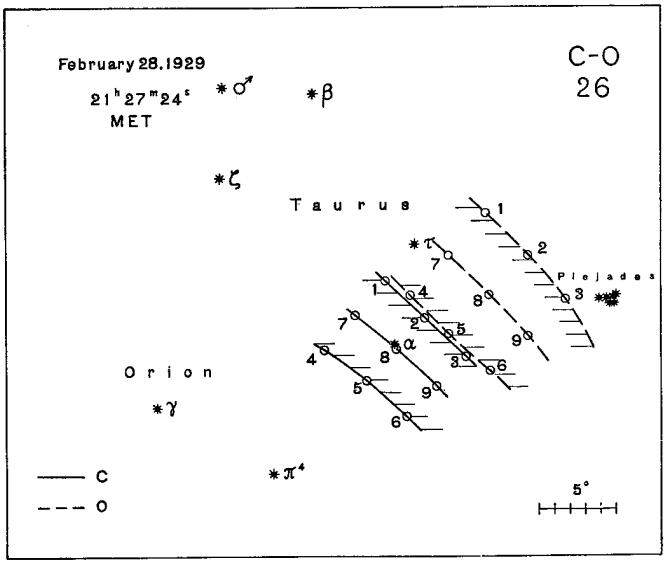
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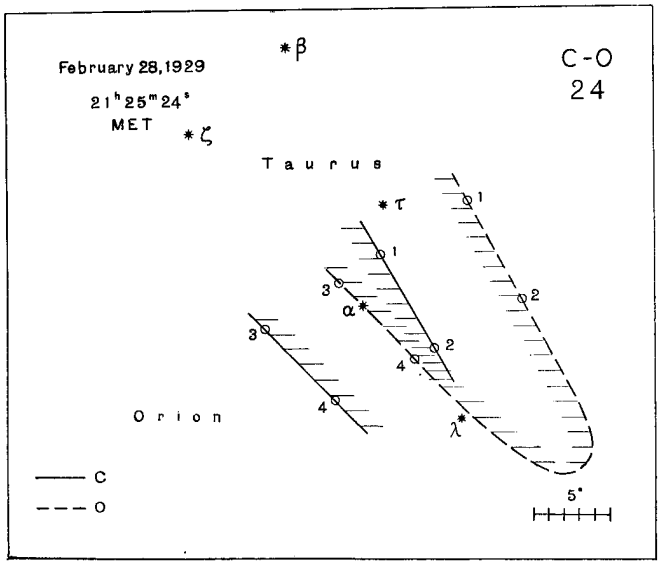
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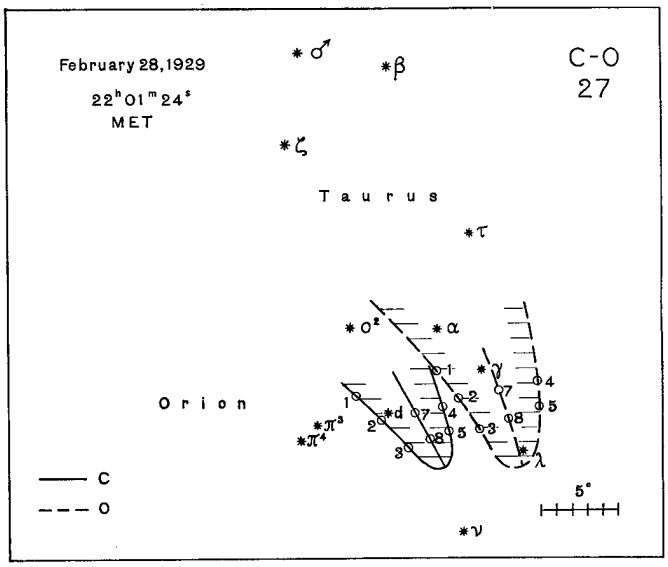
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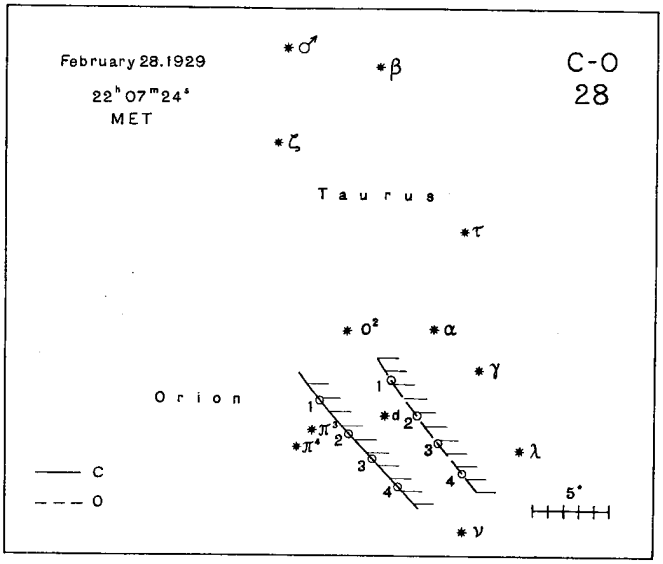
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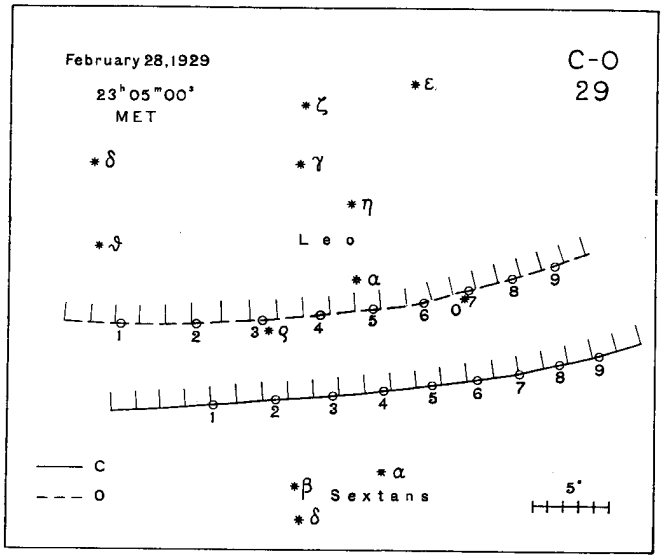
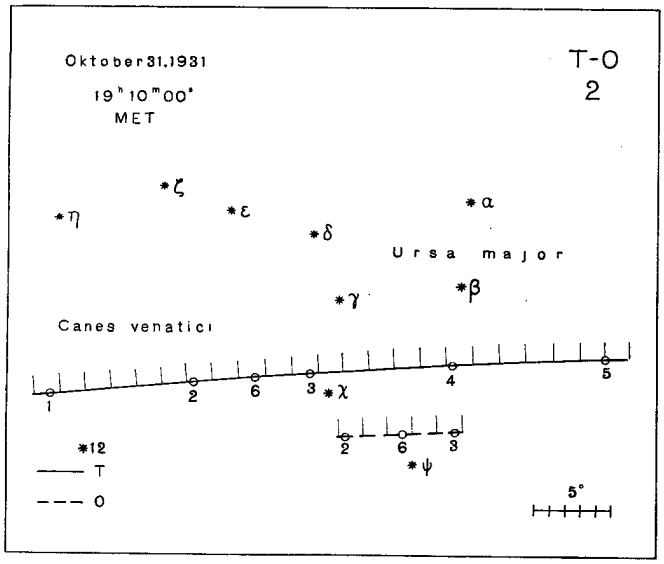
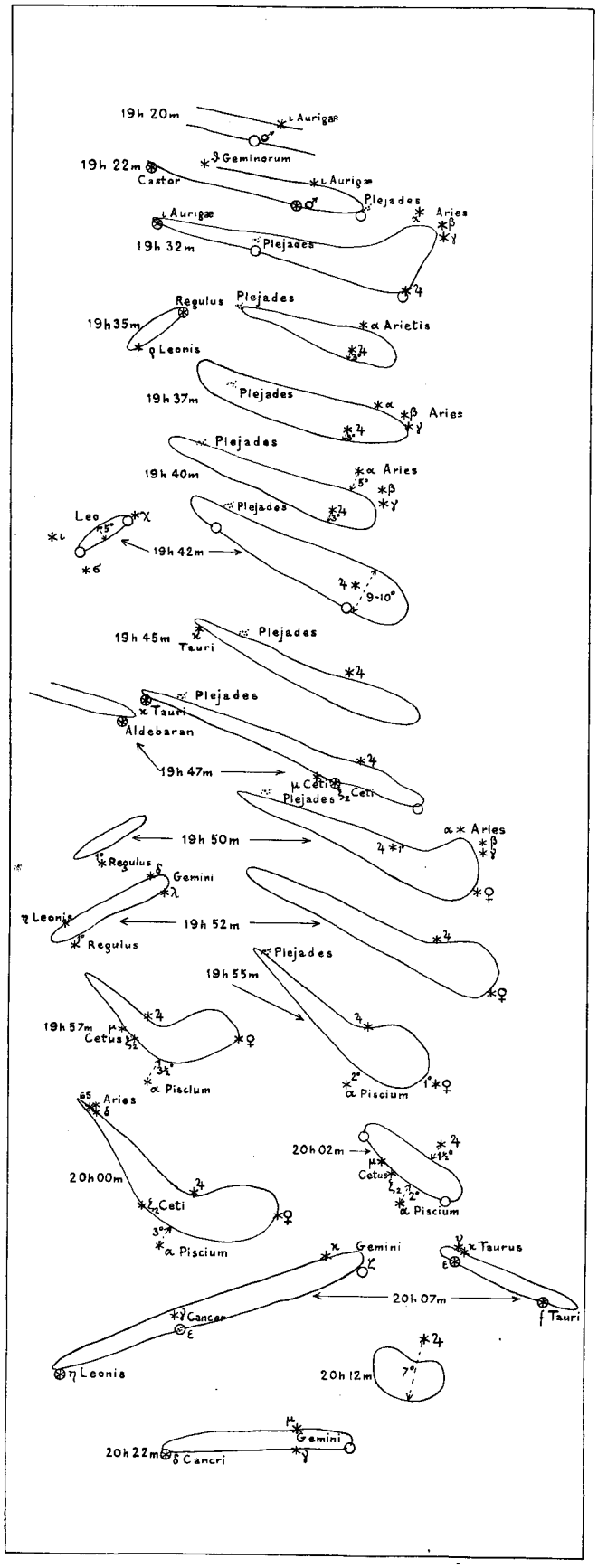
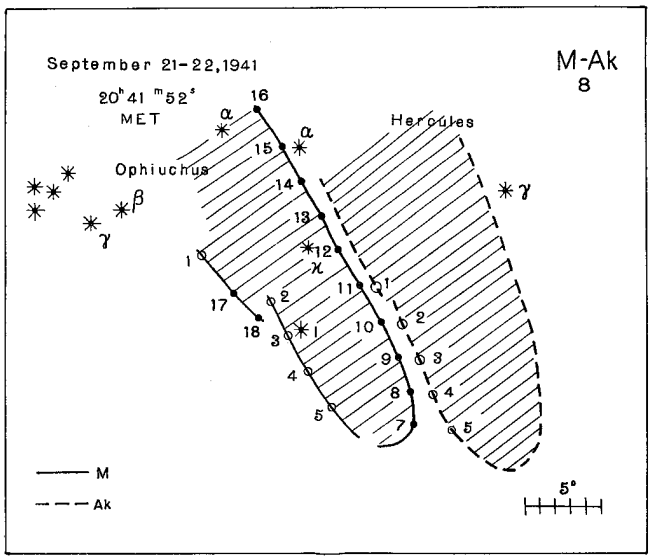
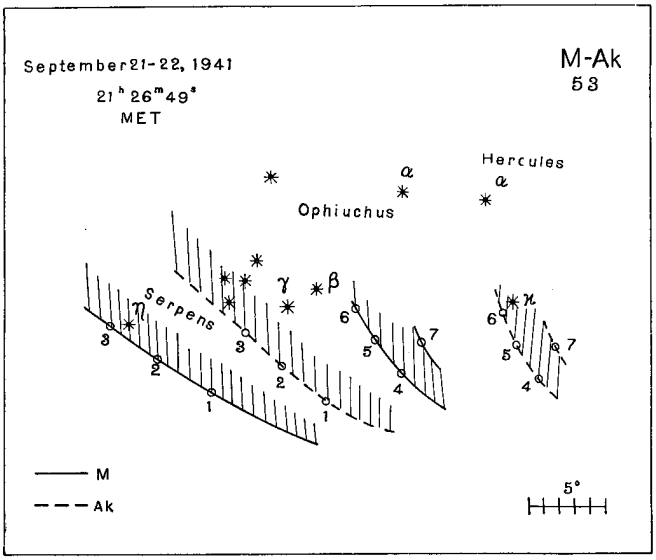
O
5°

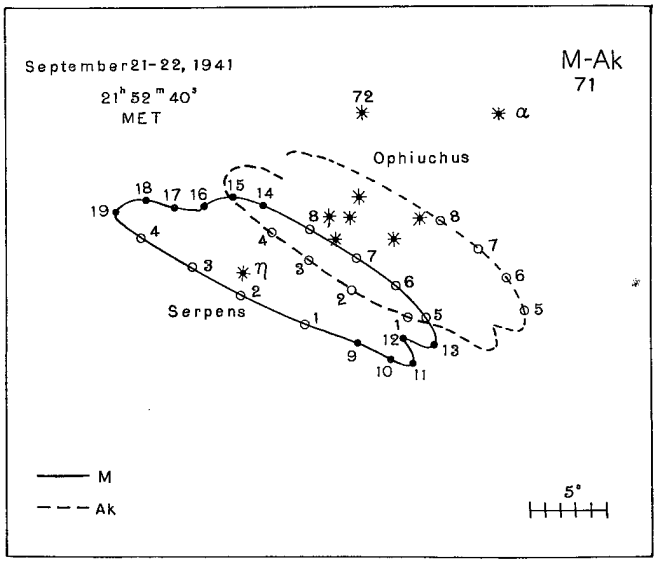

February 28,1929
23h05m00s
MET
C-O
29
Leo
Sextans
C
O
5°

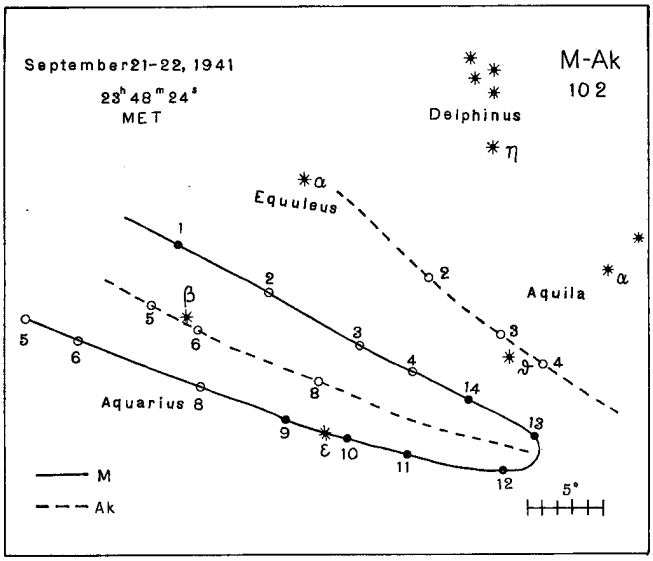

Oktober 31,1931
19h10m00s
MET
T-O
2
Ursa major
Canes venatici
T
O
5°

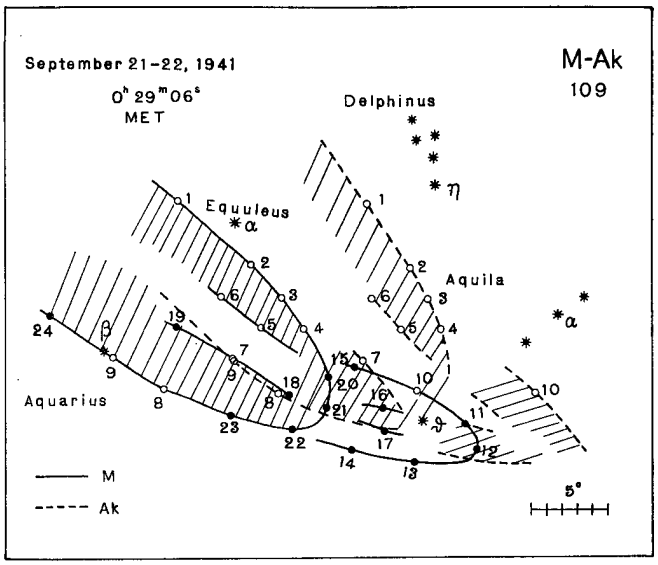

19h 20m
19h 22m
Castor
19h 32m
19h35m
Regulus
19h 37m
19h 40m
19h 42m
19h 45m
Aldebaran
19h 47m
19h 50m
19h 52m
19h 55m
19h 57m
20h 00m
20h 02m
20h 07m
20h 12m
20h 22m
Plejades
Aries
Gemini
Taurus
Leo
Cetus
Piscium
Ceti
Cancer
Leonis
Tauri
Auriga
Arietis

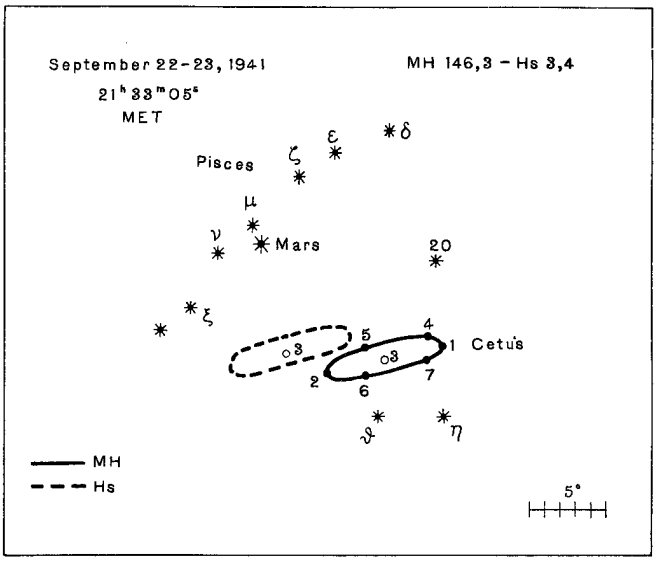

September 21-22,1941
20h41m52s
MET
M-Ak
8
Ophiuchus
Hercules
M
Ak
5°

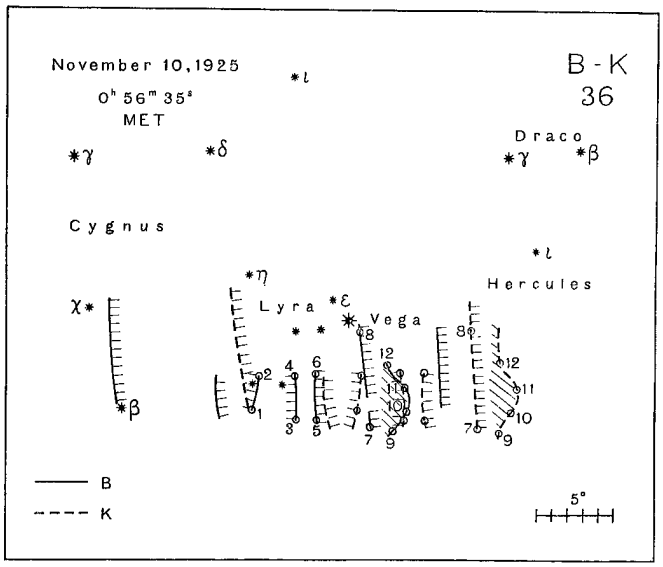

September21-22, 1941
21h26m49s
MET
M-Ak
53
Ophiuchus
Hercules
Serpens
M
Ak
5°

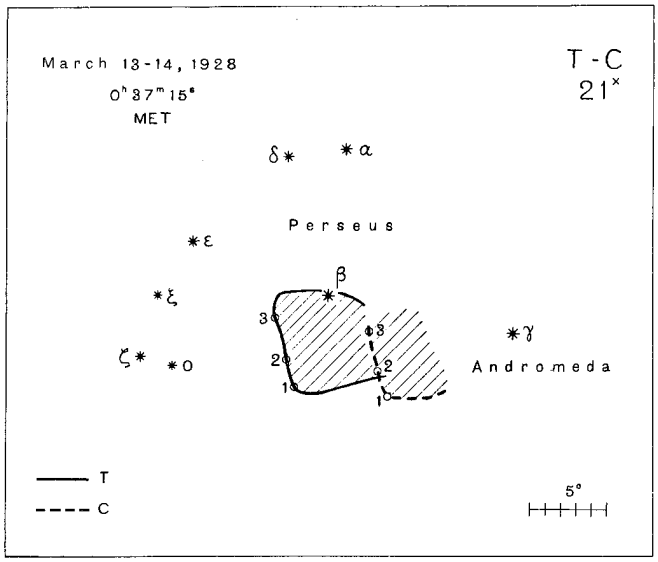

September21-22, 1941
21h52m40s
MET
M-Ak
71
Ophiuchus
Serpens
M
Ak
5°

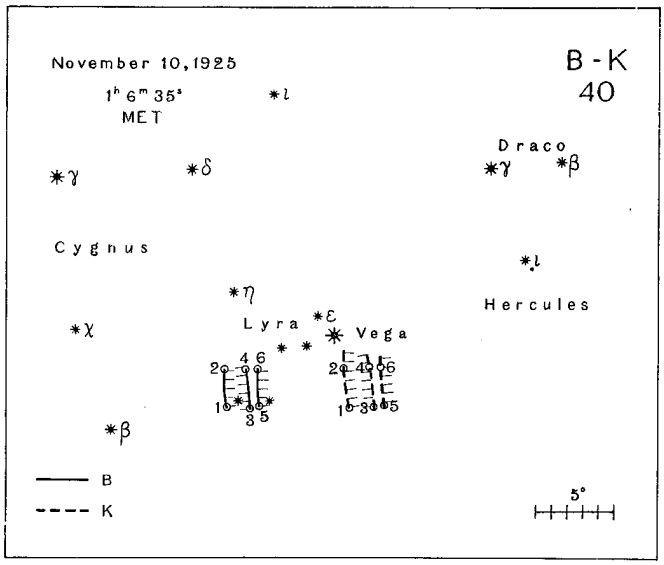

September21-22, 1941
23h48m24s
MET
M-Ak
102
Delphinus
Equuleus
Aquila
Aquarius 8
M
Ak
5°

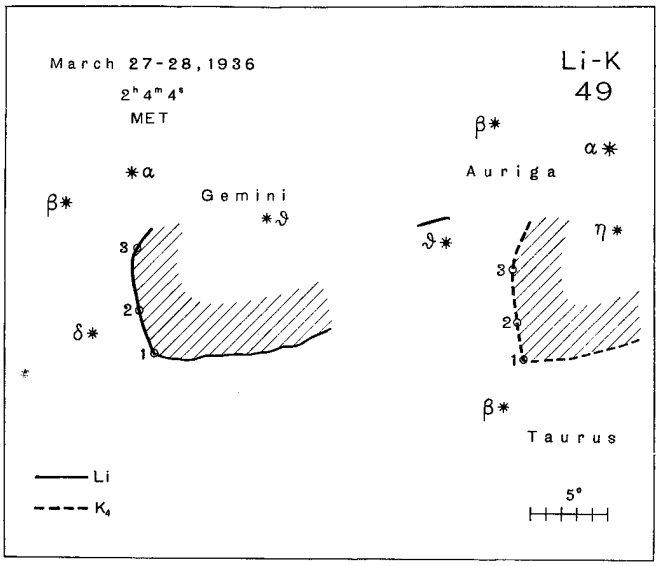

September 21-22, 1941
0h29m06s
MET
M-Ak
109
Delphinus
Equuleus
Aquila
Aquarius
M
Ak
5°

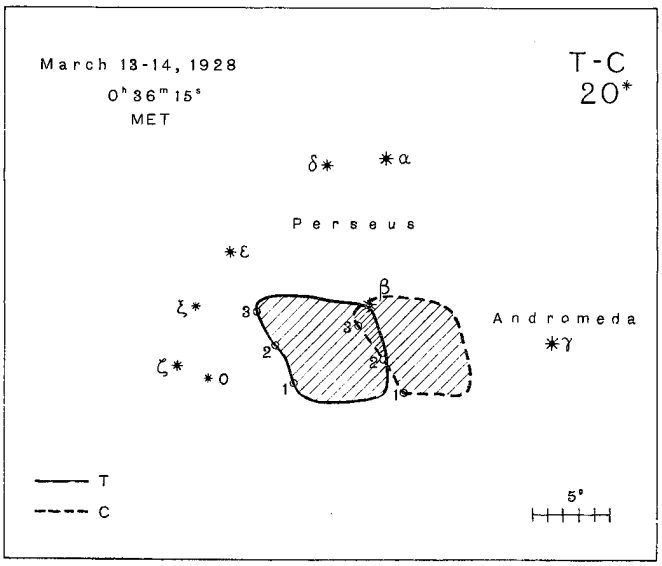

September 22-23, 1941
21h33m05s
MET
MH 146,3 - Hs 3,4
Pisces
Mars
Cetus
MH
Hs
5°

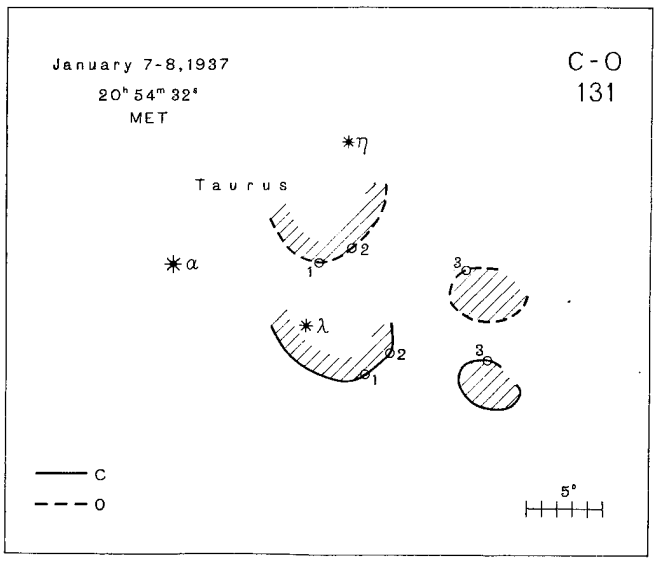

November 10,1925
0h 56m 35s
MET
B-K
36
Draco
Cygnus
Hercules
Lyra
Vega
B
K
5°

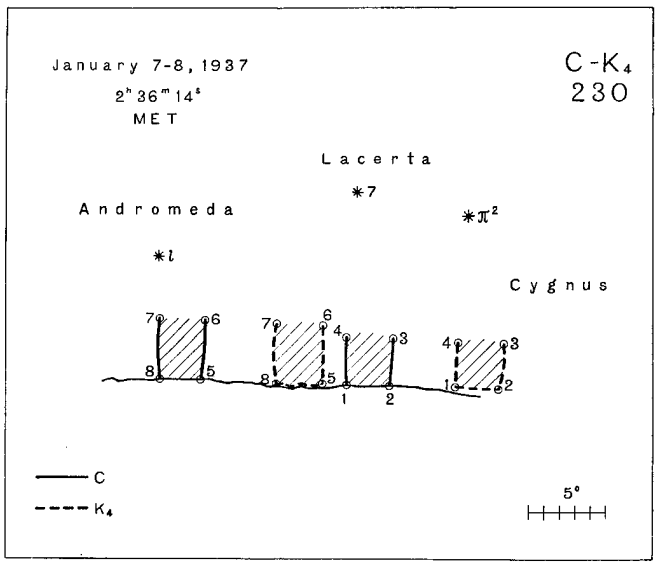

March 13-14, 1928
0h 37m 15s
MET
T-C
21x
Perseus
Andromeda
T
C
5°

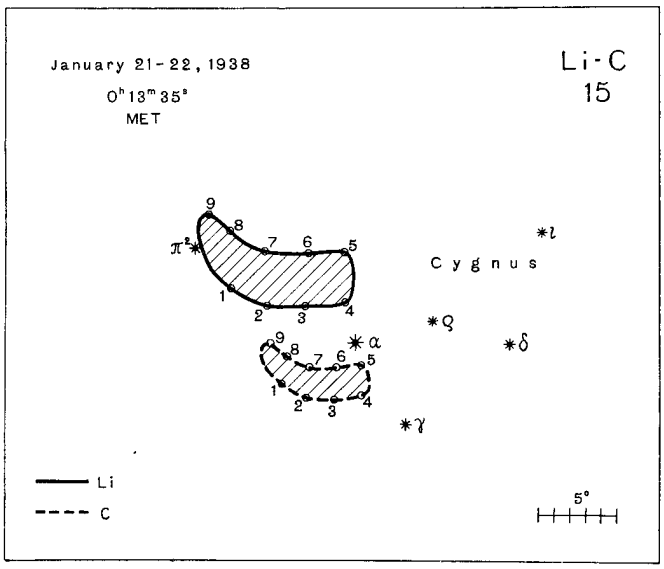

November 10,1925
1h 6m 35s
MET
B-K
40
Draco
Cygnus
Hercules
Lyra
Vega
B
K
5°

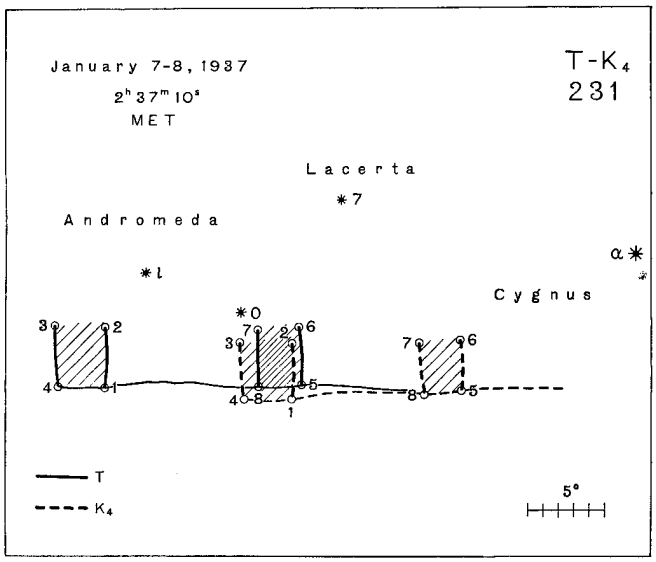

March 27-28, 1936
2h 4m 4s
MET
Li-K
49
Gemini
Auriga
Taurus
Li
K4
5°

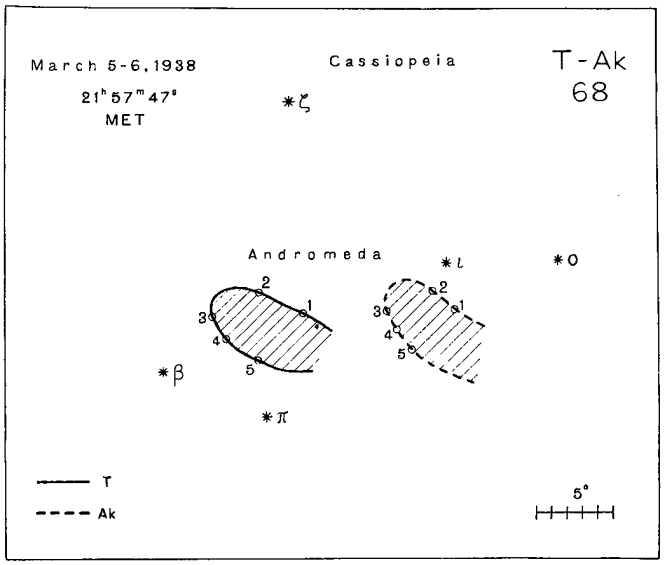

March 13-14, 1928
0h 36m 15s
MET
T-C
20*
Perseus
Andromeda
T
C
5°

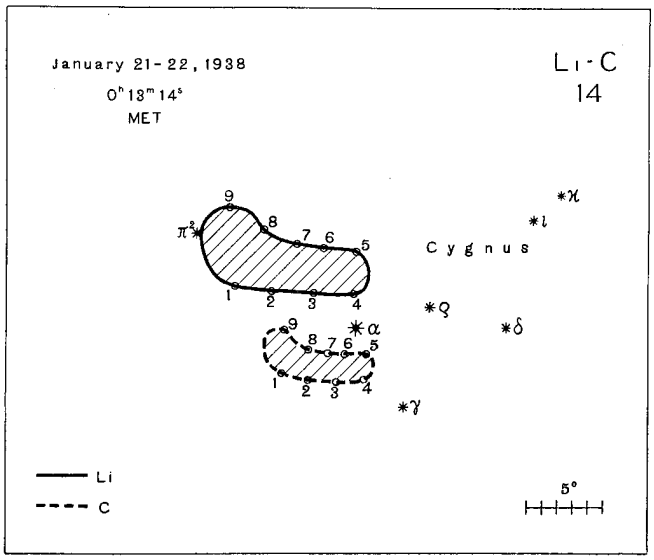

January 7-8,1937
20h 54m 32s
MET
C-O
131
Taurus
C
O
5°

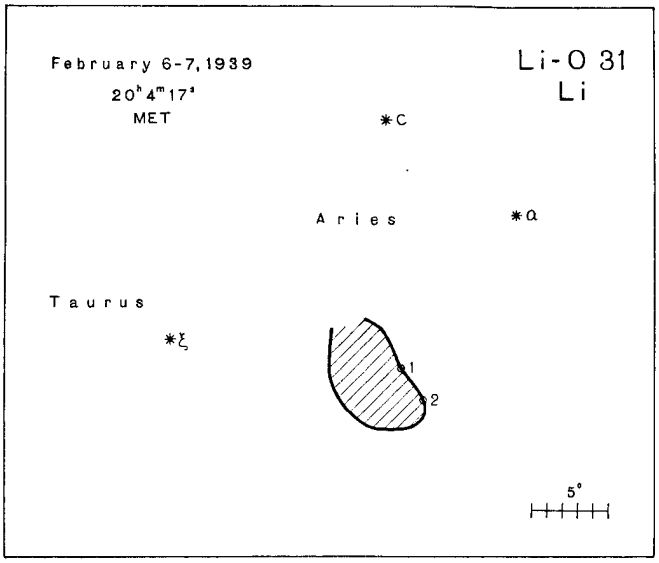

January 7-8, 1937
2h 36m 14s
MET
C-K4
230
Lacerta
Andromeda
Cygnus
C
K4
5°

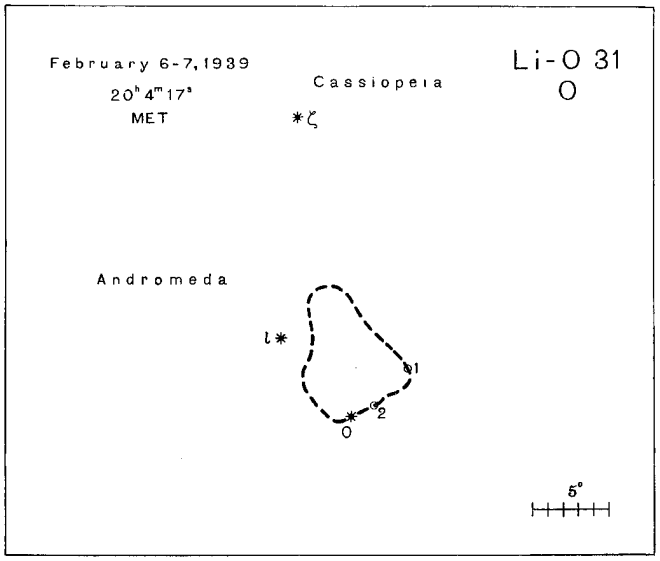

January 21-22, 1938
0h 13m 35s
MET
Li-C
15
Cygnus
Li
C
5°

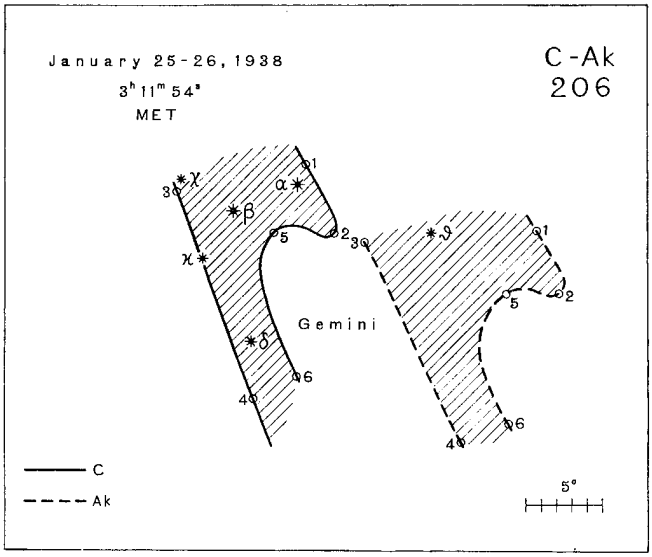

January 7-8, 1937
2h 37m 10s
MET
T-K4
231
Lacerta
Andromeda
Cygnus
T
K4
5°

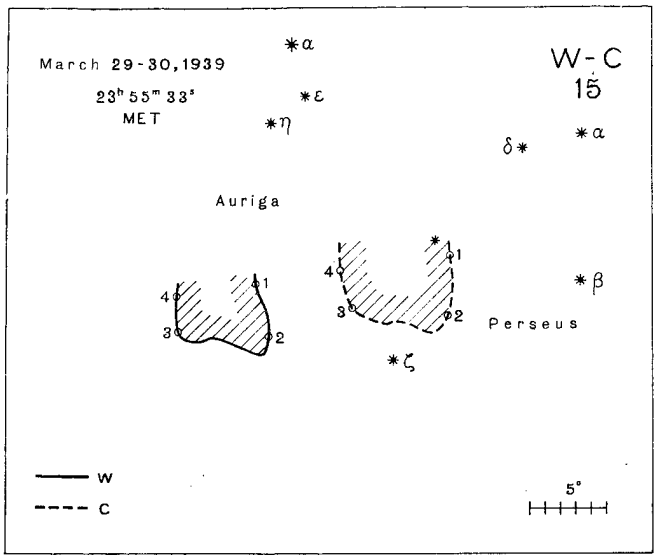

March 5-6, 1938
21h 57m 47s
MET
T-Ak
68
Cassiopeia
Andromeda
T
Ak
5°

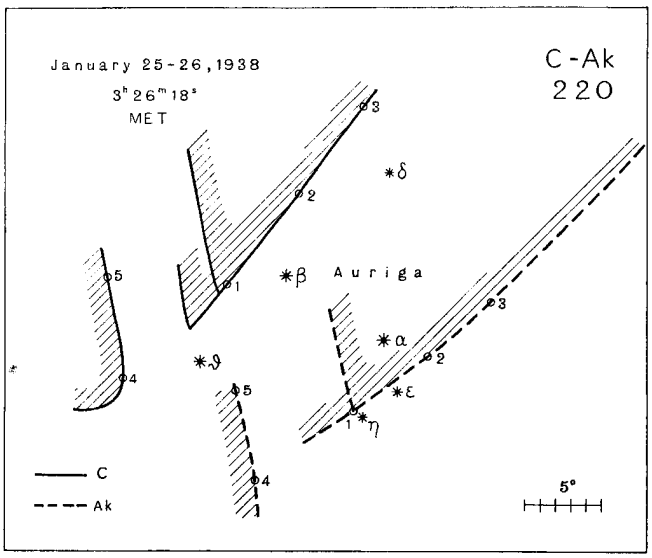

January 21-22, 1938
0h 13m 14s
MET
Li-C
14
Cygnus
Li
C
5°

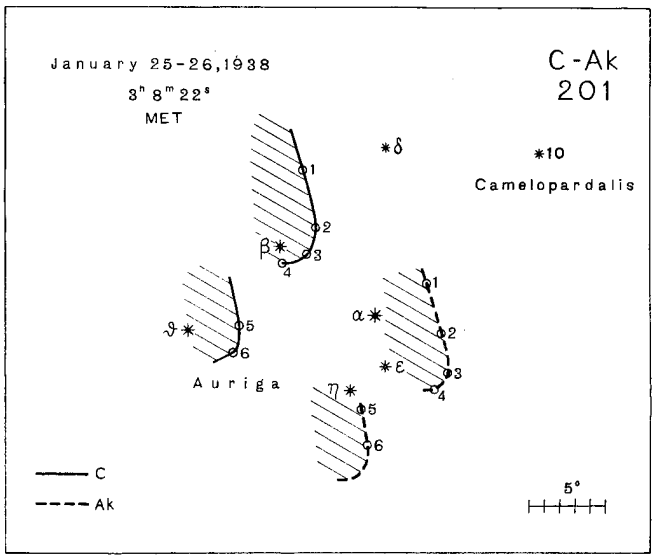

February 6-7, 1939
20h 4m 17s
MET
Li-O 31
Li
Aries
Taurus
5°

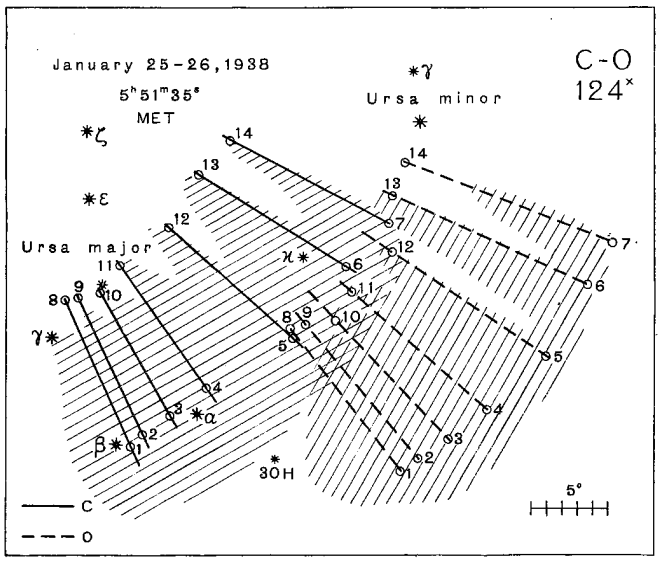

February 6-7, 1939
20h4m17s
MET
Li-O 31
O
Cassiopeia
Andromeda
5°

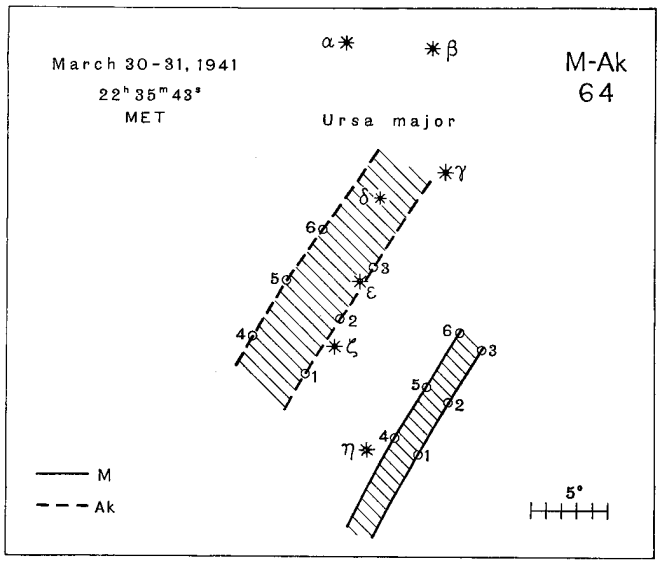

January 25-26, 1938
3h11m54s
MET
C-Ak
206
Gemini
C
Ak
5°

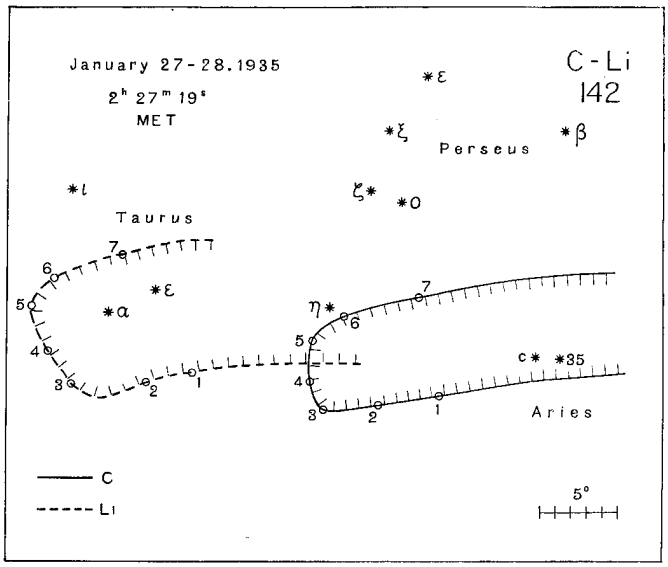

March 29-30, 1939
23h55m33s
MET
W-C
15
Auriga
Perseus
W
C
5°

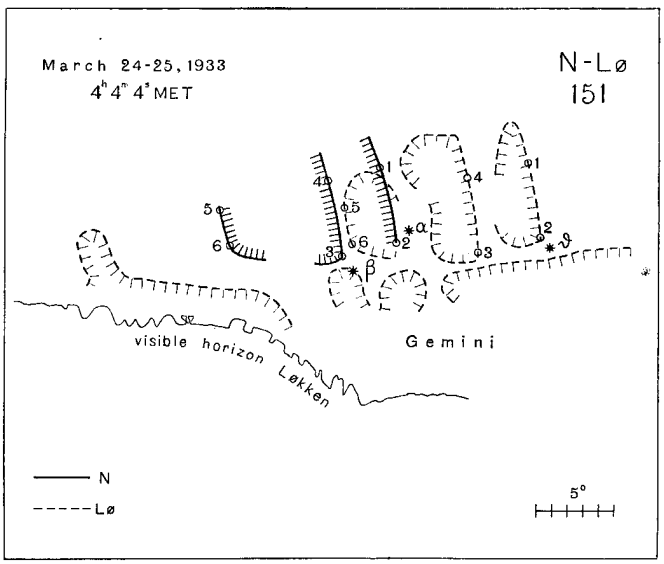

January 25-26, 1938
3h26m18s
MET
C-Ak
220
Auriga
C
Ak
5°

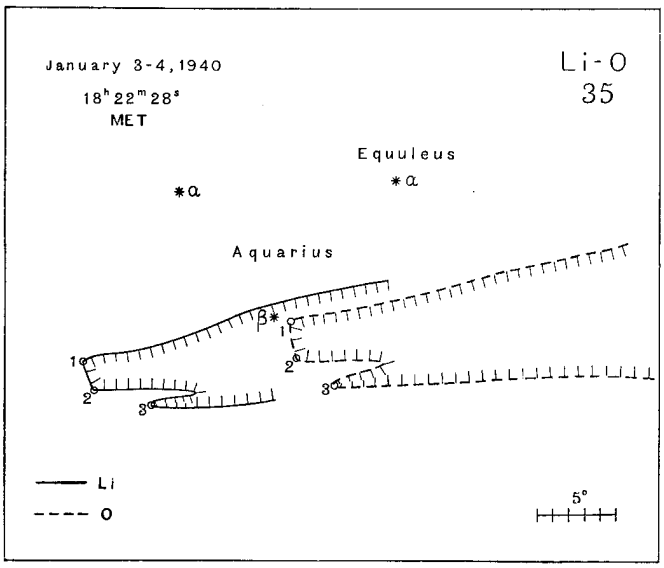

January 25-26, 1938
3h8m22s
MET
C-Ak
201
Camelopardalis
Auriga
C
Ak
5°

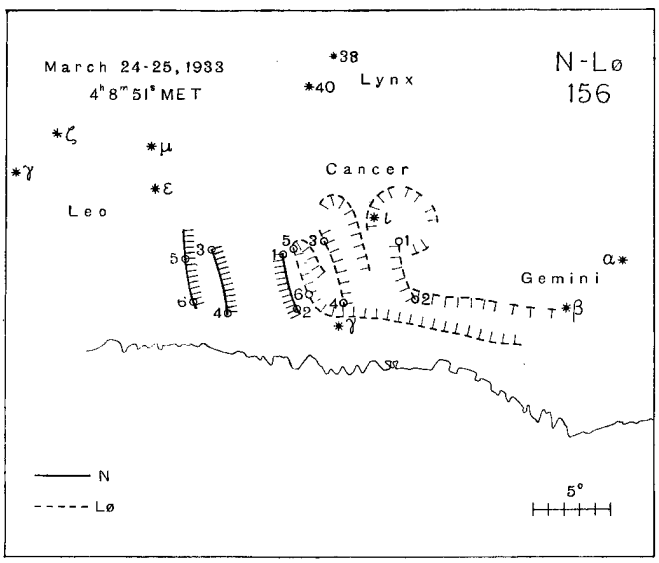

January 25-26, 1938
5h51m35s
MET
C-O
124x
Ursa minor
Ursa major
30H
C
O
5°

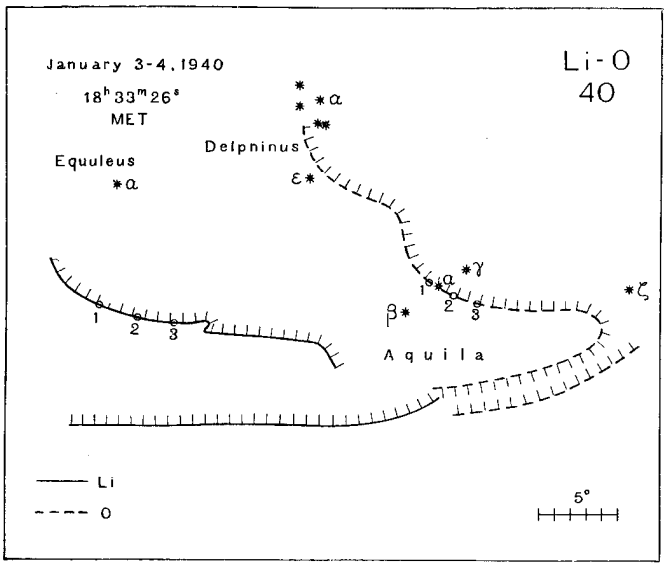

March 30-31, 1941
22h35m43s
MET
M-Ak
64
Ursa major
M
Ak
5°

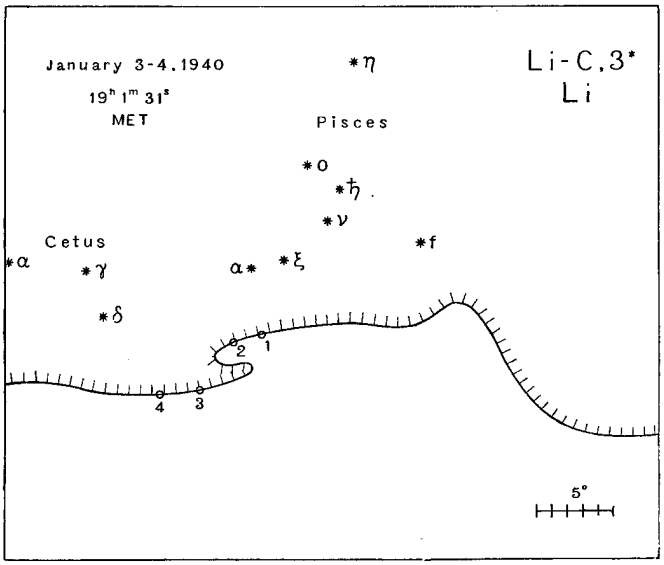

January 27-28.1935
2h 27m 19s
MET
C-Li
142
Perseus
Taurus
Aries
C
Li
5°

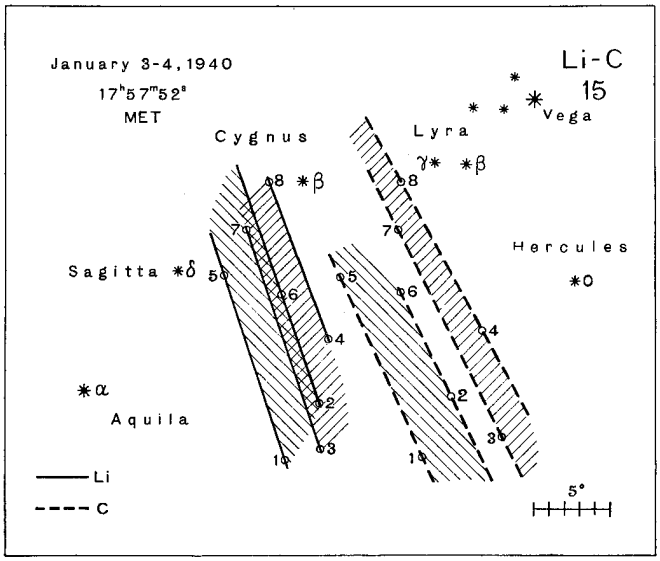

March 24-25, 1933
4h4m4s MET
N-Lø
151
visible horizon Løkken
Gemini
N
Lø
5°

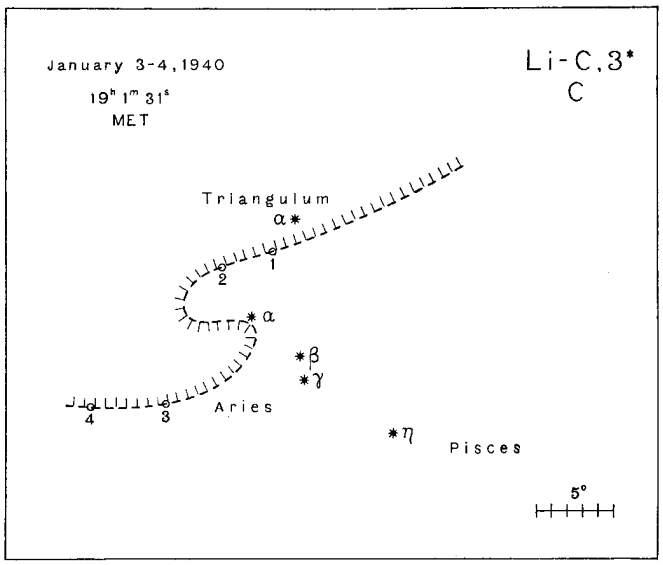

January 3-4, 1940
18h22m28s
MET
Li-O
35
Equuleus
Aquarius
Li
O
5°

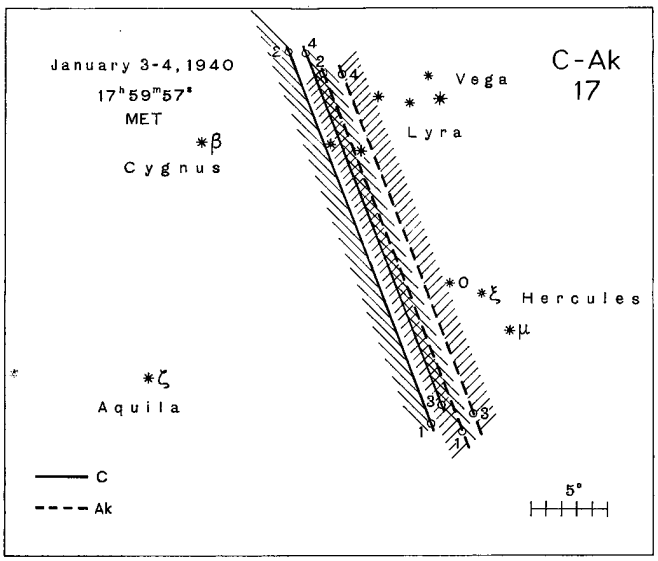

March 24-25, 1933
4h8m51s MET
N-Lø
156
Lynx
Cancer
Leo
Gemini
N
Lø
5°

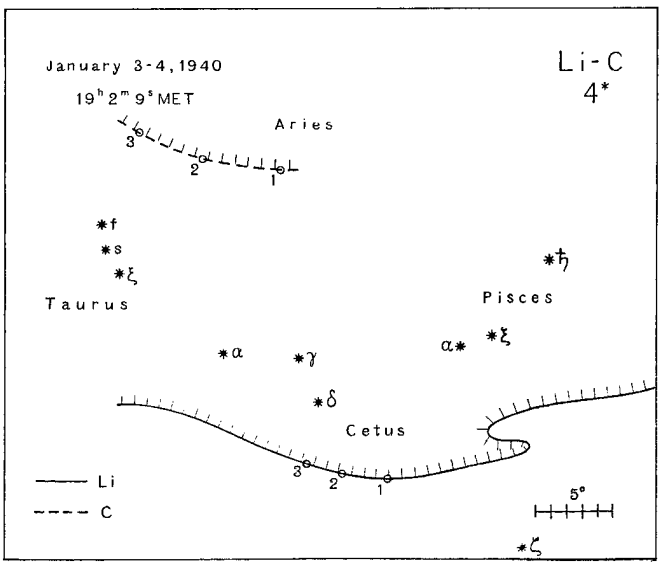

January 3-4, 1940
18h33m26s
MET
Li-O
40
Delpninus
Equuleus
Aquila
Li
O
5°

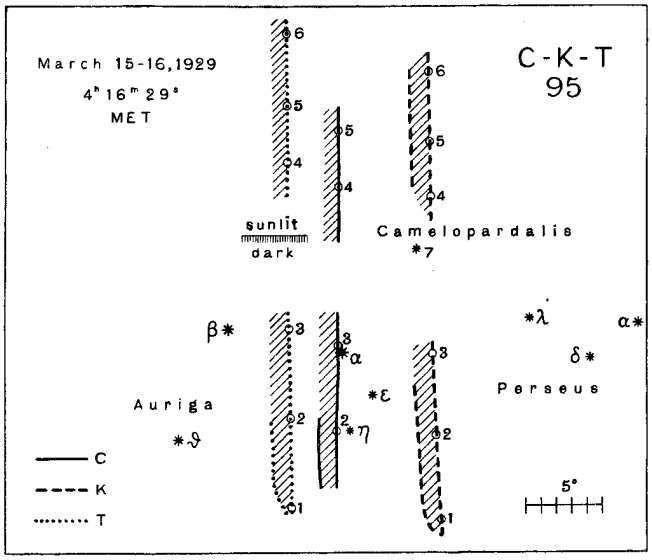

January 3-4, 1940
19h 1m 31s
MET
Li-C, 3*
Li
Pisces
Cetus
5°

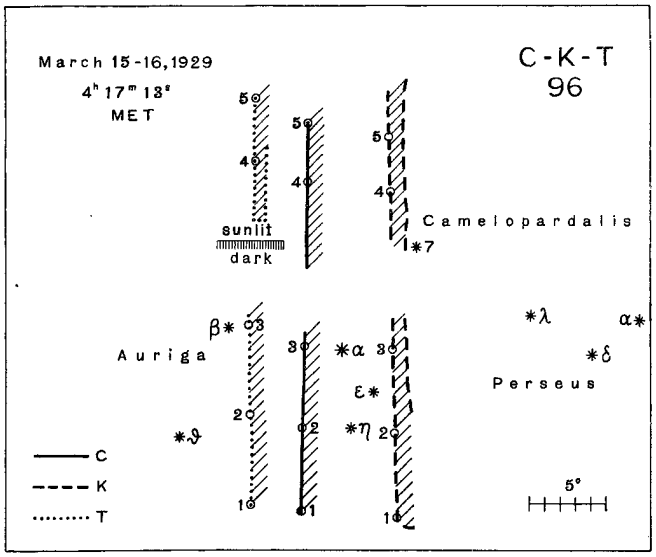

January 3-4, 1940
17h 57m 52s
MET
Li-C
15
Cygnus
Lyra
Vega
Hercules
Sagitta
Aquila
Li
C
5°

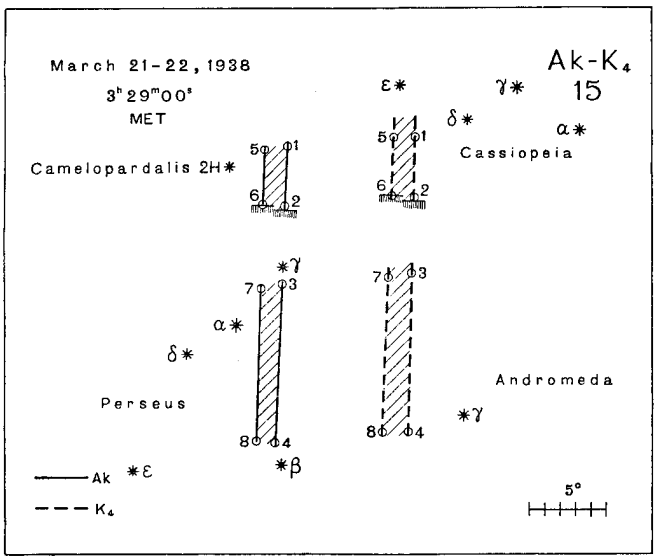

January 3-4, 1940
19h 1m 31s
MET
Li-C, 3*
C
Triangulum
Aries
Pisces
5°

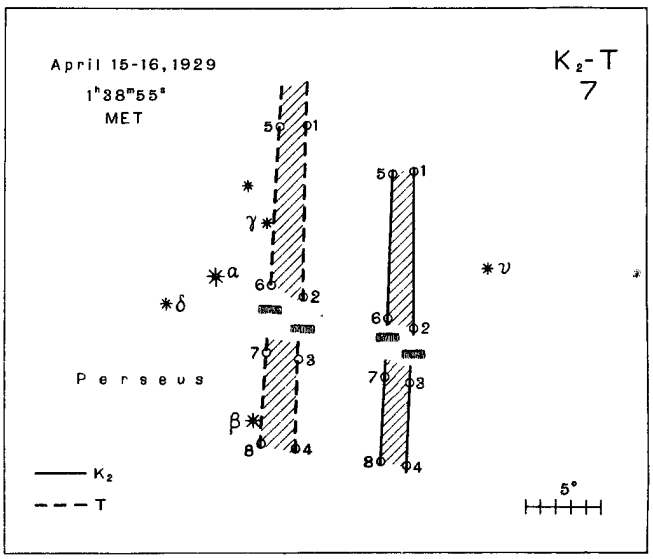

January 3-4, 1940
17h 59m 57s
MET
C-Ak
17
Vega
Lyra
Cygnus
Hercules
Aquila
C
Ak
5°

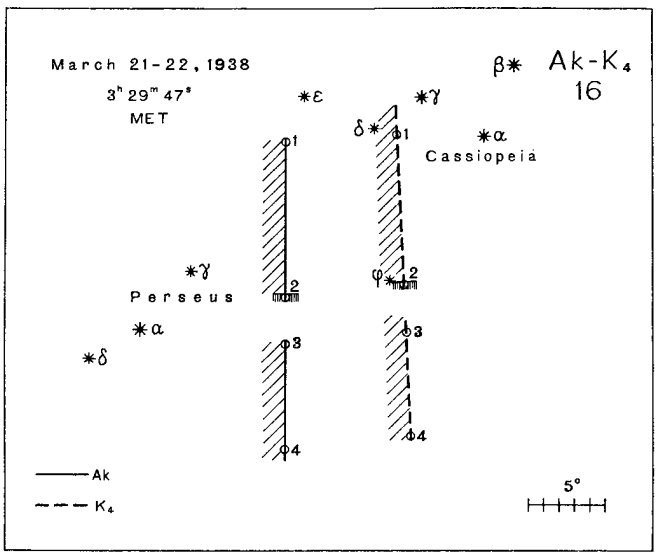

January 3-4, 1940
19h 2m 9s MET
Li-C
4*
Aries
Taurus
Pisces
Cetus
Li
C
5°

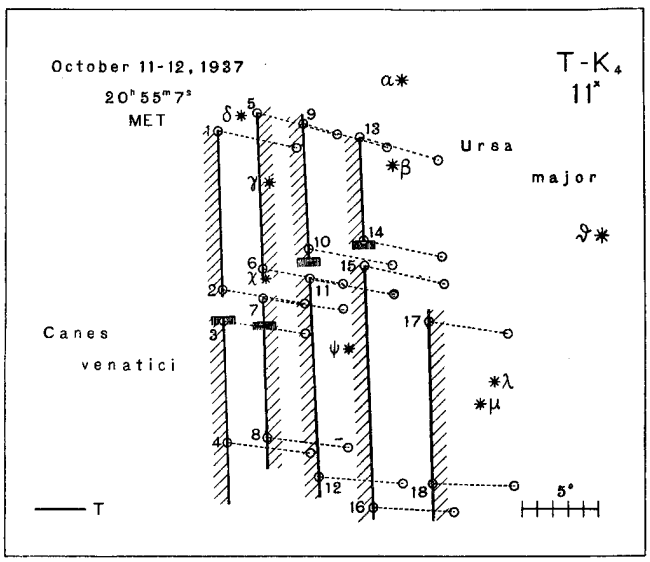

March 15-16, 1929
4h 16m 29s
MET
C-K-T
95
sunlit
dark
Camelopardalis
Auriga
Perseus
C
K
T
5°

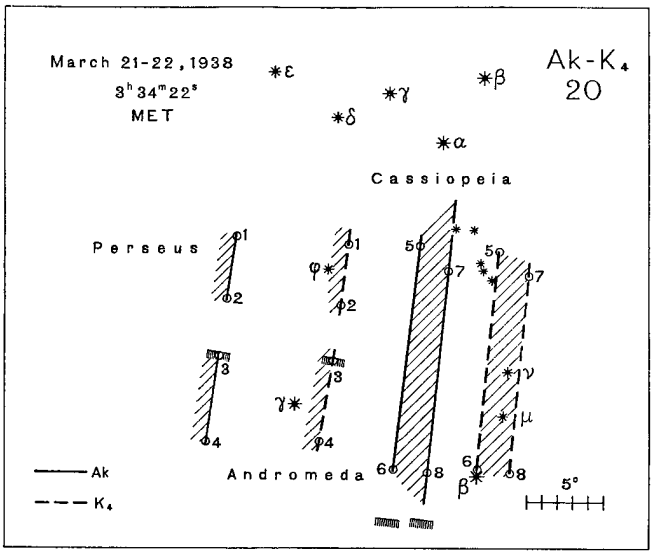

March 15-16,1929
4h17m13s
MET
C-K-T
96
sunlit
dark
Camelopardalis
Auriga
Perseus
C
K
T
5°

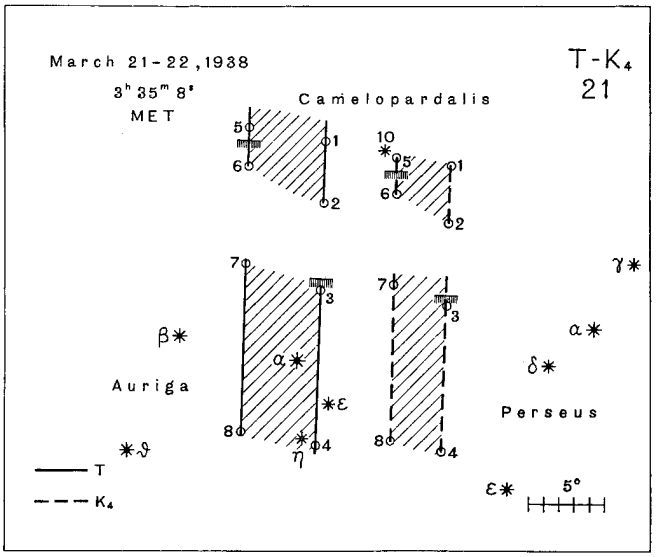

March 21-22, 1938
3h29m00s
MET
Ak-K4
15
Camelopardalis 2H
Cassiopeia
Perseus
Andromeda
Ak
K4
5°

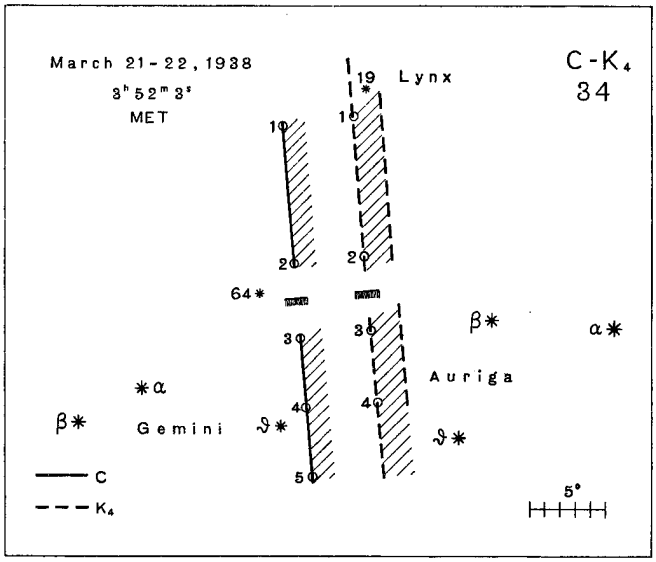

April 15-16, 1929
1h38m55s
MET
K2-T
7
Perseus
K2
T
5°

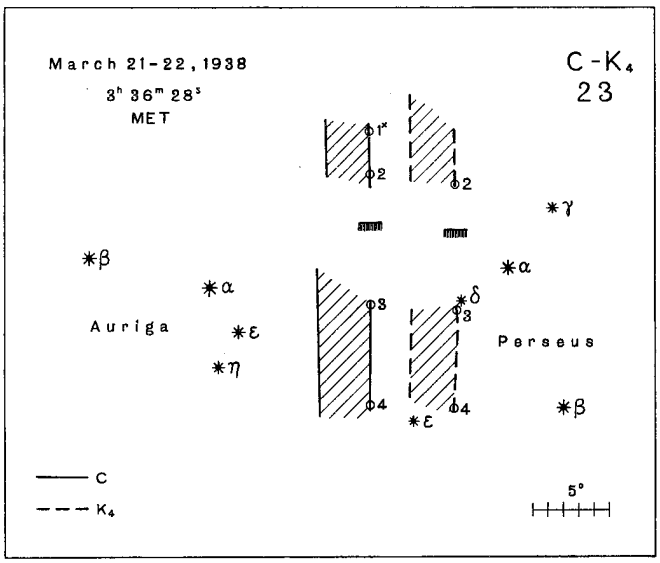

March 21-22, 1938
3h29m47s
MET
Ak-K4
16
Cassiopeia
Perseus
Ak
K4
5°

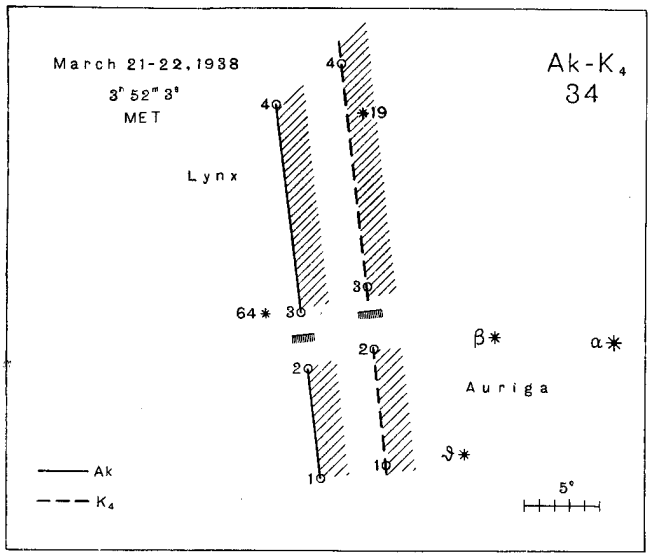

October 11-12, 1937
20h55m7s
MET
T-K4
11x
Ursa
major
Canes
venatici
T
5°

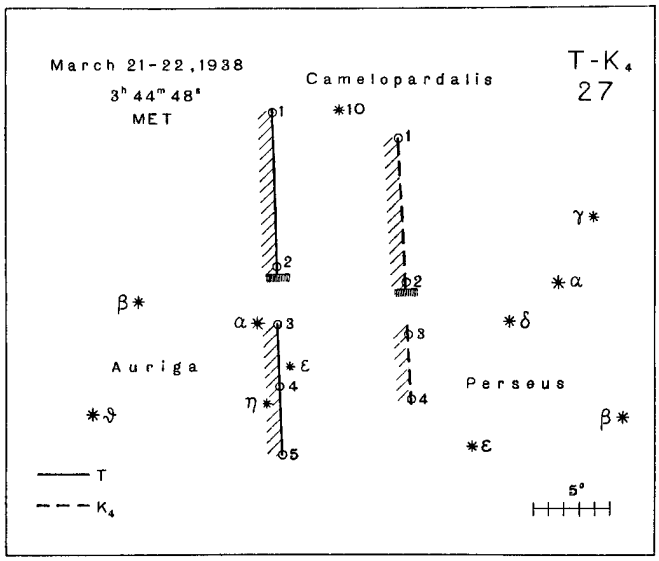

March 21-22, 1938
3h34m22s
MET
Ak-K4
20
Cassiopeia
Perseus
Andromeda
Ak
K4
5°

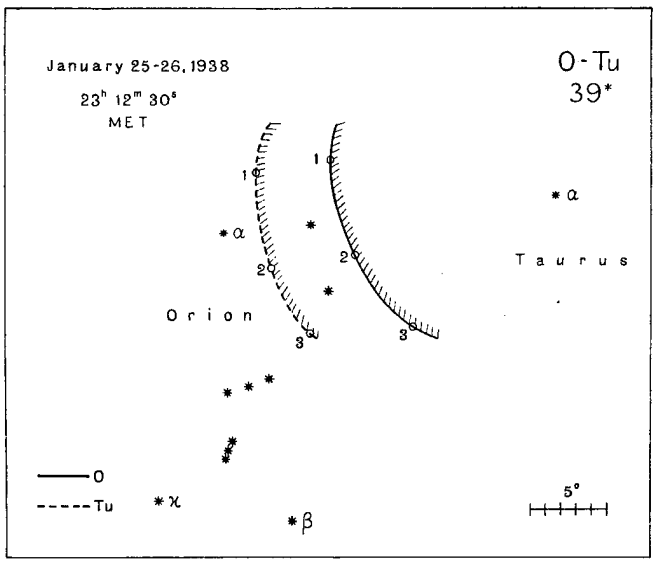

March 21-22, 1938
3h 35m 8s
MET
T-K4
21
Camelopardalis
Auriga
Perseus
T
K4
5°

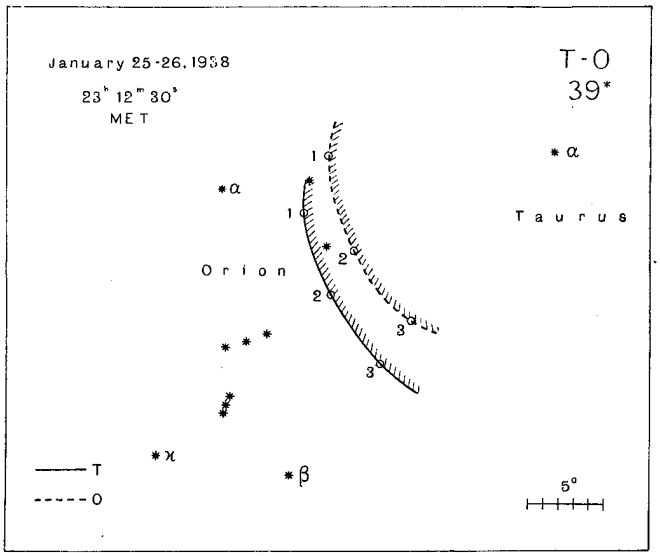

March 21-22, 1938
3h 52m 3s
MET
C-K4
34
Lynx
Auriga
Gemini
C
K4
5°

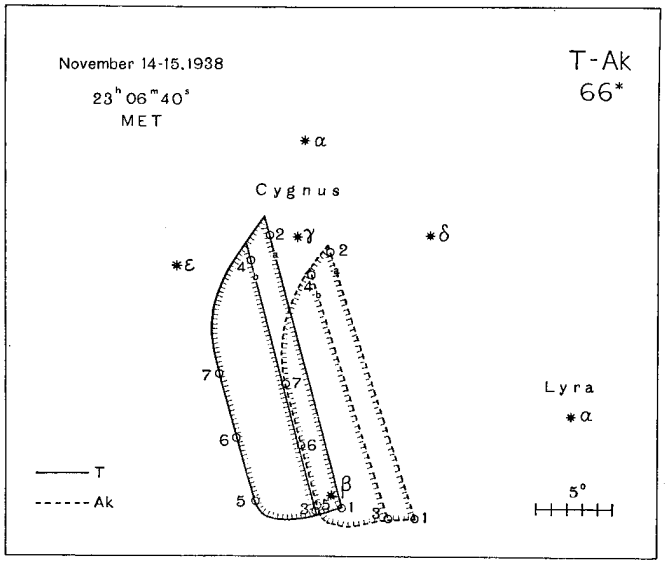

March 21-22, 1938
3h 36m 28s
MET
C-K4
23
Auriga
Perseus
C
K4
5°

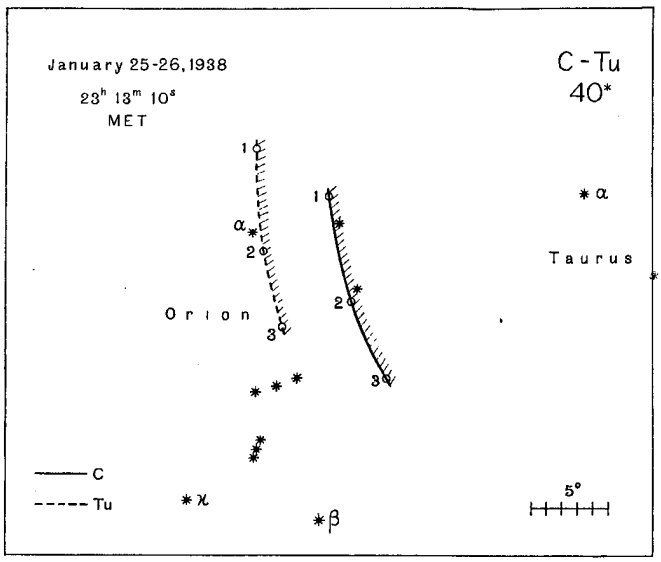

March 21-22, 1938
3h 52m 3s
MET
Ak-K4
34
Lynx
Auriga
Ak
K4
5°

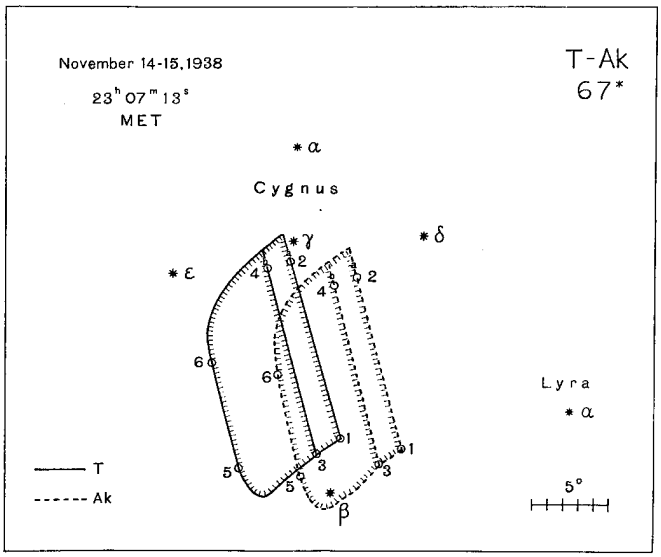

March 21-22, 1938
3h 44m 48s
MET
T-K4
27
Camelopardalis
Auriga
Perseus
T
K4
5°

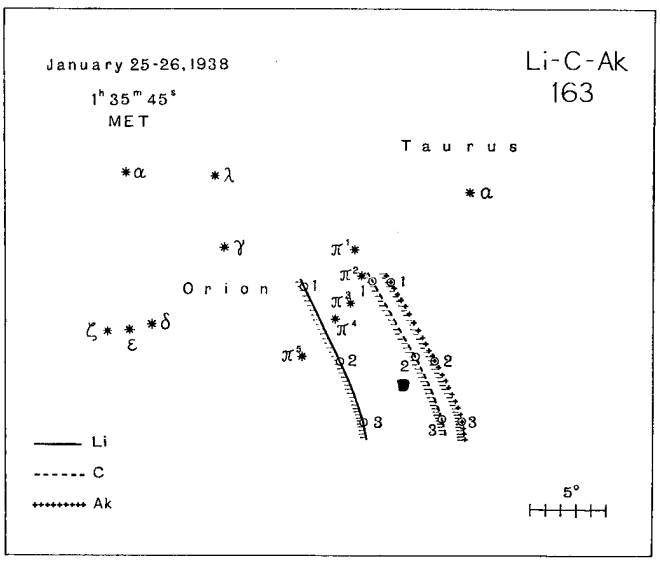

January 25-26, 1938
23h 12m 30s
MET
O-Tu
39*
Orion
Taurus
O
Tu
5°

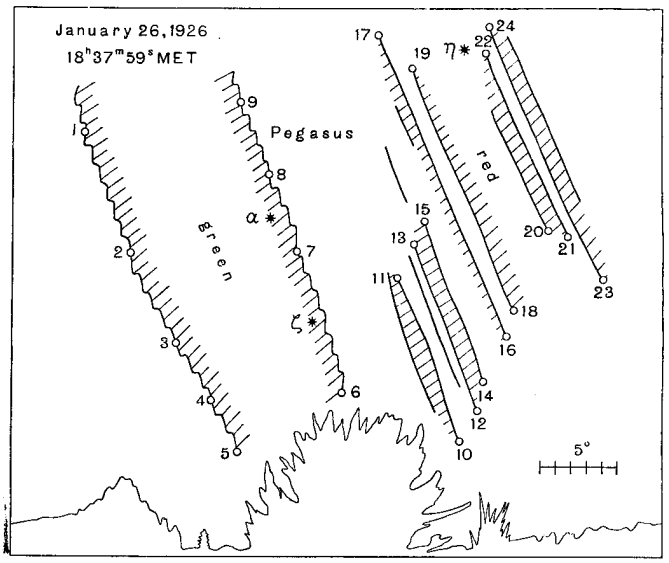

January 25-26, 1938
23h 12m 30s
MET
T-O
39*
Taurus
Orion
T
O
5°

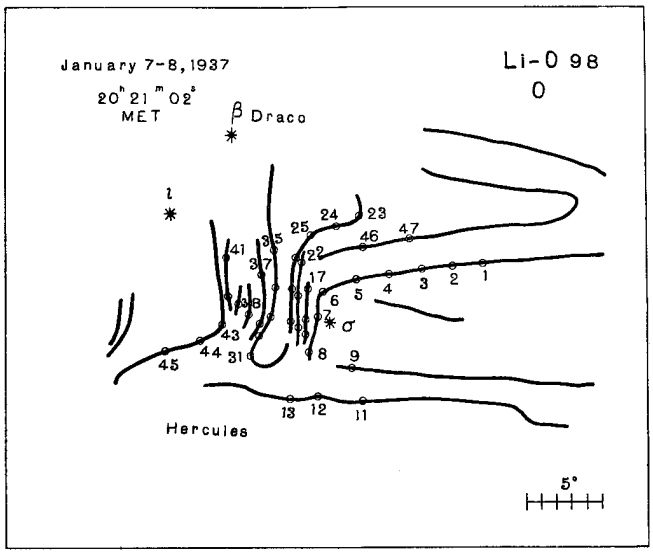

November 14-15, 1938
23h 06m 40s
MET
T-Ak
66*
Cygnus
Lyra
T
Ak
5°

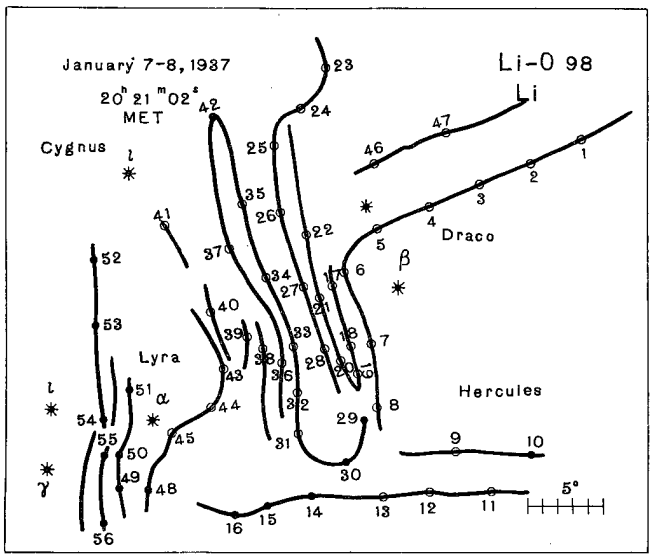

January 25-26, 1938
23h 13m 10s
MET
C-Tu
40*
Taurus
Orion
C
Tu
5°

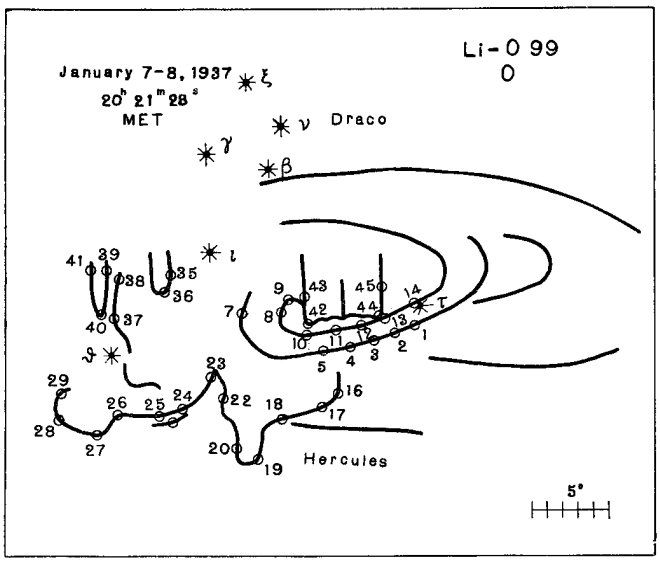

November 14-15, 1938
23h 07m 13s
MET
T-Ak
67*
Cygnus
Lyra
T
Ak
5°

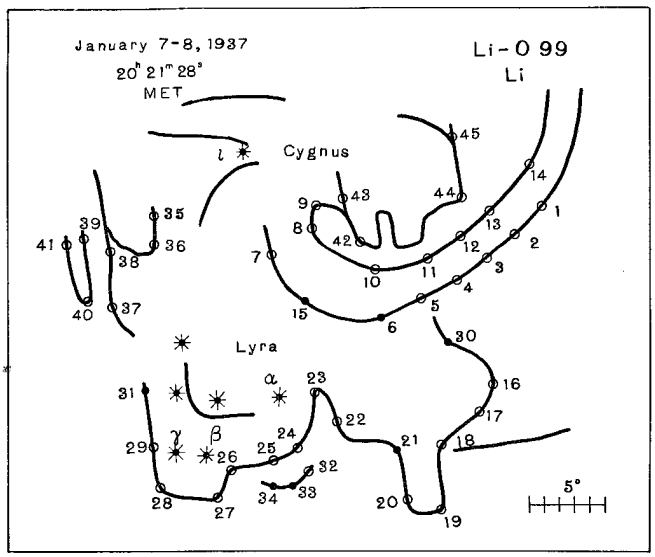

January 25-26, 1938
1h 35m 45s
MET
Li-C-Ak
163
Taurus
Orion
Li
C
Ak
5°

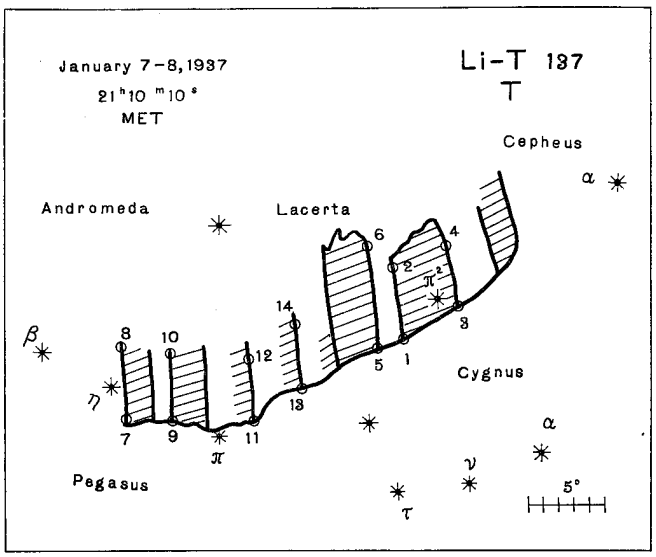

January 26, 1926
18h 37m 59s MET
Pegasus
green
red
5°

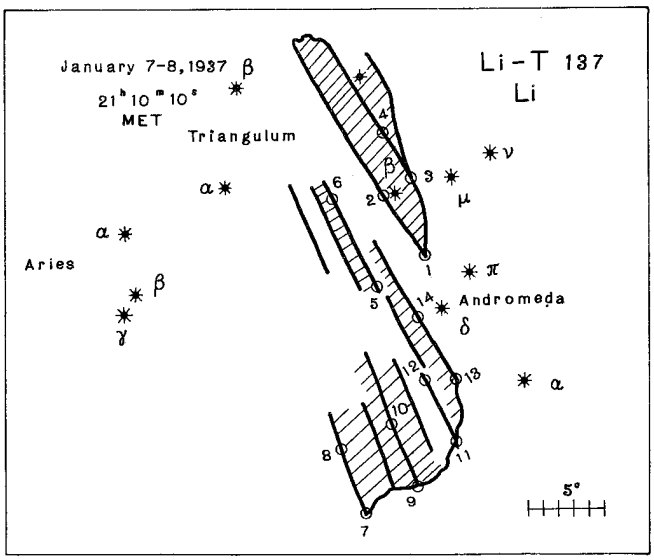

January 7-8, 1937
20h 21m 02s
MET
Li-0 98
0
β Draco
Hercules
5°


January 7-8, 1937
20h 21m 02s
MET
Li-0 98
Li
Cygnus
Draco
Lyra
Hercules
5°


January 7-8, 1937
20h 21m 28s
MET
Li-0 99
0
ν Draco
Hercules
5°

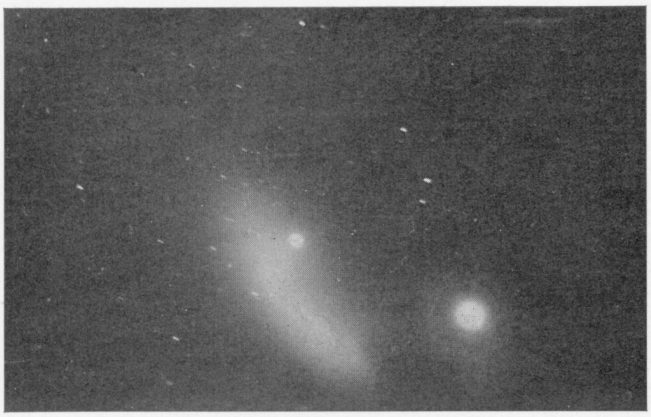

January 7-8, 1937
20h 21m 28s
MET
Li-0 99
Li
Cygnus
Lyra
5°


January 7-8, 1937
21h 10m 10s
MET
Li-T 137
T
Cepheus
Andromeda
Lacerta
Cygnus
Pegasus
5°


January 7-8, 1937
21h 10m 10s
MET
Li-T 137
Li
Triangulum
Aries
Andromeda
5°

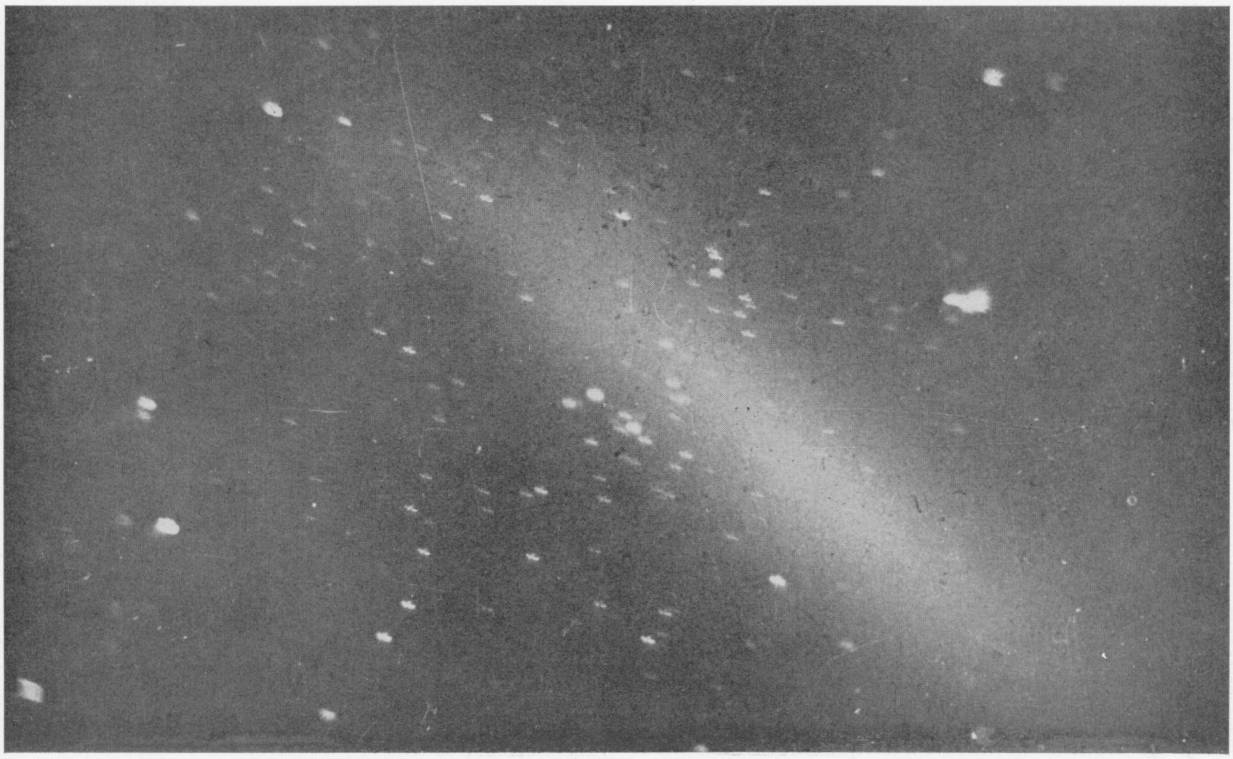
Oscarsborg $19^h\,55^m\,42^s$ M E T.

Oslo $19^h\,55^m\,42^s$ M E T.



Oscarsborg $20^h\,02^m\,44^s$ M E T.

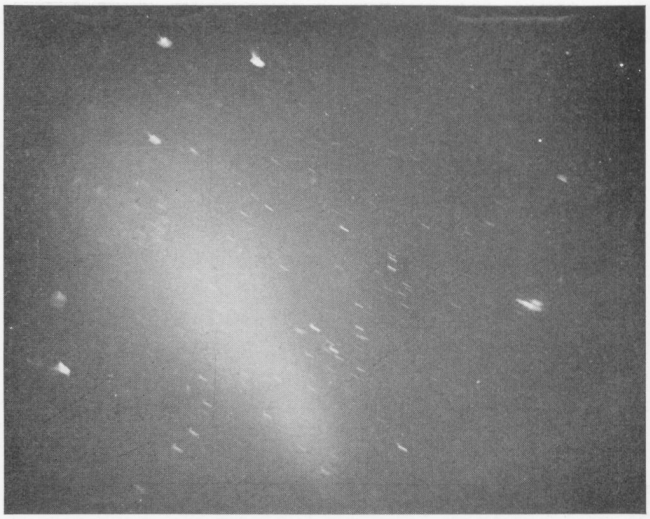
Oslo $20^h\,02^m\,42^s$ M E T.



Kongsberg $20^h\,05^m\,44^s$ M E T.

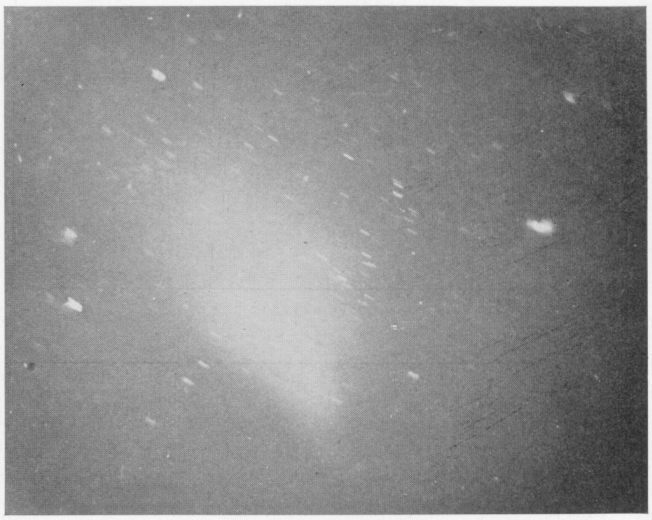
Pulsating arc on February 28th, 1929.

Oscarsborg $22^h\,01^m\,24^s$ M E T.



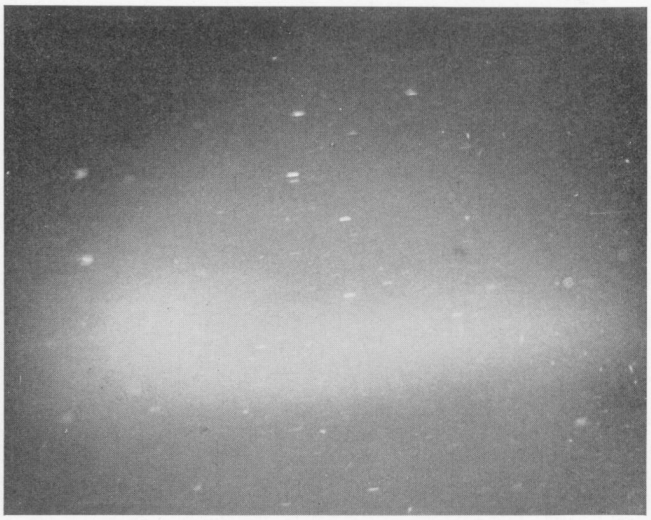
Oslo $22^h\,01^m\,24^s$ M E T.

Oscarsborg $22^h\,07^m\,24^s$ M E T.



Oslo $22^h\,07^m\,24^s$ M E T.

Oscarsborg $23^h\,05^m\,00^s$ M E T.



Oslo $23^h\,05^m\,00^s$ M E T.

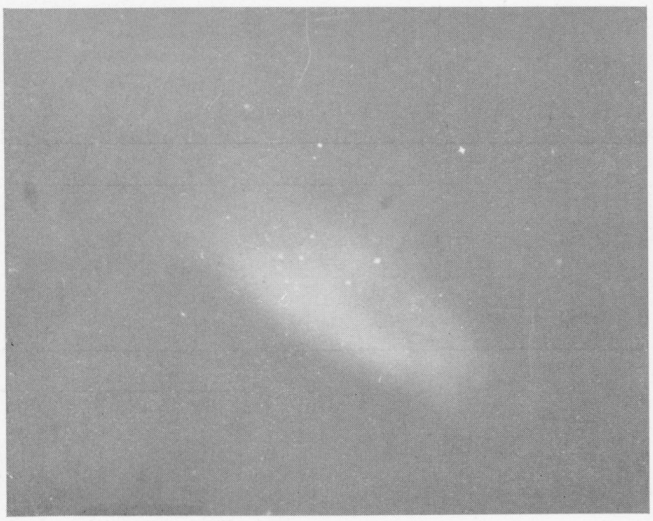
Pulsating arc on February 28th, 1929.

Askim $20^h\,41^m\,53^s$ M E T.

Oslo (*M*) $20^h\,41^m\,53^s$ M E T.

Askim $21^h\,26^m\,49^s$ M E T.

Oslo (*M*) $21^h\,26^m\,49^s$ M E T.

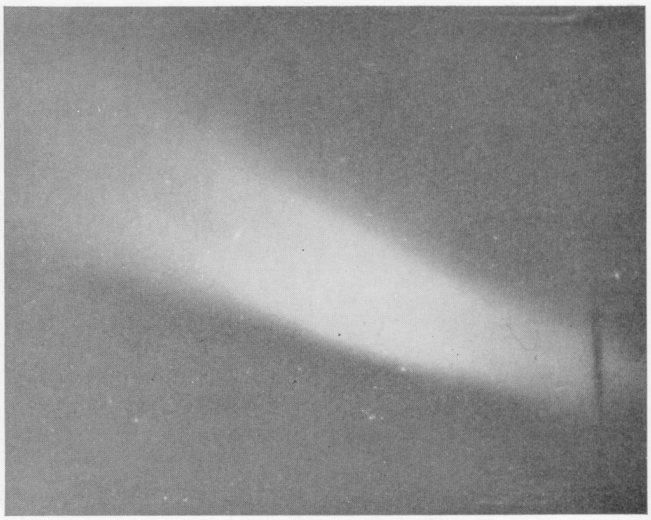


Askim $21^h\,52^m\,40^s$ M E T.

Oslo (*M*) $21^h\,52^m\,40^s$ M E T.

Pulsating arcs on September 21st—22nd, 1941.

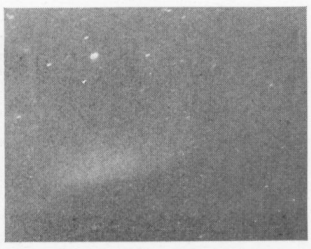
1. Askim $23^h\,48^m\,24^s$ M E T.



2. Oslo (*M*) $23^h\,48^m\,24^s$ M E T.

3. Askim $0^h\,29^m\,06^s$ M E T.

4. Oslo (*M*) $0^h\,29^m\,06^s$ M E T.



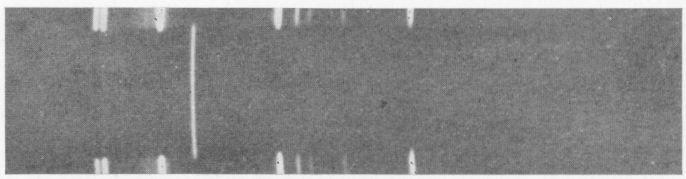
Holmestrand
Sept. 22nd
$21^h\,33^m$ M E T

5

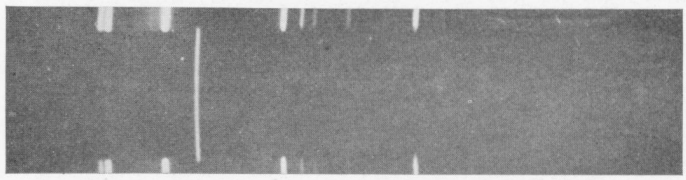
Oslo (*M*)
Sept. 22nd
$21^h\,33^m$ M E T

6

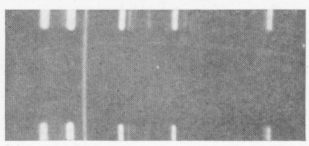
Spectrum b



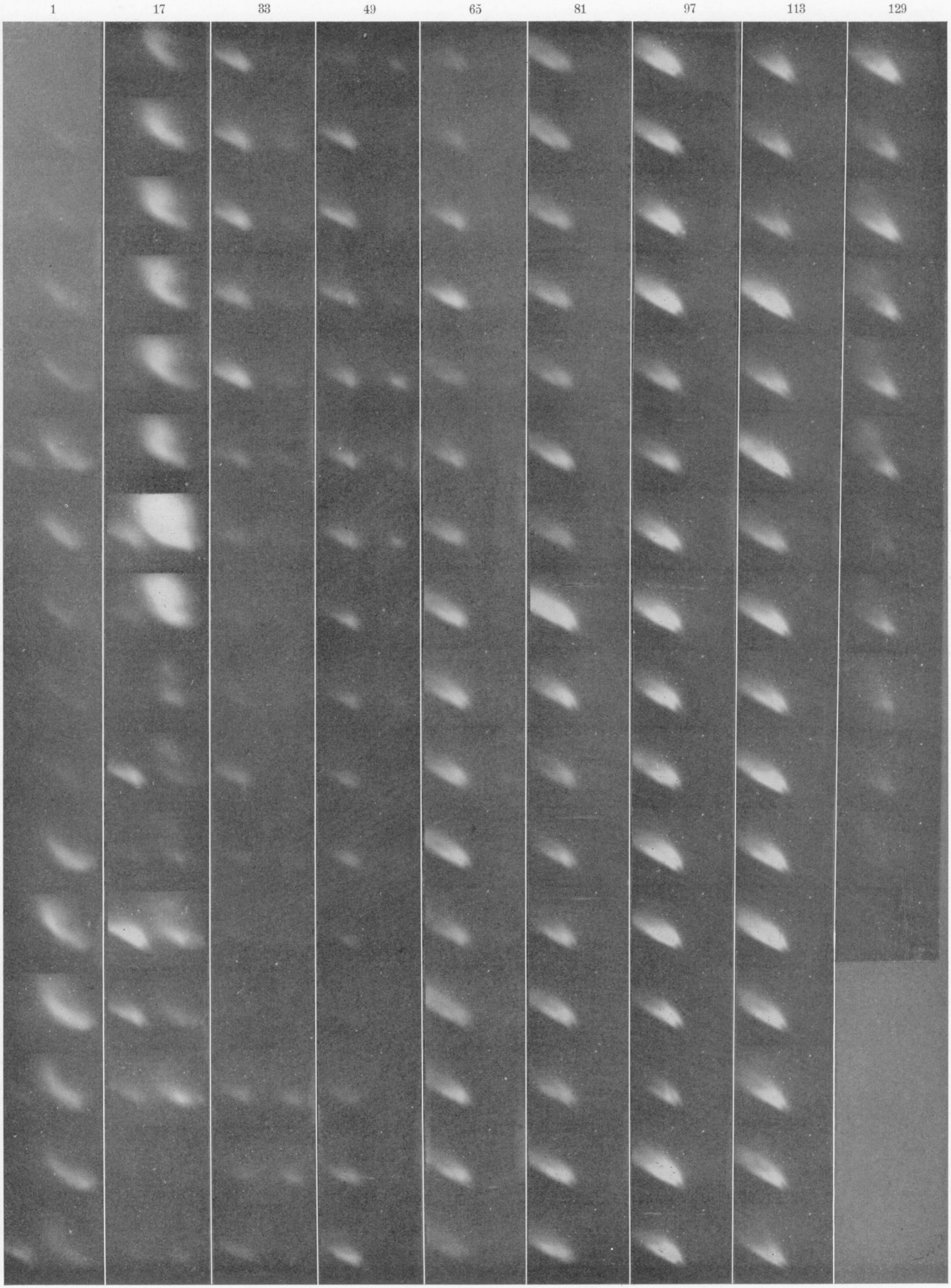
Spectrum e



Spectrum g



1—4: Pulsating arc on September 21st—22nd, 1941, with spectra.
5—6: Pulsating spot on September 22nd, 1941.



Moving picture series of pulsating aurora on September 21st, 1941.

Kongsberg, November 10th—11th, 1925,
$0^h\ 56^m\ 35^s$ M E T.

Bygdø, November 10th—11th, 1925,
$0^h\ 56^m\ 35^s$ M E T.

Oslo, March 13th—14th, 1928, $0^h\ 37^m\ 15^s$ M E T.

Tømte, March 13th—14th, 1928, $0^h\ 37^m\ 15^s$ M E T.

Kongsberg, January 7th—8th, 1937, $2^h\ 36^m\ 14^s$ M E T.

Oslo, January 7th—8th, 1937, $2^h\ 36^m\ 14^s$ M E T.

Pulsating Patches.

Kongsberg, January 7th—8th, 1937,
$2^h\ 37^m\ 10^s$ M E T.

Tømte, January 7th—8th, 1937,
$2^h\ 37^m\ 10^s$ M E T.

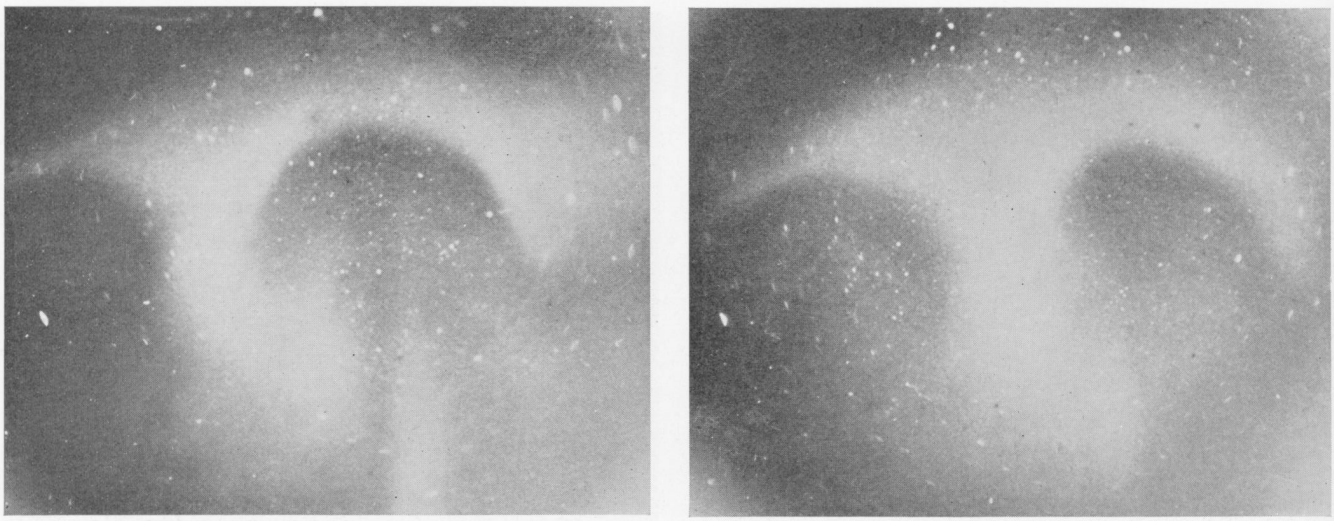
Oslo, January 21st—22nd, 1938,
$0^h\ 13^m\ 14^s$ M E T.

Lillehammer, January 21st—22nd, 1938,
$0^h\ 13^m\ 14^s$ M E T.

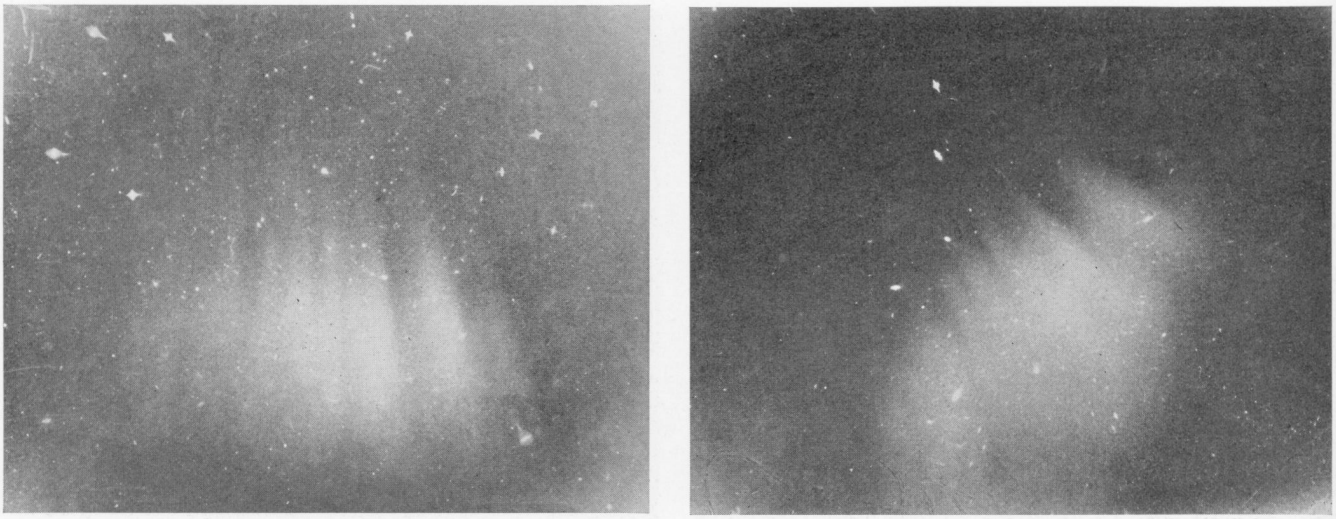
Oslo, January 21st—22nd, 1938,
$0^h\ 13^m\ 35^s$ M E T.

Lillehammer, January 21st—22nd, 1938,
$0^h\ 13^m\ 35^s$ M E T.

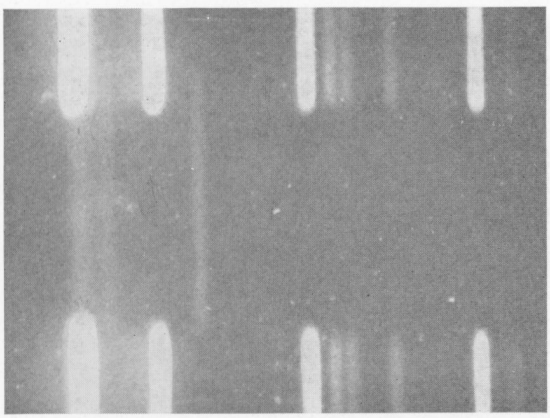
Pulsating Patches.



Pulsating surface, Bygdø, September 15th—16th, 1926. — Left $23^h\,51^m\,00^s$ M E T, right $23^h\,52^m\,50^s$ M E T.

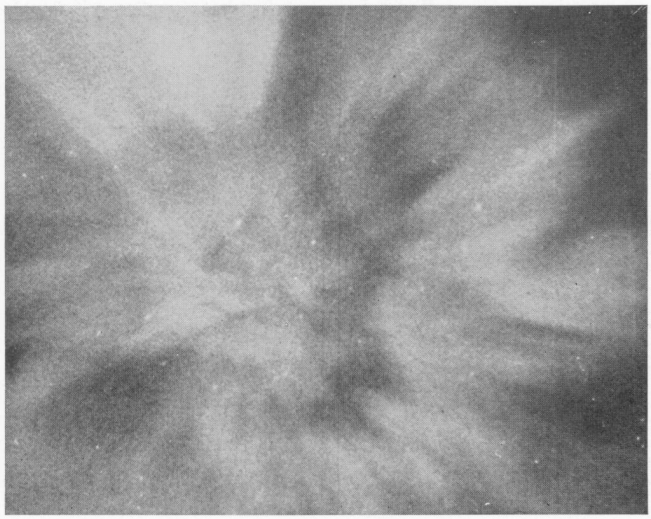


Flaming Aurora, January 25th—26th, 1938, $5^h\,51^m\,35^s$ M E T. — Left from Oscarsborg, right from Oslo.



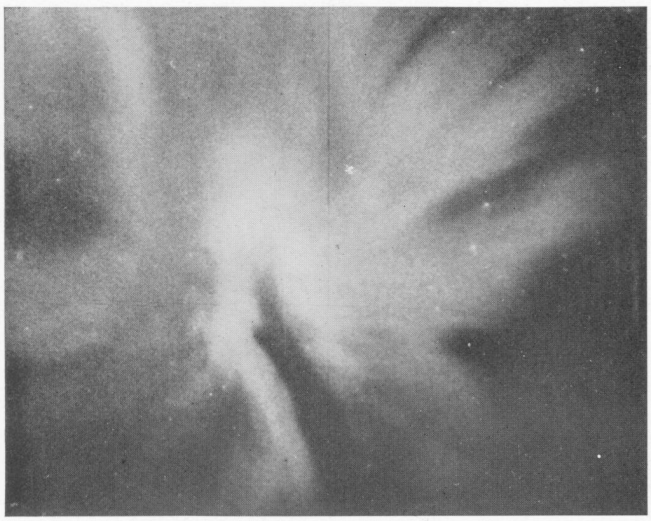
Spectrum of flaming aurora,
January 25th—26th, 1938. *He* spectrum on both sides.

Registrams of the same spectrum.



a

b



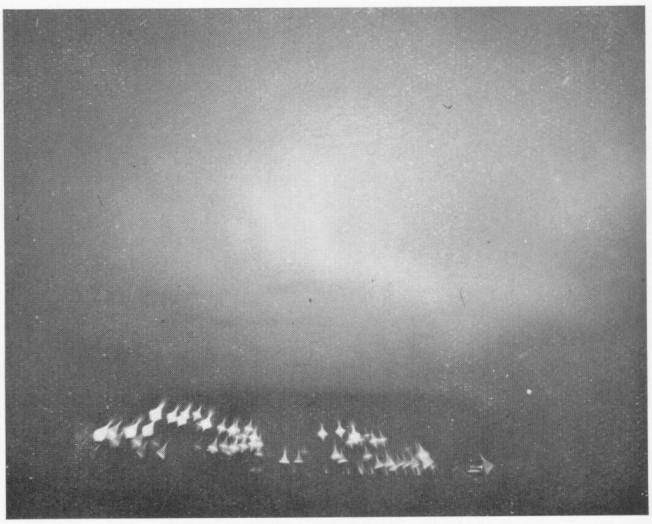
c

d

Flashing corona on March 30th—31st, 1941. Number a at $22^h\,52^m\,51^s$, b, c, and d at $22^h\,53^m$ M E T.
The time interval between b, c, and d 3 seconds.

Cloudlike aurora at $4^h\,04^m\,04^s$ M E T on March 24th—25th, 1933. Left from Løkken Verk, right from Trondheim.
The rings on the left picture due to reflection in the objective.

Løkken Verk $4^h\ 08^m\ 51^s$ M E T.



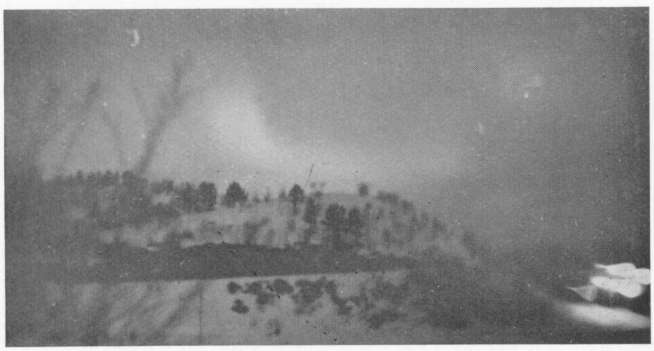
Trondheim $4^h\ 08^m\ 51^s$ M E T.

$4^h\ 04^m\ 04^s$ M E T.

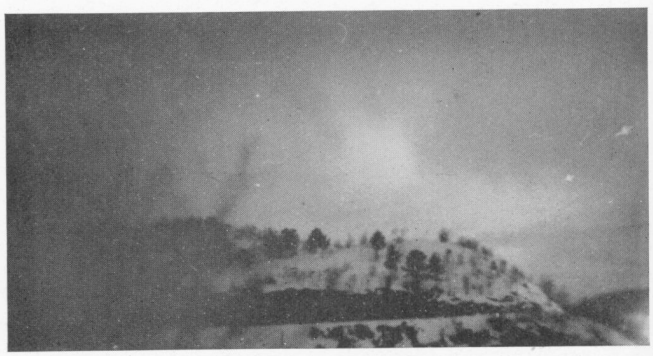
$4^h\ 06^m\ 46^s$ M E T.

$4^h\ 04^m\ 53^s$ M E T.

$4^h\ 07^m\ 53^s$ M E T.



$4^h\ 05^m\ 50^s$ M E T.



$4^h\ 08^m\ 51^s$ M E T.

Successive pictures from Løkken Verk.

Cloudlike Aurora on March 24th—25th, 1933.

Oslo, January 27th—28th, 1935,
$2^h\ 27^m\ 19^s$ M E T.

Lillehammer, January 27th—28th, 1935,
$2^h\ 27^m\ 19^s$ M E T.

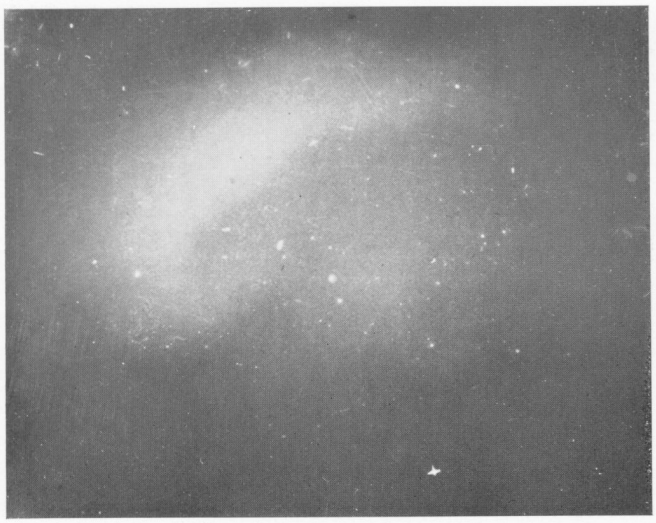
Oscarsborg, January 3rd, 1940,
$18^h\ 22^m\ 28^s$ M E T.

Lillehammer, January 3rd, 1940,
$18^h\ 22^m\ 28^s$ M E T.

Oscarsborg, January 3rd, 1940,
$18^h\ 33^m\ 26^s$ M E T.

Lillehammer, January 3rd, 1940,
$18^h\ 33^m\ 26^s$ M E T.

Cloudlike Aurora.

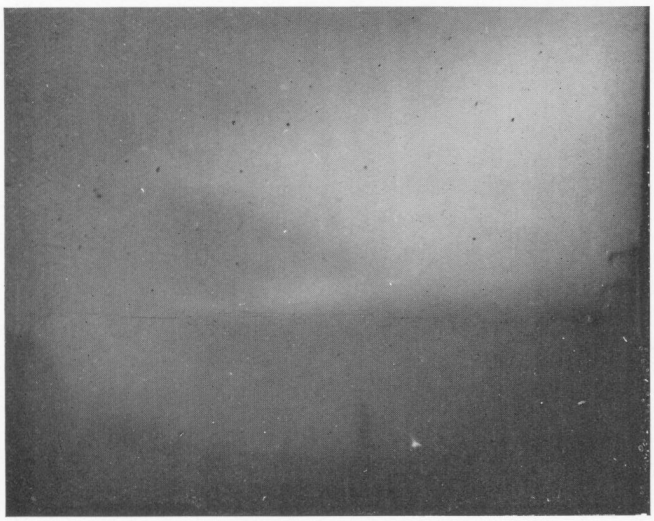


Oslo $19^h\ 01^m\ 31^s$ M E T.

Lillehammer $19^h\ 01^m\ 31^s$ M E T.

Oslo $19^h\ 02^m\ 09^s$ M E T.

Lillehammer $19^h\ 02^m\ 09^s$ M E T.



Hokksund $17^h\ 46^m\ 58^s$ M E T.

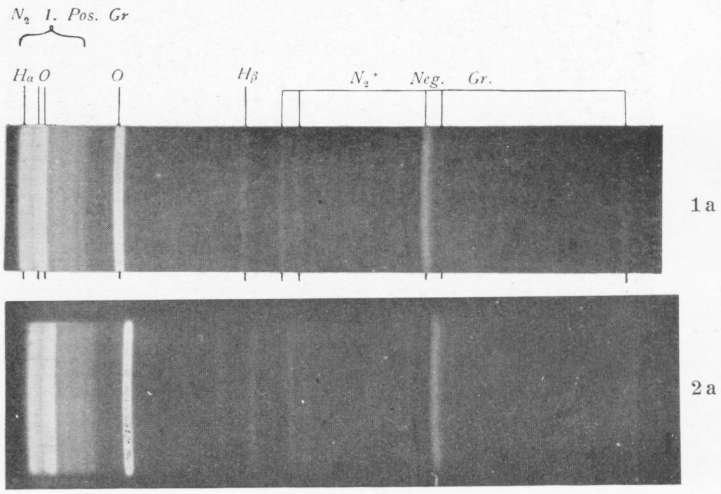
Oscarsborg $18^h\ 13^m\ 08^s$ M E T.

Cloudlike Aurora on January 3rd, 1940.

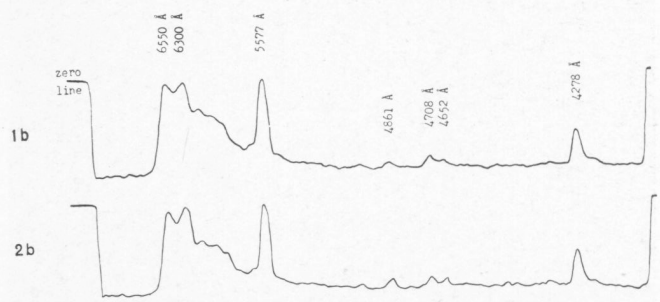
Oscarsborg $18^h\,14^m\,35^s$ M E T.

Hokksund $19^h\,21^m\,53^s$ M E T.

Hokksund $18^h\,54^m\,03^s$ M E T.



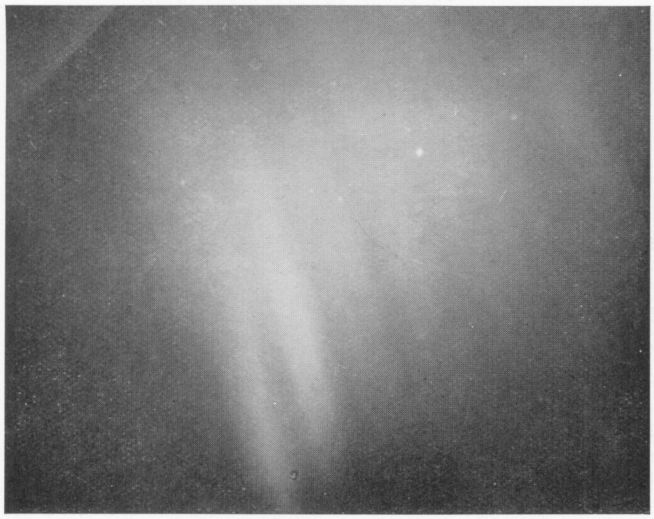
Oscarsborg $19^h\,02^m\,34^s$ M E T.



1a: Spectrum of cloudlike aurora on January 3rd, 1940, with registram 1b.

2a: Spectrum of a homogeneous arc on the same evening with registram 2b.

Cloudlike Aurora and Spectra on January 3rd, 1940.



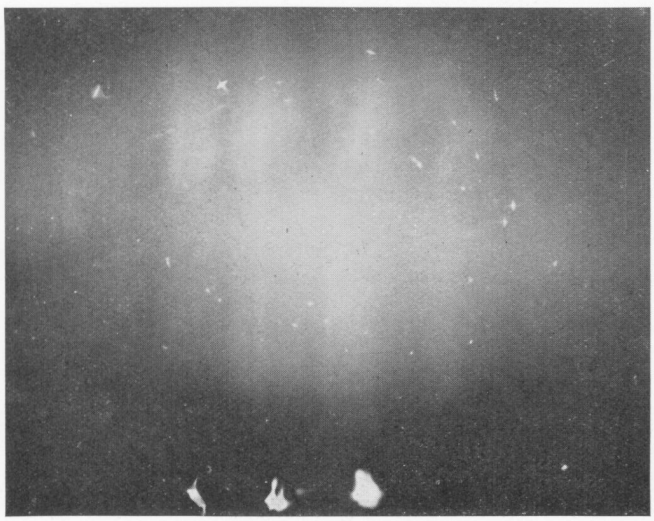
Oslo $17^h\,57^m\,52^s$ M E T.

Lillehammer $17^h\,57^m\,52^s$ M E T.

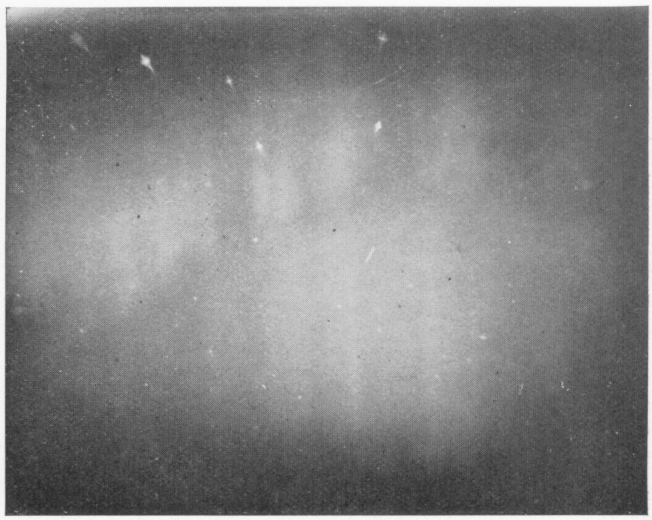
Askim $17^h\,59^m\,57^s$ M E T.

Oslo $17^h\,59^m\,57^s$ M E T.

Red sunlit rays on January 3rd, 1940.

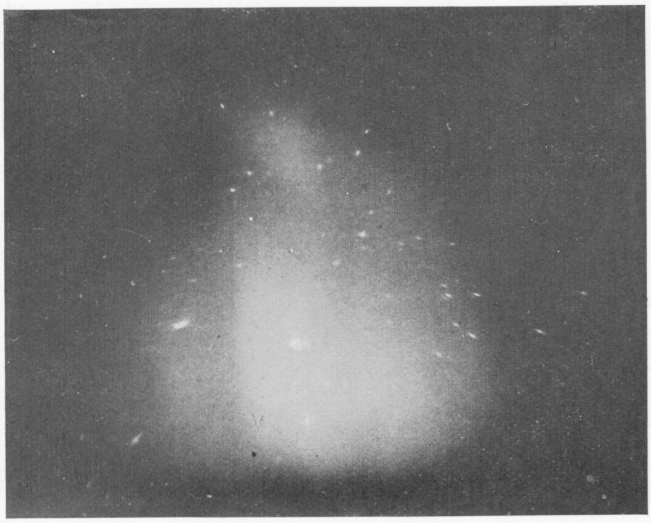


Kongsberg $20^h\,55^m\,07^s$ M E T.



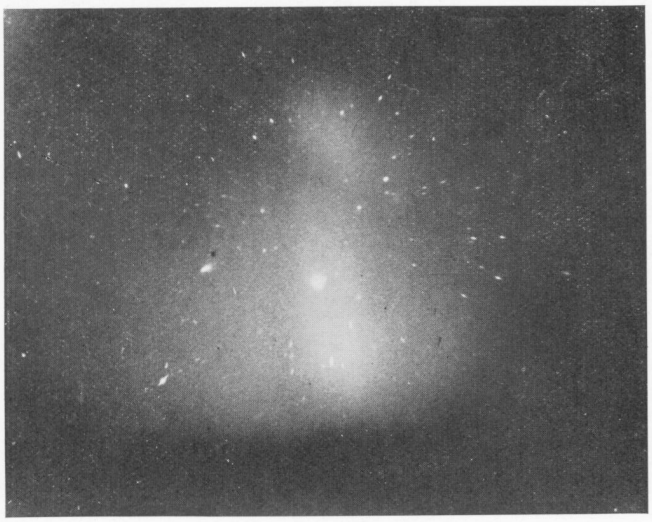
Tømte $20^h\,55^m\,07^s$ M E T.

Divided Rays on October 11th, 1937.



Tømte $3^h\,35^m\,08^s$ M E T.

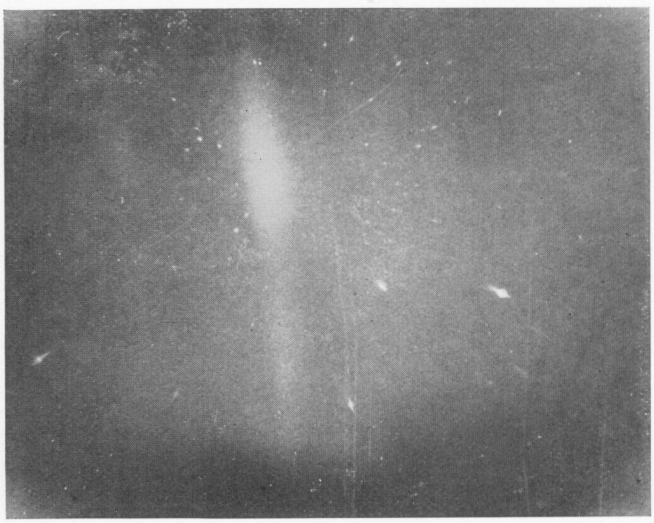
Oslo $3^h\,52^m\,03^s$ M E T.



Askim $3^h\,35^m\,08^s$ M E T.

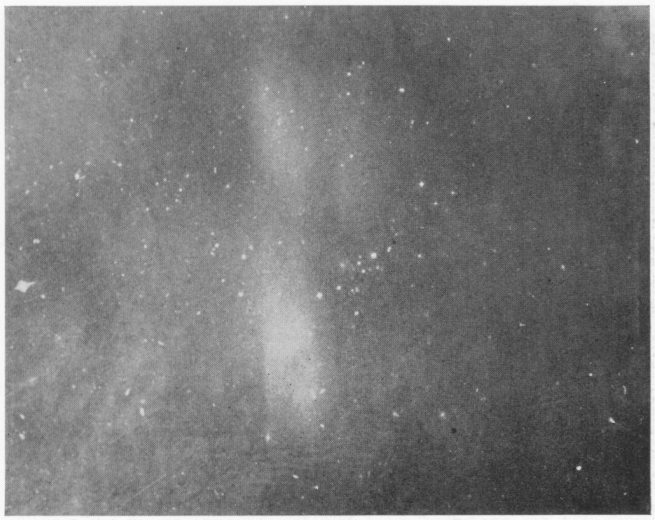
Askim $3^h\,52^m\,03^s$ M E T.

Kongsberg $3^h\,35^m\,08^s$ M E T.

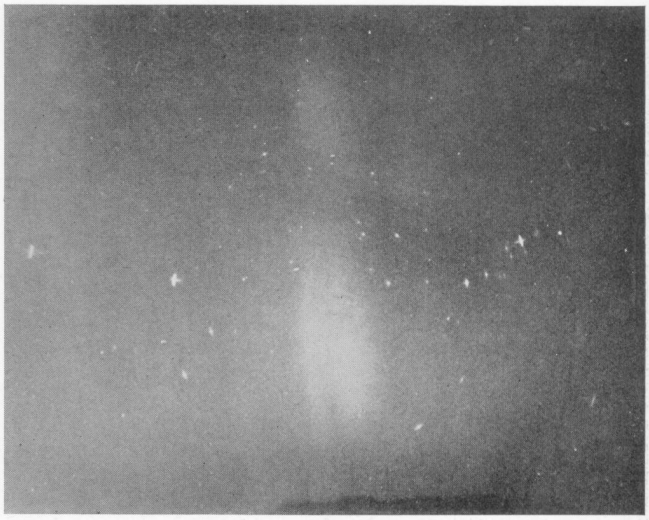


Kongsberg $3^h\,52^m\,03^s$ M E T.

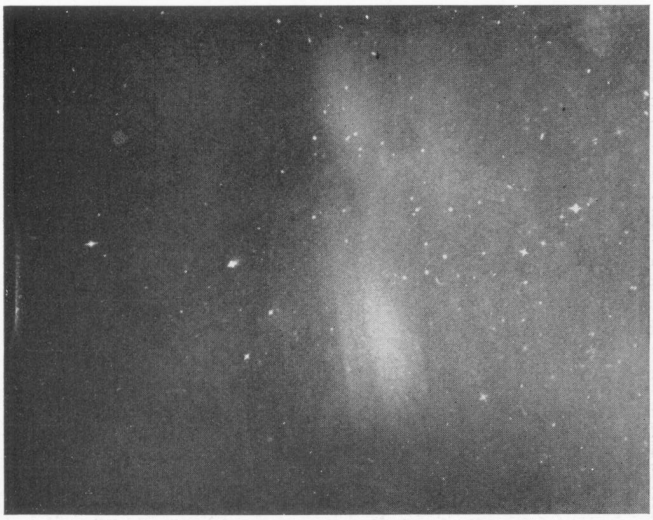
Divided Rays on March 21st—22nd, 1938.



Kongsberg $3^h\,36^m\,28^s$ M E T.

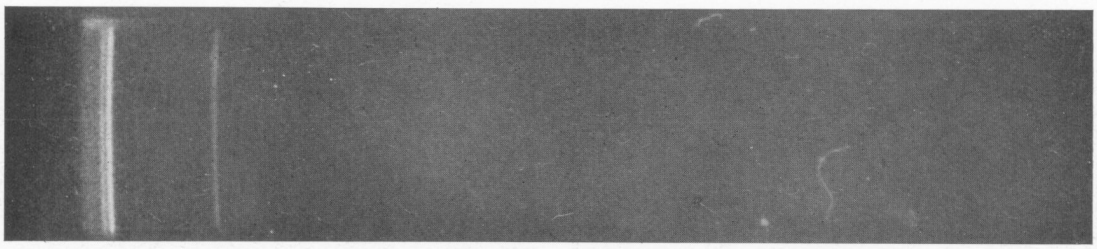


Oslo $3^h\,36^m\,28^s$ M E T.

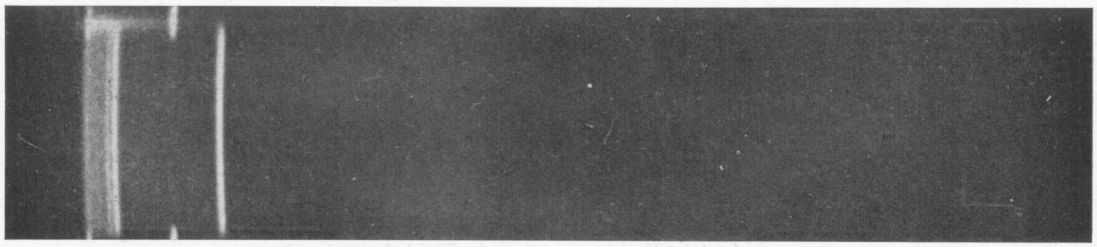


Askim $3^h\,36^m\,28^s$ M E T.

Tømte $3^h\,36^m\,28^s$ M E T.

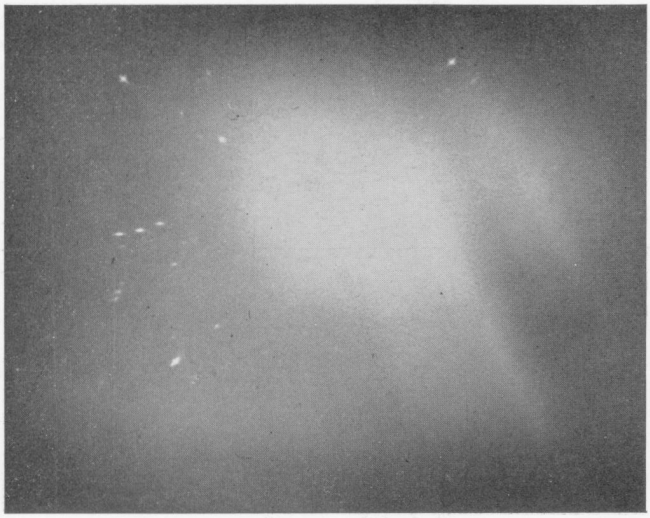


Divided rays.



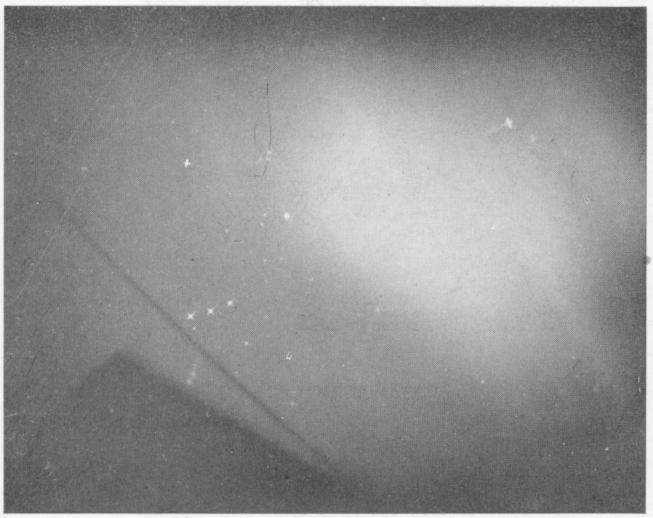
Homogeneous arc.

Divided Rays and Spectra on March 21st—22nd, 1938.

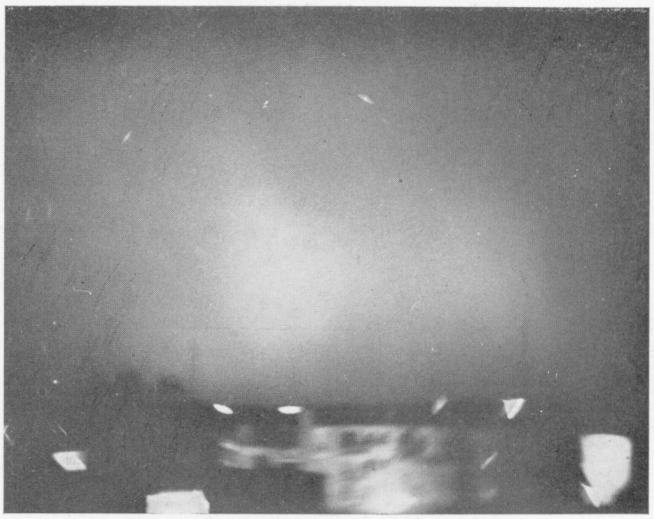


Tømte $23^h\ 12^m\ 30^s$ M E T.

Lillehammer $1^h\ 35^m\ 45^s$ M E T.



Oscarsborg $23^h\ 12^m\ 30^s$ M E T.

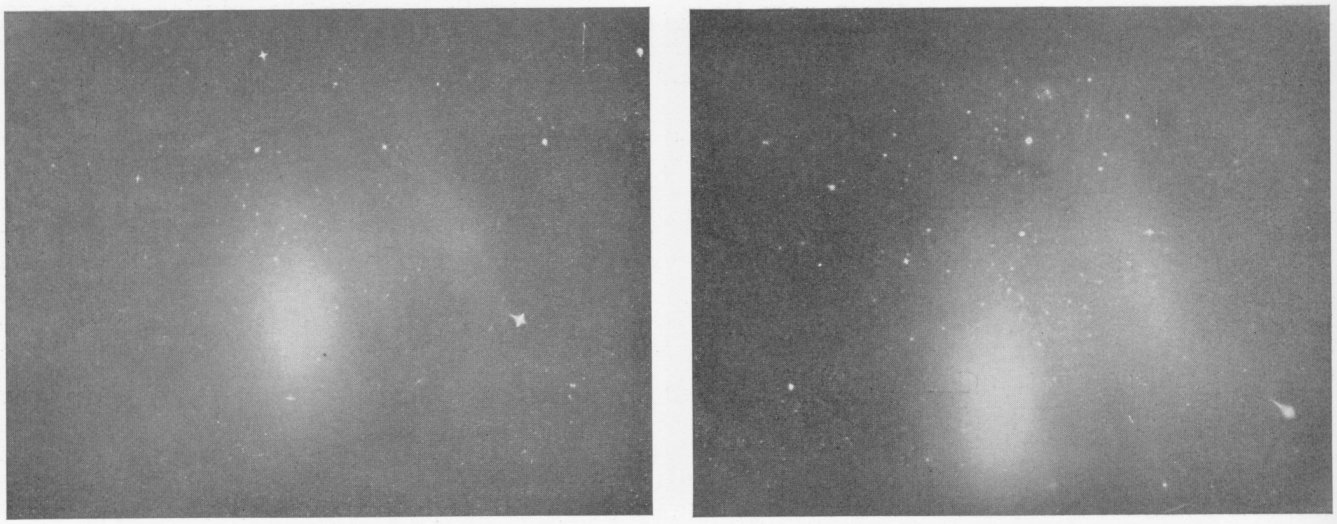


Oslo $1^h\ 35^m\ 45^s$ M E T.

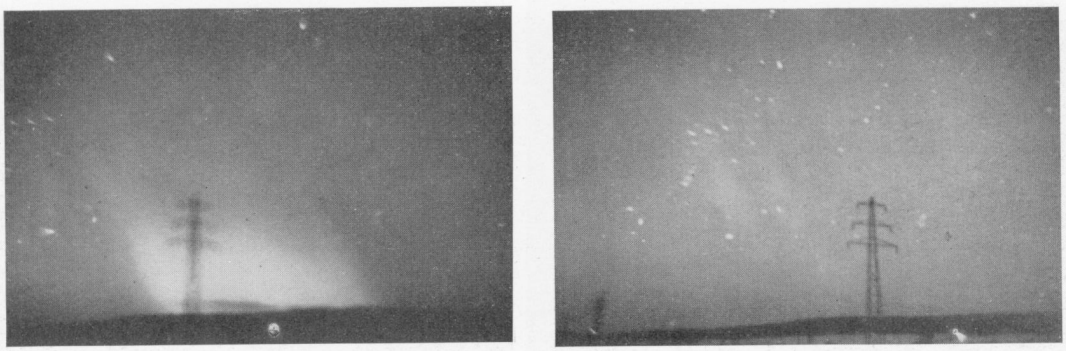
Tuddal $23^h\ 12^m\ 30^s$ M E T.

Askim $1^h\ 35^m\ 45^s$ M E T.

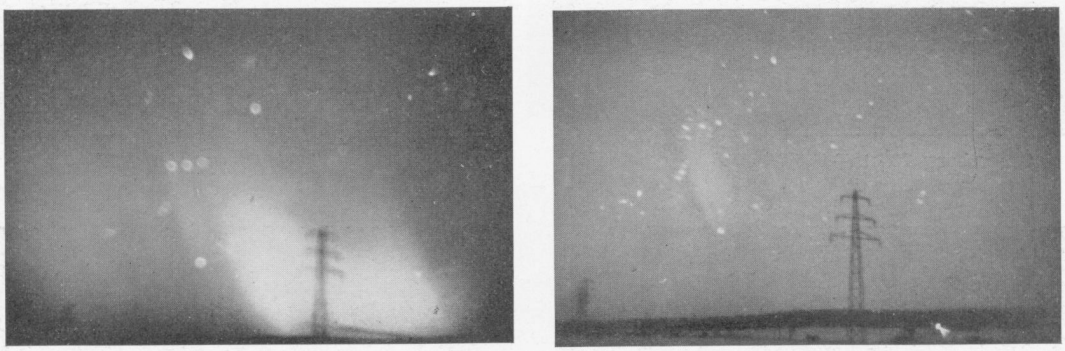
Red Patches on January 25th—26th, 1938.



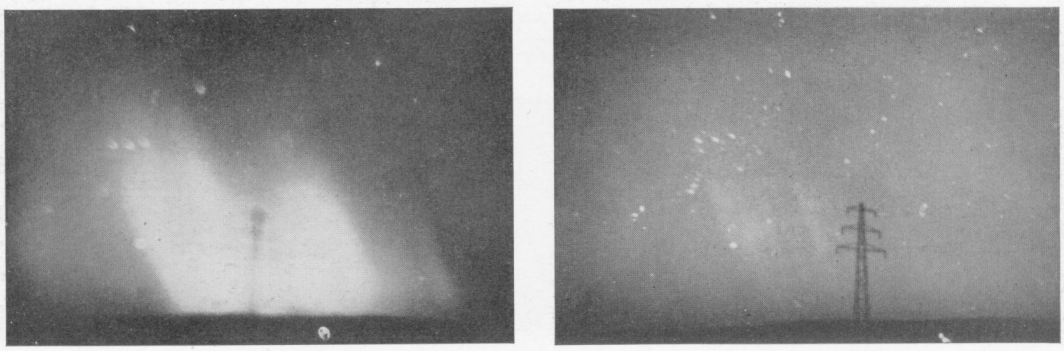
Red surface on November 14th—15th, 1938, from Askim (left) and from Tømte (right), $23^h\,07^m\,13^s$ M E T.



$0^h\,57^m\,42^s$ M E T.



$1^h\,00^m\,46^s$ M E T.



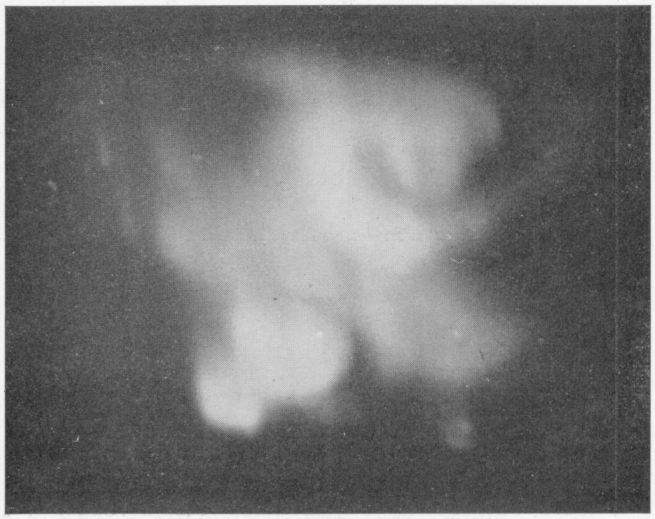
$1^h\,03^m\,19^s$ M E T.

Series of photographs of red spot from Hokksund
taken simultaneously on pancromatic Agfa ISS (left) and on non-pancromatic Sonja EW plates (right).

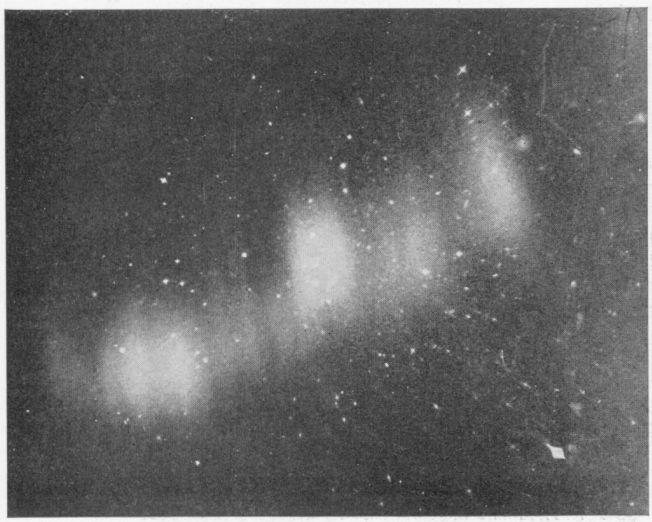
Oscarsborg $20^h\ 21^m\ 02^s$ M E T.

Lillehammer $20^h\ 21^m\ 02^s$ M E T.

Oscarsborg $20^h\ 21^m\ 28^s$ M E T.



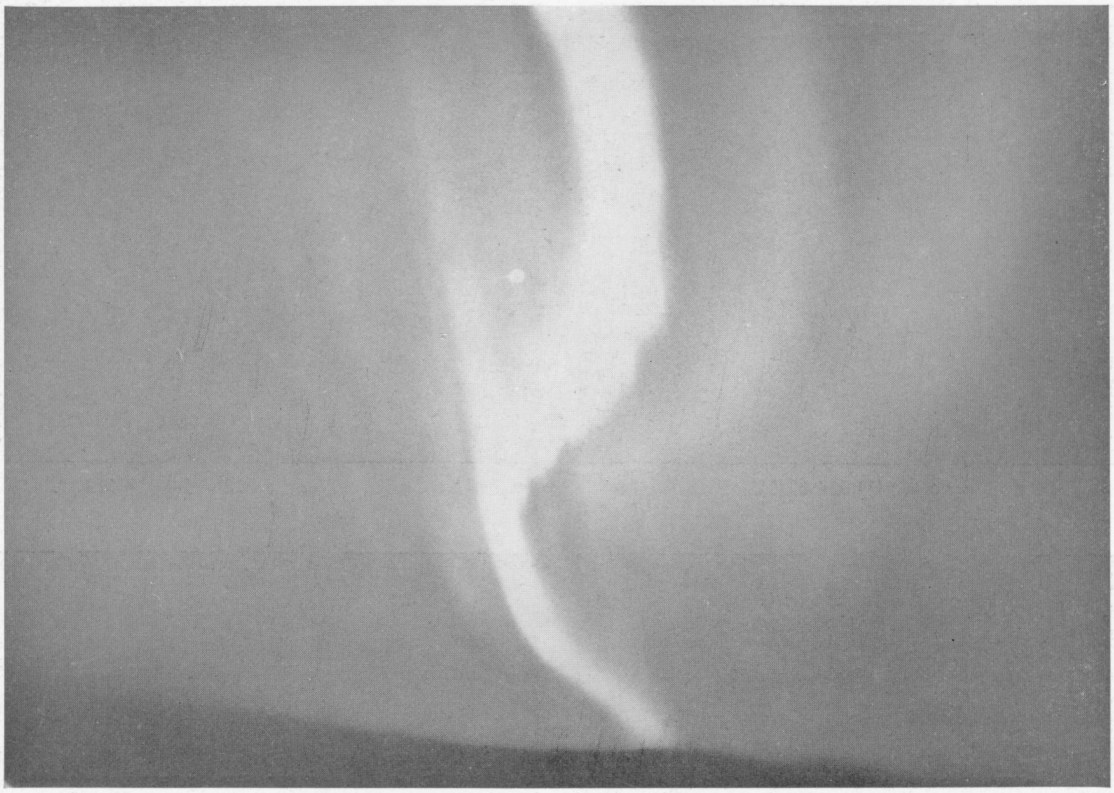
Lillehammer $20^h\ 21^m\ 28^s$ M E T.



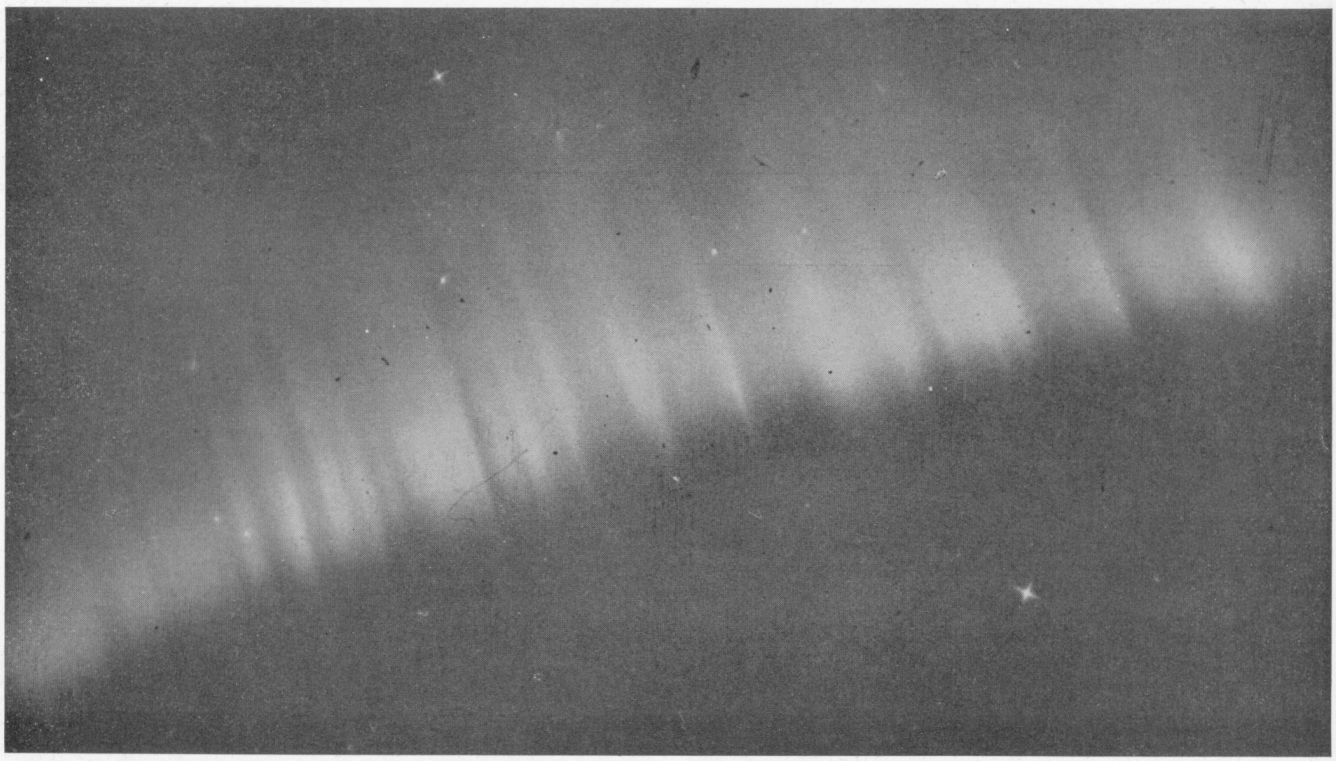
Tømte $21^h\ 10^m\ 10^s$ M E T.

Lillehammer $21^h\ 10^m\ 10^s$ M E T.

Aurora Bands on January 7th—8th, 1937.

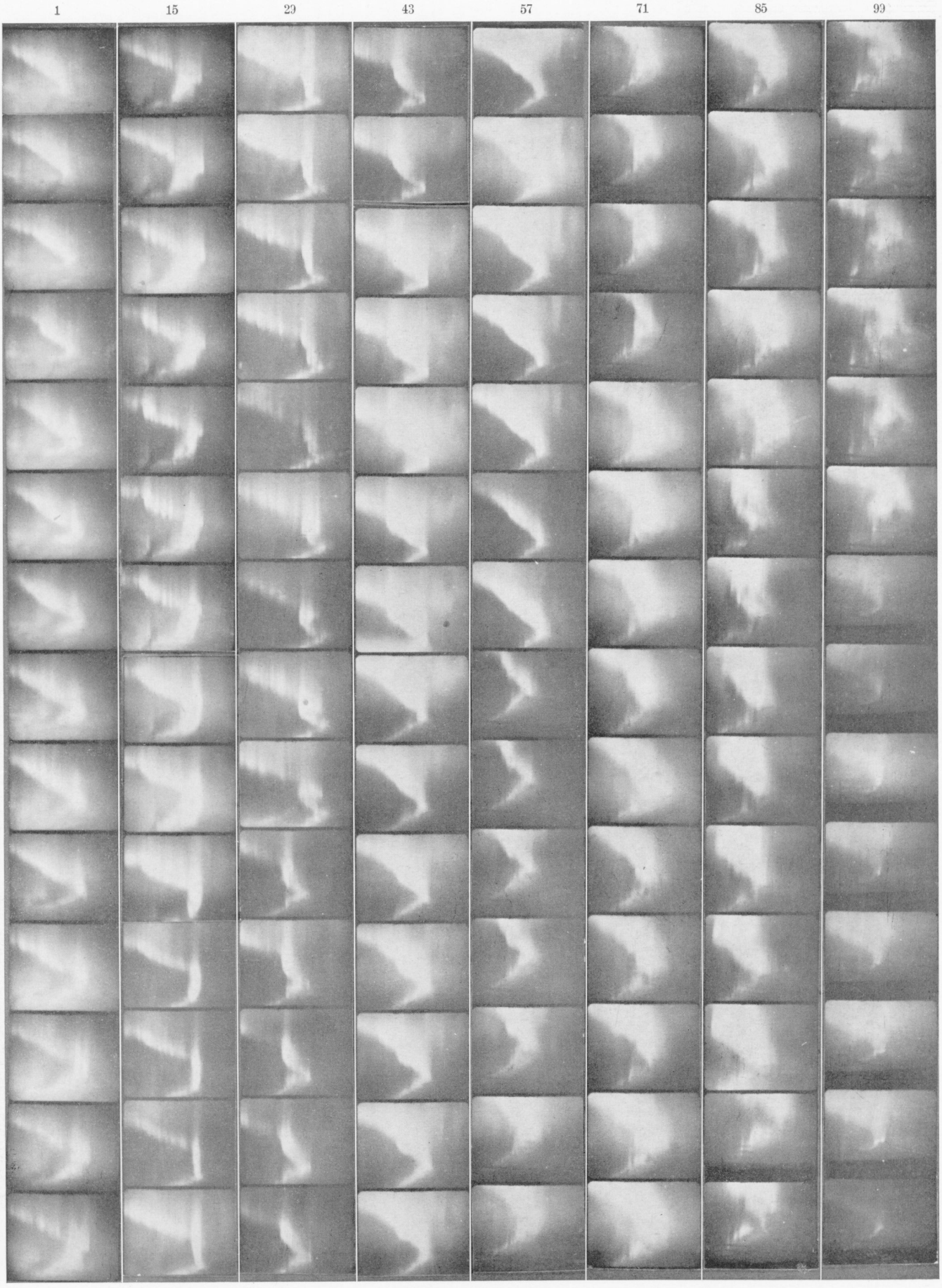


Lillehammer, September 18th, 1941, $20^h\ 25^m\ 46^s$ M E T.



Oslo (*M*), October 31st—November 1st, 1941, $0^h\ 30^m$ M E T.

Remarkable Aurora Bands.



Moving Picture Series of Aurora at $0^h\,30^m$ M E T on November 1st, 1941.