GEOFYSISKE PUBLIKASJONER

GEOPHYSICA NORVEGICA

VOL. XXII NO. 6

AURORAL INVESTIGATIONS DURING THE WINTER SEASONS 1957/58 — 1959/60 AND THEIR BEARING ON SOLAR TERRESTRIAL RELATIONSHIPS

BY L. VEGARD

FREMLAGT I VIDENSKAPS-AKADEMIETS MØTE DEN 27DE JANUAR 1961

Summary. The paper presents the results of spectral investigations of aurorae carried out at Oslo and Tromsø during the seasons 1957—1960. The two large spectrographs "V" and "F" (19, p. 1 1956) were used at Tromsø. A spectrograph "C" of smaller dispersion (page 25) was used at Oslo.

Results with the "V"-spectrograph. With the "V"-spectrograph the 5 spectrograms obtained on Kodak 103 a—E-plates were reproduced on plate Ia, Nos. 1—5. On plate Ib were reproduced 7 "V"-spectrograms (Nos. 6—12) taken on Kodak 103 a—J plates. Wavelength values and intensities were measured for the features observed (Nos. 1, 2, 4, 5) and (Nos. 6, 9, 10, 12) of the "V"-plates Ia and Ib. The results are given in the large tables 3a and 3b. The possible interpretations are given in the last column.

The ionospheric temperatures were measured from a number of (N_2^+IN)-bands from the ("V") spectrograms of plate Ia giving a mean temp. = 234° *K* (table 4a). Plate Ib gave a mean temp. 233,5° *K*, table 4b. The temperature measurements showed no indication of increase with altitude.

Spectrograms taken with the "F"-spectrograph.

A. *Spectra from Kodak 103 a—E.* Reproduced with explanation on the plates IIa, IIb, and IIc. Total number 89. Relative intensities of forbidden *OI*-lines, some nitrogen bands and H_α lines were measured and tabulated.

B. *"F"-spectrograms from Kodak 103 a—J.* Reproduced on plates IIIa and IIIb. Relative intensities measured of the bands N_2^+IN = (0—1), (1—2), (0—2), (1—3), (0—3), (1—4), H_β, *NII* (5000), *NI* (5200). The intensity of N_2^+IN (1—2) was equal to 6. The results agree with those given in paper 19 §§ 15—22.

Remarks on the features were given in the last columns of tables 5a and 5b.

The spectrograms taken on Kodak 103 a—E and reproduced on plates II (a, b, c) are classified into two types collected in the groups *E* and *P*, where those in the *E*-group are excited mainly

by primary solar electrons reaching down to the bottom edge (h_e), and the group P, typical for proton excitation from the height (h_p) and upwards. In the case of total separation in the interval ($h_p - h_e$) the luminescence is mainly produced by solar electrons.

The intensity variations relative to that of the green line (5577) is indicated in the following table (cfr. table 7):

Int. (5577) = 100.

(I) of features	OI (6300)	H_α (6563)	N_2^+IN (1—0)	N_2IP (8—5)	N_2IP (7,4)
Group E	19	0.70	3.8	5.0	6.8
Group P	675	3.57	9.1	4.9	6.9

This table shows:
The component (6300) of the forbidden red doublet is here 36 times greater when it is excited by protons, than by electron rays. The mean intensity of (H_α) is about 5 times greater in the proton group than in the group mainly excited by primary electrons.

The fact that the band N_2^+IN (0—1) is about 2.5 times greater in the P-group is due to the relative diminution of the green line (5577) with increasing altitude. The relative intensity of the two (N_2IP)-bands is the same in the group E and P, which means, that these bands are mainly excited by solar electrons down to the bottom part of the auroral luminescence.

The exitation of aurorae by protons is restricted to the transfer of the double ground state of OI ($^3P_{2,1}$) *to the metastable* $^1D_2$ *state, which stops to return to the ground states by emission of the red doublet.* The upper state $^1S_0$ is not formed and no similar increase of the green line (5577) is observed in connection with the great enhancement of the red doublet.

From the altitude (h_p), where the proton is absorbed and stops, and upwards, the red doublet may be excited by protons and emitted with great intensity, but no corresponding emission of the green line (5577) is found.

The electrons of the solar bundle, however, on the way downwards through the ionosphere to the auroral lower limit, will not be essentially influenced by the protons down to (h_p), but will transfer the ground states of the metastable states $^1D_2$ and $^1S_0$. As the lifetime of ($^1D_2 - {}^1S_0$) giving the green line *OI* (5577), according to fig. 1, is much shorter than that of the other *OI* transitions, the green line will dominate over the other forbidden *OI* lines, which are excited by electrons.

From this process it seems to follow that the green auroral lines (5577) which are sufficiently strong to be seen, are due to electron excitation.

The study of the forbidden *NI* doublet (5200, 5197) showed a similar variability of intensity as that found for the red *OI* doublet, (cfr. tables 8 and 9). Regarding the forbidden *NI*-doublet, cfr. [19], pp. 42—48.

The emission from the metastable *OI*-state showed that the enormous enhancement of the red *OI*-doublet could not be due to electron excitation, but had to be caused by a kind of chemical reaction between protons and the ground system of *OI*. In § 9 the enhancement of the *OI* doublet is briefly explained as follows:

Reaction between protons and the atomic system OI, OII, OIII, NI, NII by the formation of the forbidden $^1D_2$*-doublets.*

The collision between the neutral *O*-atom and the proton, which leads to the excitation of the red doublet emitted from the metastable $^1D_2$-state, differs most essentially from electronic excitation of *OI* already dealt with. We must first of all remember the positive charge of the proton and its great mass compared with that of the electron.

When a proton strikes an *OI*-atom it will attract one of the *OI*-electrons, and try to form a hydrogen atom. This interaction may partly result in the formation of a *H*-atom and a *OII*-ion, partly in the transfer of the ground state of *OI* to the metastable state *OI* $^1D_2$, which results in the emission of the red doublet. On account of the chemical coupling, the lifetime of the $^1D_2$-states is greatly reduced, so the probability of the emission of the red doublet is increased. This may account for the enormous enhancement of the emission of the doublet *OI* $(^3P_{2,1}-{}^1D_2)$ which is responsible for the red aurorae of type *A*.

The same reasoning may also account for the emission of the other doublets of the forbidden lines from a $^1D_2$ state to its corresponding ground state of *OI, OII, OIII, NI, NII.*

The chemical reaction between *O*-atoms and the protons of the solar bundle, which result in the formation of the *D*-doublet from the metastable ground state *OI* $^3P_{2,1}$, *has no influence on the higher metastable state OI* $^1S_0$, *or the emission of the green line OI* $(^1D_2-{}^1S_0)$ *(5577). This leads to the remarkable result that the famous green auroral lines are excited by photo-electrons contained in the solar bundles produced by sunspot X-rays.*

It is to be expected that the following corresponding forbidden lines from the upper metastable states behave like the green auroral line in so far as they are only excited by electrons like the following 5:

$$OI\ (^1D_2-{}^1S_0),\ OII\ (^2D_{3/2}-{}^2P_{3/2}),\ OIII\ (^1D_2-{}^1S_0)$$
$$NI\ (^2D_{5/2,\,3/2}-{}^2P_{1/2}),\ NII\ (^1D_2-{}^1S_0).$$

The electron excitation also holds for the transitions *P—S* and *S—P*.

Only the doublets *P—D* and *S—D* are excited by protons (cfr. table 1 (abcd), through a kind of electro-chemical reaction.

This forbidden reaction is called "catalysis in gas reaction", where in the present case the *OI*-electrons and the proton kinetic energy serve as catalyst.

Spectrograms taken in Oslo with spectrograph "*C*". During the period from 29.8. 57 to 5.11. 59, 72 spectrograms were taken at Oslo, 61 on Kodak 103 a—E and 11 on Kodak 103 a—J-plates. The spectrograms are reproduced on the 3 plates IV (a, b, c). Each plate is provided with explanations in the usual way. The spectral types show a great difference, and in most cases we can clearly distinguish between spectral types mainly excited by electrons or by protons (positive ions).

Part A. Table 11 shows group *E* (electron excit.), *P* (proton excit.) and mixed (*E, P* excit.)

The features of *E* and *P* are usually over-exposed so the intensity distribution cannot be accurately measured. But the distribution of the types can be approximately studied from the spectrograms on the plates IV (a, b, c).

The spectrograms from Kodak 103 a—E (No. 1—61) show great variations of bands from the *E*-group and of the red doublet in the *P*-group.

Part B. The spectrograms (No. 62—72) from Kodak 103 a—J show great variations in the intensity of (N_2^+1N) bands and the forbidden green *NI*-doublet.

Regarding the excitation of electrons and protons cfr. section *9*.

1. Remarks on previous results forming the background of the present paper. Our knowledge of the solar-terrestrial relationships is mainly based on the spectral analysis of the auroral luminescence, combined with the properties of the upper atmosphere and the solar phenomena.

These cosmic studies based on auroral research have been continued for more than 50 years. The results have been gradually obtained and dealt with in a number of papers, some of which are referred to in the list of papers [1, 2, 3, 4, 5, 6, 7, 8 and 9].

The gradual accumulation of auroral observations and results derived from related problems, has gradually been coordinated to a theoretical understanding of problems related to solar — terrestrial relationships, such as, aurorae, magnetic disturbances, zodiacal light, development of comets, the structure of the ionosphere (terrestrial corona), the solar corona and the "electron ray bundles", which are neutralized by protons and probably other positive rays, and which produce aurorae and allied cosmic — terrestrial phenomena.

The theory connecting these phenomena is based on what is called "the coronal effect of solar X-rays".

In addition to the papers already referred to, the following summaries of the theory of solar-terrestrial relationships based on "coronal effect of solar X-rays" have recently been published:

a. Paper read at the conference of Chemical Aeronomy sponsored by Geophysics Research Directorate, Cambridge, Mass, held on 25—28. June 1956 [12]. Published in "The Threshold of Space" edited by M. Zelekoff, p. 22, Pergamon Press, New York, London.

b. Preface to the paper [13] "Results of Auroral Observations at Tromsø and Oslo from the four Winters 1953/54—1956/57. Geof. Publ. XX No 9, 1958.

c. Phenomena in Planetary and Space physics governed by the "Coronal Effect of Solar X-rays". Det Norske Vid. Akad. Oslo. Avhandl. Mat. Naturv. Klasse, 1960, No. 1 [14].

At the end of that paper a short survey of some of the most important results from my investigations on aurorae and kindred cosmic phenomena covering a period of about 50 years, has been given. Following mostly historical lines, [14] provides proper justification for the various steps which have led to the theory of aurorae and solar-terrestrial relationships. The property of the cosmic phenomenon we consider is first of all a function of the frequency of the X-ray = type which is responsible for the phenomenon in question.

d. The following two reports were read by Professor, Dr. G. Fanselau, Geomagnetisches Institut, Potsdam, at the Symposium held in Berlin June 13—18. 1960.

Report I: The Theory of aurorae and other solar and terrestrial phenomena resulting from coronal effects of solar X-rays.

Report II: Separation and identification of the positive ions in the neutralized bundles which produce the aurorae.

The reports are expected to be published in connection with papers from the Symposium.

2. Remarks regarding the auroral observations of this period and the problems to be treated. With regard to aims and methods the present paper is to be regarded as a continuation of previous auroral investigations.

During the present period of three years, auroral spectrograms have been taken at the Tromsø observatory with the two large spectrographs "V" and "F". In Oslo we have now only used spectrograms from the spectrograph "C". The optical properties are found in previous papers [cfr. e.g. 19. 21].

With the spectrograph "V", 5 spectrograms were taken on photographic plates Kodak 103a—E and 7 on Kodak plates 103 a—J. The E-plates have the advantage of being very sensitive in the region covered by H_a and the red OI-doublet (6300, 6364), and were particularly favourable for the study of red features. The J-plates are insensitive to red, but very sensitive in a region near 5200. The J-plates were therefore used with advantage for the study of the forbidden NI-doublet ($^4S_{3/2}-^2D_{5/2,\ 3/2,}$ 5200.1, 5197.8).

The "F" spectrograph with its great light power and short time of exposure, was used for the study of variations of the auroral luminescence. With this spectrograph 89 spectrograms were taken with Kodak 103 a—E, and 61 with Kodak 103 a—J plates.

In Oslo 61 spectrograms were taken with Kodak 103 a—E and 11 with Kodak 103 a—J plates.

As pointed out in our investigations, the auroral theory based on the coronal effect of solar *X*-rays, leads to numerous consequences to be tested and verified by continued auroral observations regarding the variability of the spectral composition of auroral luminescence, combined with the different conditions of the exposure.

According to our theory the aurora is produced by bundles of photo-electrons neutralized by positive ions, preferably protons. When a neutralized bundle enters the ionosphere, it is no longer tied up with the condition of neutralization. The electric particles (photo-electrons and positive ions) used for neutralisations are free to move and to be absorbed independently of each other. This separation of the components of the bundles open up an important possibility for determining the nature of the particles and the altitudes they reach.

As a rule, the photo-electrons of the bundle will have the greatest range and will be absorbed at a height (h_1) near the bottom edge of the auroral streamer. The protons, however, will stop at a greater altitude, h_2. In the layer between h_2-h_1, the auroral luminescence will be excited by the photo-electrons of the bundle and have the typical features of excitation by electron rays, which may be characterized as follows:

Strong bands, few and mostly weak lines. Near the bottom edge, where the velocity rapidly decreases, while the intensity of the $N_2$1P bands increases to a sharp and great maximum value, the result is often that a strong red auroral band is formed along the bottom edge (red aurorae of type B).

Above the altitude (h_2) the intensity of the electron excitation is much reduced, while the excitation of positive ions (mainly protons) is taking the lead. The luminescence due to positive ions is here characterized with a great number of strong atomic lines, while the bands are very weak or absent.

Thus the fact that the luminescence produced by electrons differs in typical ways from that produced by protons and other positive ions, is a matter of great importance for the analysis of the composition of the auroral bundles.

3. The auroral light from forbidden transitions between metastable states of oxygen and nitrogen. Since it was found that the green auroral line was due to a forbidden transition of neutral oxygen atoms, it has gradually been shown that emissions from the two metastable ground states of *O*- and *N*-atoms (neutral and ionized) play a most important part in the spectral composition of the auroral bundles and for the study of ionospheric physics.

In 1926 it was shown that the red aurorae, which sometimes appeared, originated from a red line, which, however, in spectrographs of greater dispersion, appeared to be a red doublet.

Some of the forbidden lines from the metastable states of neutral and singly ionized oxygen and nitrogen are given in Table I.

Table I

OI (Terms)	λ	Life Time	*OII* (Terms)	λ	Life Time
$^1D_2-{}^1S_0$	5577.35	0.78 sec	$^2D_{3/2}-{}^2P_{3/2}$	7330	
a { $^3P_2-{}^1D_2$	6300.3	145 sec	c { $^4S_{3/2}-{}^2D_{3/2}$	3729	20 sec
a { $^3P_1-{}^1D_2$	6363.8	455 sec	c { $^4S_{3/2}-{}^2D_{5/2}$	3726	
$^3P_2-{}^1S_0$	2958.3		$^4S_{3/2}-{}^2P_{3/2}$	2471	
***NI* (Terms)**	**λ**	**Life Time**	***NII* (Terms)**	**λ**	**Life Time**
b { $^4S_{3/2}-{}^2D_{5/2}$	5200.1		$^1D_2-{}^1S_0$	5755	0.93 sec
b { $^4S_{3/2}-{}^2D_{3/2}$	5197.8	13 sec	d { $^3P_1-{}^1D_2$	6548	250 sec
$^4S_{3/2}-{}^3P_{1/2,3/2}$	3466.5	260 sec	d { $^3P_2-{}^1D_2$	6583	250 sec
$^2D_{5/2}-{}^2P_{1/2}$	10398	27 sec	$^3P_2-{}^1S_0$	3070	29 sec
$^2D_{3/2}-{}^2P_{1/2}$	10407		$^3P_1-{}^1S_0$	3063	

The green line and the red doublet of *OI* and the ultra violet line and the (green) doublet of *NI*, have been subject to investigations of great interest for the analysis of the composition of the neutralized auroral bundles, the physical properties of the metastable states of the neutral *O*- and *N*-atoms, and the excitation of these forbidden lines. In the case of *OII*, the doublet, but not yet the line 7330, has been observed in the aurorae, perhaps for the reason that the plates used have not been sufficiently sensitive in that region.

The *OI* and *NI* lines and especially the doublets are very variable. In papers published in 1936—38 it was shown that the red *OI*-doublet compared with the green *OI* line was greatly enhanced towards greater altitudes. [23].

A comparison between spectrograms obtained by means of comparable instruments and plates at Oslo and Tromsø had indicated that the red *OI* doublet is relatively enhanced towards lower latitudes.

From 1938 to 39 two instruments equally constructed and adjusted were used with the same sort of photo-plates at Oslo and Tromsø. At both places a considerable number of auroral spectrograms were taken with the following results [24]:

a. The average intensity of the red *OI* doublet (6300, 6364) relative to the (N_2IN) band 4278 came out about three times as great at Oslo as at Tromsø.

b. The green *OI* line was also enhanced towards lower latitudes, but not so much as in the case of the red doublet.

c. The enormous enhancement of the red doublet towards lower latitudes entails that the red aurorae of type *A* are more frequent and stronger towards lower latitudes [27, 24, 18].

These variability effects of the forbidden *OI*-lines were found to be simple consequences of the auroral theory based on the "coronal effect of solar *X*-rays" and the auroral electron bundles neutralized with positive ions (mainly protons).

The enhancement of the red doublet with altitude is just a consequence of the fact that the protons (and other positive ions) stop at a greater height (h_2) than the primary photo-electrons, reaching down to the lower limit of the aurorae at (h_1).

The enhancement towards lower latitudes is a consequence of the relative increase of the proton flux, which means greater velocity and increase of the magnetic stiffness of the protons resulting in diminuition of latitude or increased distance from the magnetic axis point. Cfr. [27], [18], [19] (§ 14, 15, 16), [20], point 3 (a, b, c), fig. 1 and table 1, and [21], point 8, table 8.

Now the behaviour of the forbidden lines *NI* of table 1 is found to be very similar to the corresponding ones of the green line and the red doublet of *OI*.

At Tromsø and partly also in Oslo, the *NI* doublet (mean $\lambda = 5199$) appears near the band N_2^+IN (0—3) 5228, and a group of O_2^+ bands near 5250. On spectrograms of small dispersion the features appeared as a diffuse line, at first called "the second green auroral line". With greater dispersion, however, this second green line was split up into the sharp *OI* doublet 5199, and to the N_2^+ and O_2^+ bands.

It soon appeared that the green *NI*-doublet was very variable, and, like the red *OI* doublet, it was greatly enhanced towards low latitudes. This effect is clearly seen by comparing the two spectrograms [17], pl. I, No. 1 and No. 3 from Tromsø with No. 4 from Oslo.

With regard to previous investigations of the properties of the forbidden *NI*-lines, we may refer to [19] section 22: "Correlation between the intensity variations of the forbidden *NI*-lines and that of the proton flux."

In the paper we are now preparing for publication, the work on the properties and the variability of forbidden lines, will not merely be devoted to *OI*, but perhaps quite as much to the green *NI* doublet near the group at region 5197 to 5250.

4. Results regarding the use of the three spectrographs "V", "F" and "C". In the previous paper [21] all spectrograms were taken with photographic plates which were sensitive to red. With the exception of a few (Kodak 103 a—F) plates they were taken with Kodak 103 a—E plates which were very sensitive to H_α and the red *OI*-doublet, and were found to be very favourable for the study of the effect of protons (*H*-lines) on forbidden *OI*-lines.

On the other hand, the sensitivity was very small on wavelength (5199) near the *NI*-doublet, and for the study of the variability and behaviour of this doublet.

A considerable number of spectrograms was therefore taken with Kodak 103 a—J plates. These had, however, the drawback that they were not sensitive in the red part, so the spectrograms could not give any direct information regarding the enhancement of H_α and the red *OI*-doublet or of the appearance of red aurorae of type *A*. Their appearance had to be followed by visual observations of the auroral display.

All successful spectrograms for each spectrograph were in the usual way reproduced on an enlarged scale on plates, each of which was followed by an explanation regarding slit, kind of plate, date and duration of exposure, and remarks regarding the auroral display.

In the explanations and in connection with interpretations of auroral features, we use the abbreviations given in Table 2.

Table 2.

List of abbreviations.

Aur: Aurorae.
St.: Strong.
We.: Weak.
V. st.: Very Strong.
V. we.: Very weak.
Type A: Red aurorae of type A.
Type B: Red aurorae of type B.
Cor.: Corona.
A, B, D, R, Puls, Fog: Arc, Band, Drapery, Rays, Pulsating, Foggy.
AU, BU, DU etc: Upper part of A, B, D, etc.
AL, BL, DL etc: Lower part of A, B, D, etc.
El. ex.: Electron Excitation.
Pr. ex.: Proton Excitation.
NSEW: North, south, east, west.
Magn. Z: Magnetic zenith.

5. Spectrograms taken at Tromsø with the spectrograph "V" and the results obtained with it.

a. *The "V"-spectrograms, taken on Kodak 103 a—E.* The 5 "V"-spectrograms taken on *E*-plates are reproduced on Pl. I—a, with explanations. Two enlarged reproductions of the long-wave part from (5577 to 6773), and taken from Pl. 1—a No. 4 and 5, are shown on fig. 1. These spectrograms are copied with the greatest intensity on the part to the left. The distinct features are marked with lines provided with corresponding wavelength values. The comparison spectrogram is shown on the section to the right.

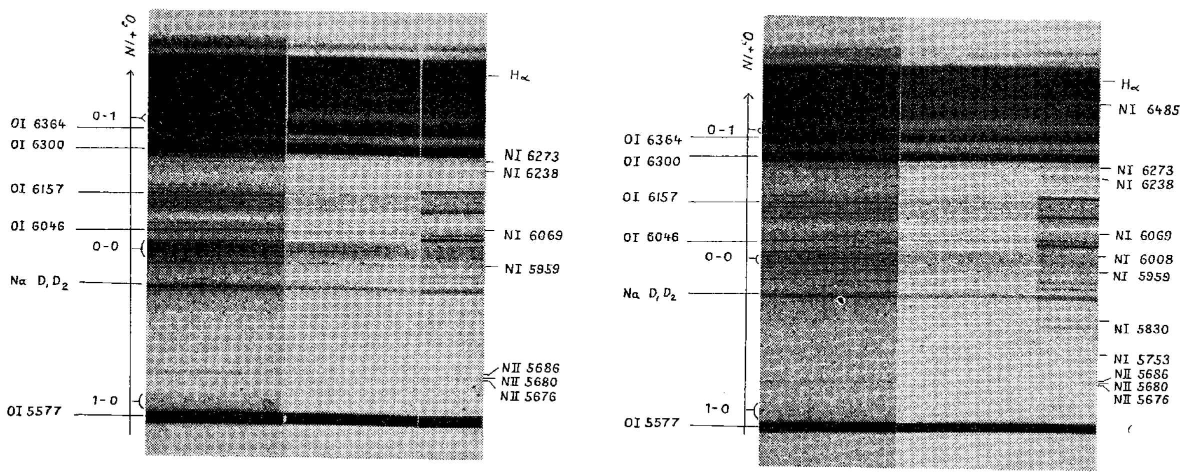


Fig. 1

Wavelength measurements have only been carried out for the four strongest spectrograms Nos. 1, 2, 4 and 5 of plate 1—a. The results are given in Table 3a, which also includes the intensities (*I*) of the features, which are sufficiently strong and distinct for intensity measurements. The last wavelength column contains corresponding auroral features from previous observations [cf. papers 15, 17, 19].

The determinations of (λ) and (*I*) have been carried out by using a *Knorr-Albers* registering photometer.

The number of features amounts to about 310, of which about 18 have not been previously observed. Most of these have been marked with a dot (●).

The last column gives the possible interpretations, but in many cases several lines or bands give about equally good coincidence with an observed feature.

It is a matter of interest to notice that a number of features gives remarkably good coincidence with *OIII* and *NIII*-lines.

From the plate I—a and the Table 3a it will be seen, that the forbidden *OI* lines (5577, and the doublet 6300, 6364) usually have been too heavily exposed for intensity measurements. In the case of the *NI* doublet (5199) the spectrograms on pl. I—a, Nos.

Table 3a.

Results from 4 "V" Spectrograms on Plate I—a.

Sp. No. 1 λ	Sp. No. 1 I	2 λ	2 I	4 λ	4 I	5 λ	5 I	Prev. obs.	Interpretation
				3883.8		3883.9		3883	OII (82.4, 83.2)
		3886.8				87.8		87.8	V. K. (0−11) (87.8) S. R. (3−19) (87.6)
3914	str.	3914	str.	3914	str.	3914	str.	3914	N_2^+1N (0−0). S. R. (1−18) (12.8)
				40.7				38.6	V. K. (7−16) (39)
44.6								45.	OII (45.0)
						47.0		47.2	V. K. (4−14) (47.8)
						48.0			OI (47.3, 47.5, 47.6
50.2		50.8						49.0	NOβ (2−13) (49.8)
						52.8		54.	OII (54.4) OI (53.1, 53.0)
		55.9						55.	OI (54.7, 54.6), NII (55.9)
		58.2	3.5						NI (57.2)
		61.7		61.6		62.0	1.1	61.	NOβ (2−13) (62.7)
				72.7		73.4	0.9	73.4	OII (73.2)
				82.6		83.3	0.8	82.5	OII (82.7)
						84.6	1.1	85.5	OII (85.5)
		95.5		95.0	1.4	94.2	1.7	95.0	NII (95,0), NI (94.9)
96.5	1.5	97.9	2.8	97.1	2.5	96.5	1.8	97.3	2P (1−4)
						98.7	0.7		NIII (98.7)
						4002.9		●	
						03.8		4005.8	NIII (03.6)
4010.7								10.7	NI (11.0)
						36.3	0.5	36.6	NI (37.4)
				4041.5		41.3	1.0	41.2	NII (41.3), OII (41.3), NOβ (0−12) (41.8)
						43.4	0.5	43.2	NII (43.5)
						45.8	0.6	45.0	OII (45.0), NII (44.8), S. R. (5−21) (44.8)
				46.6		46.7	0.9	47.0	OII (46.2)
						53.1	0.7	52.6	
				54.9	0.6			53.6	OII (54.1), (54.6)
		4057.1						57.0	NII (57.0)
57.6	1.4	58.5	2.2	58.6	2.1	58.4	1.9	58.5	2P (0−3) (59)
						71.8	0.8	72.2	OII (72.2), V. K. (2−13) (71.7)
				75.4		74.8	0.9	75.9	OII (75.9)
						80.0	0.7	79.1	OII (78.9)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
98.4								97.7	OII (97.2, 97.3)
						99.3	0.6	99.7	2P (7–11), NI (99.9),
						4101.5	0.6		NI (01.7)
				4102.9				4103.0	OII (03.3), NI (02.2)
						18.2	0.7	18.3	OII (19.2)
				33.5	0.4	31.8	0.5	33.0	OII (32.8), NII (33.7)
						40.1	0.9	40.1	N_2^+IN (4–5)
4142.9								42.7	OII (42.0, 42.1, 42.3)
46.3								45.5	NI (45.8), NII (45.8), V.K (6–16) (45.7)
				52.9				53.3	OII (53.3)
				77.0	0.5			76.2	NII (76.2)
				89.8	0.5			89.7	OII (89.8)
						94.7	0.7	93.5	OII (92.5), NI (93.5)
		4200.0	1.6	4200.1	1.0	98.1	1.3	99.7	N_2^+IN (2–3), 2P (2–6), NOβ (2–14) (00.7)
				05.6	0.3			4205.1	NI (05.7)
						4209.8	0.7	08.2	NI (09.1)
				15.0	0.3	15.1	0.6	15.1	NI (14.7, 15.9), NOβ (2–14) (15.2)
				19.1	0.4	18.3	0.9	19.1	V. K. (0–12) (18.3)
		25.1	1.5					24.	NI (24.7)
4227.6	1.0	27.6	1.4					26.5	NII (27.8), S.R. (5–22) (27.4)
		29.4	1.3					29.0	NI (29.6)
36.1	8.9	36.1	9.5	36.0	5.7	36.0	6.4	36.2	N_2^+IN (1–2), NII (36.9, 37.0)
40.6		41.3		41.1	0.7	41.5	1.4	41.5	NII (41.8)
76.9	str.	79.0	str.	77.8	str.	76.1	str.	78.0	N_2^+IN (0–1)
						91.1	0.5	92.2	OII (92.1)
				93.5				94.4	OII (94.7), S. R. (1–20) (92.2)
		4314.2						4313.5	NI (13.1), OII (13.4)
				4318.2	0.7	4316.3	0.7	17.8	OII (17.2, 17.7), NI (17.7)
		19.0						19.2	OII (19.9), V.K. (1–13) (18.8)
				21.1	0.3			21.3	NI (22.0)
						4327.8	0.6	26.3	OII (27.5, 27.8, 28.6)
				32.8	0.3			31.3	OII (31.8, 31.4)
		36.2				36.8	0.8	37.0	OII (36.9), NI (36.5)
		39.7	0.9	38.7	0.4	38.0	0.6	39.	OII (40.3)
		41.5				42.1	1.2	42.	OII (42.0)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
		43.9	1.0	43.5	1.0	43.7	1.0	43.8	OII (42.8, 43.4), 2P (0−4) (43.6)
		44.7	0.9			45.5	0.9	46.7	OII (45.6, 44.3)
				47.2	0.5	47.2	1.0	48.	OII (47.4)
				48.3	0.5			49.0	OII (49.4)
		51.6		51.0	1.0	50.5	1.3	51.0	OII (51.3)
4357.8	1.1	58.2	1.0	58.4	1.5	58.2	1.9	58.0	OII (58.5, 57.3), NI (58.3)
				62.5	0.3			●	
67.4	4.4	68.6	2.5	68.8	3.1	68.5	4.1	68.3	OI (68.3)
		77.2						77.4	OII (78.0)
		78.1				79.7	0.5	78.8	OII (78.4)
				87.5		85.9	0.6	88.0	NO_{β} (1−14) (86.0)
						95.1	0.8	97.	OII (96.0)
4411.2	1.6							4411.4	S. R. (9−25) (11.3)
13.5	1.7	4415.3	1.5			4414.2	2.4	15.1	OII (14.9)
				4416.5	1.8			16.7	2P (3−8), OII (17.0)
						23.0	0.8	22.6	S. R. (5−23) (22.3)
		25.9		24.2				24.0	V. K. (2−14) (24.0)
						26.6	0.8	27.3	NII (27.2)
						31.1	0.9	} 32.6	NII (31.8)
				33.2	0.5	32.6	0.8		NII (32.7, 33.5)
				35.5	0.4			●	OII (34.2)
						50.7	0.6	51.4	OII (52.4)
				64.4	0.5	66.9	0.9	66.0	OII (66.3, 65.5), NII (65.5)
						68.9	0.8	67.8	OII (67.8), N_2^+1N (6−8)
						82.4	0.7	82.8	OII (82.9)
						85.3	0.7	84.6	NI (85.1)
				87.9	0.3	87.6	0.6	88.2	OII (87.7)
						88.5	0.6	} 88.2	OII (88.2), NII (88.2)
						89.4	0.7		N_2^+1N (5−7) (89.0)
4528.1		4529.3	1.1	4531.5	0.5	4530.2	0.9	4530.8	NII (30.4), N_2^+2N (9−2) (30)
		32.9	1.3	33.1	0.6	32.8	0.8	32.8	V. K. (3−15) (34.2)
						45.6	0.7	47.0	N_2^+2N (9−2) (45)
						50.1	0.9	49.8	
		52.1	1.4	51.0	0.3	52.1	0.8	52.0	NII (52.5)
				54.3	0.4			53.1	N_2^+1N (3−5), NI (54.2, 53.4)
						66.3	0.7	65.0	NII (64.8)
				73.3	0.3	72.8	0.8	} 73.5	2P (1−6) (73.0)
						74.2	0.8		NO_{β} (3−16) (74.0)
		88.4	1.4	88.8	0.4	89.5	0.8	89.2	OI (89.9, 89.0)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
				90.5	0.6	91.6		} 91.8	OII (90.9), NOβ (3–16) (90.8)
						92.5	0.8		
		97.6	1.4			95.0	0.8	96.7	OII (96.1)
				98.4	0.5			4600.1	N_2^+1N (2–4)
				4601.5	0.3	4602.4	0.8	02.0	NII (01.5), OII (02.1)
		4607.6	0.8	08.2	0.3			08.0	NII (07.2), S. R. (7–25) (07.7)
						12.7	0.7	14.6	NII (13.9), OII (13.7)
				23.7				22.4	NII (21.4), OII (21.3)
				30.5	0.7	31.5	0.8	31.3	NII (30.6)
4631.9	1.0			33.9	0.4			33.5	S. R. (11–27) (32.2)
42.1	1.2	40.9	2.5	41.8				42.3	OII (41.8), NII (43.1)
51.3	4.6	51.3	6.4	51.3	3.4	51.3	3.9	51.2	N_2^+1N (1–3), OII (50.9), NI (51.1)
		59.4	1.4	60.3	0.5			60.3	NI (60.0)
				61.8	0.5	61.1	1.2	61.8	OII (61.7)
						63.3		●	N_2^+2N (10–3) (62)
						68.7	1.1	68.	2P (0–5), NI (69.8)
						73.3	1.1	71.5	OI (73.7, 72.8), OII (73.8), S. R. (3–23) (72.5)
75.3	1.3			74.7	0.3			} 77.4	NII (75.0)
		77.0	1.7			76.5	1.1		OII (76.2, 77.0)
78,7	1.3			78.9	0.7	78.2	1.1	77.4	NII (77.9)
4710.3	12.7	4708.3	18.0	4709.4	10.1	4709.6	9.6	4709.1	N_2^+1N (0–2)
				88.1				87.2	NII (88.1)
		4804.3	1.5					4804.5	NII (03.3)
						4845.1	1.0	45.5	NI (47.4)
				4855.6				57.0	OII (56.8)
				58.3 }	1.0	59.4	1.1	} 61.4	[OII (60.9) NII (60.4)]
				62.2 }		60.9	1.1		Hβ
				65.3	0.7			64.8	OII (64.9)
				69.1	0.4	67.7	1.0	67.0	NI (68.9)
		72.1	1.7					74.5	OII (72)
						96.4		96.4	NII (95.2)
				4901.7		4901.2	1.1	99.2	V. K. (6–18) (99), N_2^+2N (8–2) (00.0)
		4912.9						4913.3	NOβ (3–17) (12.1)
						56.2	0.9	57.0	N_2^+1N (4–7), OII (55.7)
				60.2		61.1	0.9	61.5	V. K. (3–16) (61.1)
		74.5	2.1	73.0	0.7			73.3	2P (4–11)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
						96.2		95.0	NII (94.4), S. R. (4–25) (96.7)
5001.4		5001.9	2.3	5000.9	0.7	99.8	1.0	5001.5	NII (01.5, 01.1, 97.2)
						5003.6	1.9	02.9	NII (02.7)
				05.2	1.1	05.8	1.0	04.8	NII (05.1)
				08.8	0.9			10.2	NII (10.6)
						13.9		14.0	NII (16.4, 12.0), N_2^+1N (3–6)
		81.8	2.8					78.0	N_2^+1N (2–5), S. R. (11–29) (75.6)
						5165.5	1.7	5166.0	NI (65.8)
				5176.5	1.0			77.	NII (75.9), OII (75.9)
5199.3		5199.3	4.6	99.3	1.8	99.3	3.3	99.5	NI ($^4S_{3/2}-{}^2D_{5/2}$) (97.1)
				5201.9	1.7	5201.8	2.7	5201.0	NI ($^4S_{3/2}-{}^2D_{3/2}$) (01.6)
						05.7	1.7	●	OII (06.6)
		5227.9	3.6	30.5	1.7	31.2	2.2	28.2	N_2^+1N (0–3) (28), NI (27.0)
				34.8	1.0			34.0	V. K. (5–18) (30.4)
				49.3	1.1	50.3	1.9	50.0	S. R. (4–26) (49.3)
				57.3	1.5			57.0	1P (15–10) (57), O_2^+1N (4–2)
5324.5	2.5							5321.2	1P (13–8) (24), NII (21.0)
				5353.7		5354.0	1.4	54.4	NII (51.2)
61.2	2.3							58.6	NI (60.1)
		5484.5	3.4					5487.5	OI (86.6), N_2^+1N (4–8) (88)
						5512.8	1.4	5511.6	OI (12.7)
						19.0	1.6	16.7	1P (8–3) (16), NI (19.4)
				5522.2				21.0	O_2^+1N (5–4), NI (24) S. R. (4–27) (20.3)
						28.1	1.7	31.0	NI (30.3), NII (30.3), V.K. (7–20) (29.5)
5535.3	2.0							38.2	O_2^+1N (4–3)
						41.8	1.6	43.9	1P (7–2) (41), NII (43.5)
48.1						48.3	1.5	} 51.5	1P (7–2) (46), NII (52.0), NI (51.4)
						52.9	1.7		S. R. (7–29) (49.8)
						55.5	1.8	55.0	1P (7–2) (54), OI (54.9)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
77.	str.	5577.	str.	77.	str.	77.	str.	77.	OI ($^1D_2-^1S_0$)
						94.3	3.0	96.9	O_2^+1N (1–0), 1P (6–1) (92.9), 1P (15–11) (95)
				5604.5	2.2	5605.5	2.5	5601.8	O_2^+1N (1–0), V.K. (0–15) (05.6), NI (04., 00.3)
				10.5	1.9			09.8	O_2^+1N (1–0), 1P (5–0) (12), NI (11.3)
						15.3		} 16.7	1P (15–11) (15)
				17.1	1.8	17.8	2.1		O_2^+1N (1–0), NI (16.5)
						22.7	2.1	21.3	O_2^+1N (1–0), 1P (5–0) (20), NI (23.0) (18.0), S.R. (2–26) (20.8)
				25.4	1.6			25.8	O_2^+1N (1–0), 1P (5–0) (25)
				31.0	1.1	30.6	1.7	30.3	O_2^+1N (1–0), 1P (5–0) (33)
				66.7	0.5			66.5	NII (66.6)
						5668.3	1.2	●	
		5676.8	2.6					} 79.8	NII (76.0)
		81.4	2.6	80.7	1.4	80.9	1.8		NII (79.6)
						84.0	1.7	} 86.2	1P (13–9) (85)
						88.6	0.9		NII (86.2)
				93.5	0.5			91.3	1P (13–9) (92)
						5701.1	0.6	98.2	1P (13–9) (99)
						13.0	0.8	5710.4	NII (10.8), NI (10.7), 1P (13–9) (06)
		5744.3	1.7					45.6	NII (47.3), NI (47.3), 1P (12–8) (43), S. R. (0–25) (45)
		53.0	1.6	5754.7	0.8	55.9	1.0	53.8	1P (12–8) (55), NI (52.7), N_2^+1N (1–5) (53), NII ($^1D_2-^1S_0$)
						91.8	0.6	91.8	NI (93.5, 90.4)
		5800.2	1.3			5803.2	0.6	5801.0	1P (11–7) (97), NI (03.3)
				5808.3	0.5	06.4	0.7	06.9	1P (11–7) (04)
						20.2	0.4	●	S. R. (7–30) (24.3)
				26.7	0.6	28.7		27.4	NI (29.6)

Table 3a (cont.)

Sp. No. 1 λ	I	2 λ	I	4 λ	I	5 λ	I	Prev. obs.	Interpretation
				33.3	0.8			31.3	1P (10−6) (33), NI (34.8)
		35.7	1.9					36.8	S. R. (1−26) (39.1)
				43.7	0.9	40.7	1.0	43.9	1P (10−6) (40), NI (41.1)
						48.7	1.1	●	1P (10−6) (48)
						54.0	1.1	52.1	1P (10−6) (54), NI (54.1)
		59.7		58.2	0.9			59.0	NI (56.1)
						66.3	1.4	65.6	N_2^+IN (0−4) (66)
				69.9	1.1	70.6	1.5	70.3	
						78.7	1.3	77.9	
5886.0	2.4	86.0	5.5	86.2	1.8			87.6	1P (9−5) (84)
90.5	2.4	92.3	5.7	94.5	3.2	91.8	4.1	92.2	NaD_1D_2, 1P (9−5) (92)
				98.0	3.0			96.6	NI (98.2), 1P (9−5) (99)
		5904.9				5905.0	1.6	5903.3	NI (05.5)
				5908.0	1.3	08.1		08.3	1P (9−5) (06), S. R. (5−29) (09.4)
						25.7	1.4	27.1	NI (27.5), NII (27.8)
		29.7	1.3					32.0	NII (31.8), NI (31.2)
		36.6		35.7	1.4	36.0	2.0	36.9	1P (8−4) (36)
5953.5	1.5	50.6	2.4	49.4	1.3	51.4	1.7	51.0	1P (8−4) (51), NI (51.1), NII (52.4)
				60.9	2.5	60.0	3.0	58.9	1P (8−4) (59), NI (58.8), NII (60.9)
		71.8	3.3					69.0	O_2^+IN (1−1)
		74.7	3.9			72.8		74.7	O_2^+IN (1−1), NI (72.1)
				78.1	2.5	78.2	2.5	76.6	O_2^+IN (0−0)
82.7	1.0	84.3	3.9	83.8	2.6	82.7	2.9	84.2	O_2^+IN (0−0)
						87.2		87.1	O_2^+IN (0−0), NI (87.5)
				89.1	2.9	91.4		90.5	O_2^+IN (0−0), 1P (7−5) (91), OI (91.9, 91.3)
						94.6	2.9	93.5	OI (95.3, 93.2), O_2^+IN (0−0)
97.8	1.1	6000.6	3.9			97.0		98.0	O_2^+IN (0−0), NI (99.6), 1P (7−3) (99)
				6003.6	2.8	6004.1	2.8	6002.0	O_2^+IN (0−0)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
6008.7	1.4					07.4	2.7	08.0	1P (7−3) (07), NI (08.4)
				10.7	2.8	14.4	2.3	12.4	1P (7−3) (14), NI (12.0), S. R. (6−30) (10.7)
17.7						16.5		16.8	O_2^+1N (0−0), NI (17.7, 15.4)
				23.9	1.4	23.3	1.5	24.6	O_2^+1N (0−0)
						28.5	1.3		S. R. (3−28) (27.7)
				36.1	1.2			●	
40.5		38.2	1.9			38.5	1.1	39.8	O_2^+1N (0−0)
				46.4	2.3	43.5	1.6	44.2	OI (46.5, 46.2), NI (44.8)
						50.9	2.6	49.2	1P (6−2) (47)
53.2								53.8	1P (6−2) (55)
		60.7	1.9			61.3	1.7	60.9	1P (6−2) (63), NI (61.9)
				67.0	1.6	67.1	1.6	70.1	1P (6−2) (70), NI (69.0)
						75.4	0.7	78.	NI (75.7)
				97.7	1.1			97.5	1P (5−1)
						6102.3	1.7	6103.4	1P (5−1) (03)
6105.6	1.1	6105.1	3.5			06.5		09.8	OI (06.3)
				6110.7	2.2	10.2	2.2	09.8	1P (5−1) (11)
						15.7	2.1	19.0	S. R. (7−31) (16.0), 1P (5−1) (20)
						19.3			
		23.9	3.8	27.9	2.1	24.0	2.2	26.9	1P (5−1) (27), V. K. (7−21) (23), S. R. (4−29) (24)
						32.6		●	
		37.3	3.7	37.4	2.2	36.7	2.2	35.6	NII (36.9), N_2^+2N (8−4) (36)
						43.9		●	
		58.2	3.5	57.4	2.3	57.3	2.6	57.1	1P (4−0) (60), OI (58.2, 56.8, 56.0)
						61.4		63.3	
67.1	1.8					63.8			1P (12−9) (62), N_2^+2N (8−4) (64)
		75.6	2.1	72.4	1.3	75.7		74.9	1P (12−9) (75), S. R. (1−27) (76.5), NII (73.4)
83.3				82.9	0.9	80.9	0.9	84.1	1P (12−9) (85), (4−0) (85)
87.9								●	

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
						96.4		●	
				6223.3				6222.0	NI (24.1), S. R. (5–30) (21.5)
		6239.4	1.3	37.1	0.6	6238.3	0.9	38.8	NI (37.5), 1P (11–8) (38)
				42.6	0.6	41.4		43.8	NI (43.2), 1P (11–8) (44)
						49.9	0.4	51.9	1P (11–8) (53)
6260.7				59.0		60.4		60.8	
						65.6		65.	OI (64.6, 66.9)
		72.0	1.9	71.5		73.0	1.7	71.8	NI (72.8), S. R. (2–28) (70.2)
						77.3		76.0	NI (75.5)
98.8	str.	6301.1	str.	6300.3	str.	6301.0	str.	6300.3	OI $2P^4$ ($^3P_2-^1D_2$)
6318.9		16.8						18.	1P (10–7) (14)
23.7		22.8						20.7	1P (10–7) (23), NI (21.7)
						31.6		29.6	
63.8	str.	63.8	str.	63.8	str.	63.8	str.	63.8	OI $2P^4$ ($^3P_0-^1D_2$)
78.8		80.5				83.8		81.4	NI (78.0) O_2^+1N(0–1) 1P (9–6) (85) (78)
				87.3		89.0		●	
						93.0		91.9	NI (93.6)
96.1								98.0	O_2^+1N (0–1), 1P (9–6) (95)
6412.7				6414.7		6418.2		6417.0	O_2^+1N (0–1), NI (17.1)
33.9		6436.7		35.0		38.5		38.6	NI (37.3)
						40.8		42.0	1P (8–5) (43), N_2^+2N (5–2) (44)
50.0		53.3		50.5		52.9		56.0	OI (53.6, 54.5), 1P (8–5) (52)
59.6		62.2				62.0		61.8	1P (8–5) (60)
						65.8		68.0	1P (8–5) (69)
		77.9		75.1		81.3		79.3	NII (82.0), N_2^+2N (5–2) (75)
						83.2		85.5	NI (84.9)
						6506.2		6506.1	NI (06.0), NII (04.9)
6509.1		6511.4				11.1		11.9	NI (10.3)
25.6						25.8		} 24.9	NII (22.3)
						28.6		}	1P (7–4) (27), NI (28.4)
		30.0				33.2		32.4	NII (33.0)
37.4						37.5		●	1P (7–4) (36)
48.2								43.0	1P (7–4) (45)

Table 3a (cont.)

Sp. No. 1		2		4		5		Prev. obs.	Interpretation
λ	I	λ	I	λ	I	λ	I		
		55.0				53.4		54.5	NII (54.7), H_α
81.6		86.5		6585.0		83.3		83.3	NII (83.4), $2P^2$ ($^3P_2-{}^1D_2$), forbidden
93.3		98.1				95.7		92.6	1P (6—3) (97)
						99.9		●	
						6629.2		6630.0	NII (30.5), N_2^+2N (6—3) (24)
						40.1		●	
						45.2		49.0	NI (46.5)
						52.3		●	OI (53.8)
6654.5						56.5		55.2	NI (56.6), N_2^+2N (6—3) (57)
		6659.6				60.1		●	
				6662.3				65.9	OII (66.9), NI (66.8)
		77.3		78.1		77.5		74.5	1P (5—2) (77), OII (78.2)
		92.4		91.7		92.6		93.5	1P (5—2) (94)
						6700.9		98.7	
						14.9		●	
				6741.1		41.9		6742.9	NI (41.3)
				47.8				48.5	1P (4—1) (56)
				63.6				63.3	1P (4—1) (68)

2, 4 and 5 have been measured, but show only small variations. This is probably due to the long exposure (cfr. explanation to pl. I—a), where intensities are measured from the same locality.

b. *The "V"-spectrograms taken on Kodak 103 a—J.* With the "V"-spectrograph seven spectrograms were taken on 103 a—J plates, and reproduced on Pl. I—b.

Wavelength values were measured for the features from the spectrograms Nos. 6, 9, 10 and 12 on pl. I—b and given in table 3b.

On these four spectrograms, the intensities (I) were determined for those features which could be distinctly observed. The J-plate is practically insensitive in the region for which $\lambda >$ than that of the green line (5577). Consequently, the lines H_α, the red *OI*-doublet and a great number of known auroral features in the long wave region did not appear on the spectrograms.

Fig. 2a and b show a Knorr-Albers photometer curve of spectrum 6. The numbers indicating some of the most prominent lines which refer to the outer left column in Table 3b.

We want especially to call attention to features that appear in the region between the band 4709 and the strong green auroral line 5577. Within this region we first of

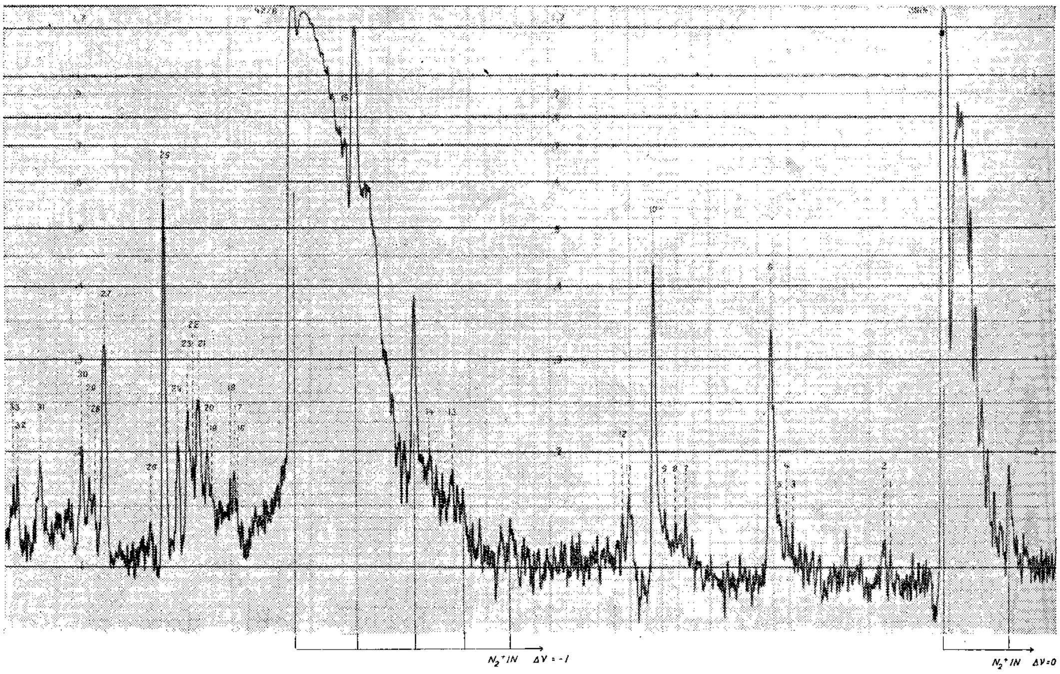

4278
3914
N₂⁺IN ΔV = -1
N₂⁺IN ΔV=0

Fig. 2a.

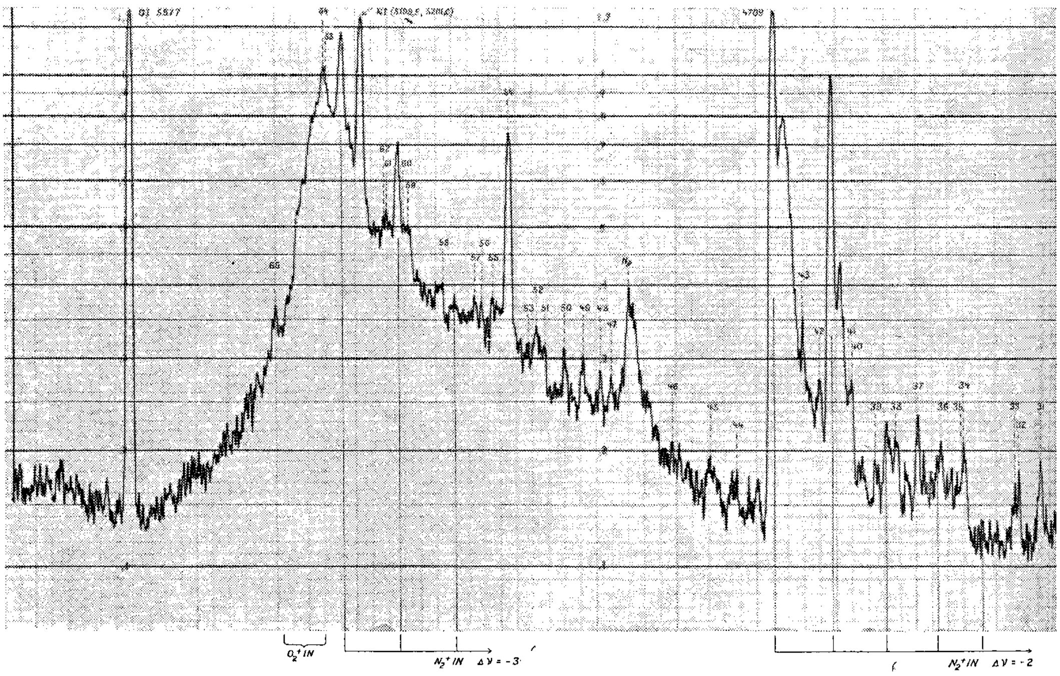

OI 5577
4709
O₂⁺IN
N₂⁺IN ΔV = -3
N₂⁺IN ΔV = -2

Fig. 2b.

all notice the green forbidden *NI* doublet (5199.5, 5201), the negative band N_2^+1N (0—3) (5228), the negative oxygen bands (O_2^+1N), the group of *NII* lines near 5001, and the quite intense H_β-line 4861.

From previous investigations it is known that the forbidden *NI* doublet shows great relative variability, which will be subject to more detailed studies in connection with spectrograms taken with the "F"-spectrograph on Kodak 103a—J plates.

In spite of the absence of the long wave part, the observed number of features was about 340, which is even somewhat greater than that found from the spectrograms taken on the *E*-plates. About 45 lines and bands were not previously observed. Most of them are marked with a dot (●).

The *J*-spectrograms showed about the same average intensities of the forbidden *NI* doublet. With the exception of the weak spectrogram No. 7, all the other 6 showed the H_β-line quite distinctly.

We have already in previous papers drawn attention to the fact that the forbidden *NI*-doublet (5199) showed variations similar to those of the red *OI* doublet, and that the *NI* doublet was enhanced through the excitation of protons, which also means emission of *H*-lines [19, 20].

6. The ionospheric temperatures determined by auroral (N_2^+1N)-bands taken with the "V"-spectrograph. With regard to the procedure to be followed by determinations of temperatures by means of auroral bands, we refer to papers [5, 28, 19, 21, 29].

The temperature can be found by the formulae (1a) or (1b):

$$T_m = 2{,}96\, K_m\, (2\, K_m + 1) \tag{1a}$$

where (K_m) is the rotational quant number corresponding to maximum intensity of the *R*-branch, or from equation (1b):

$$\log_{10}\, (I_K/K) = -\, \varkappa\, (K + 1)\, K \tag{1b}$$

I_K is the intensity of the line at the rotational quant number *K*, and:

$$\varkappa = \frac{h^2 \log_{10}^{\varepsilon}}{8\, \pi^2 jk} \tag{2a}$$

k is Bolzmann's constant, *j* the moment of inertia of the N_2^+ ion in the excited state. This gives the temperature:

$$T_\varkappa = \frac{1.286}{\varkappa} \tag{2b}$$

T_m should be equal to $T_\varkappa$ provided the intensity distribution follows Maxwell's law, and that the rotational components are separated on the spectrograms. These conditions, however, are usually not strictly fulfilled.

Table 3b

Results from 4 "V"-Spectrograms on Plate I—b.

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
	3881.1								3880.5	NO_β (1—12) (80.7)
	85.9		3885.7		3885.1		3885.7		85.0	N_2^+ 1N (1—1) (84.3)
	89.1								87.8	V. K. (0—11) (87.8), S. R. (3—19) (87.6)
	3914		3914		3914		3914		3914	N_2^+ 1N (0—0), S. R. (1—18) (12.8)
	30.4								30.5	
1	39.8	0.5							38.6	V. K. (7—16) (39.0), NIII (38.5)
2	42.8	1.0	42.2	1.1					42.0	2P (2—5) (43.0), NII (42.8)
	44.1	0.3							45.0	OII (45.0)
			47.7	1.3					47.2	V. K. (4—14) (47.8), OI (47.3, 47.5, 47.6)
			52.5	1.1					54.0	OI (53.1, 53.0, 52.0), OIII (51.8)
	54.8		53.4	1.2						OII (54.4), OI (54.7, 54.6)
	56.2	0.3							55.0	NII (55.9)
	61.9	0.3			60.6	1.1			61.0	NO_β (2—13) (62.7), OIII (61.6)
	73.7	0.4	74.8	0.9					73.4	OII (73.2)
	77.6	0.4					78.2		77.9	V. K. (1—12) (77.9)
							79.8		79.0	
	80.8	0.4					80.8		81.0	
	82.5	0.4							82.5	OII (82.7)
3	87.0	0.6			88.7				87.5	S. R. (2—19) (87.1)
4	90.4				89.9				89.1	
					92.0				91.5	
5	92.9	0.8	92.7	1.0	93.5		92.9		92.6	
			95.0	1.3	95.0	1.2	94.8		95.0	NII (95.0), NI (94.9)
6	97.9	3.2	97.6	2.4	97.4	2.3	97.9	2.2	97.3	2P (1—4) (98.4), NIII (98.7)
	4004.3								4005.8	NIII (03.6)
	37.5		4038.4	0.6					36.6	NI (37.4)
7	41.5	0.5							41.2	NII (41.3), OII (41.3)
	42.5	0.5								NO_β (0—12) (41.8)
	43.8	0.4					4042.7		43.2	NII (43.5)
	44.4	0.4							45.0	NII (44.8), S. R. (5—21) (44.8)
	46.0	0.3								OII (45.0), V.K. (5—15) (44.4)

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
8	47.1	0.6							47.0	OII (46.2)
			4049.0	0.8	4048.1	0.8	4047.5	0.8	48.1	OII (48.2)
	50.3	0.6	50.5	0.6						
							51.4		51.5	
	52.7	0.6	52.9	0.6			53.3		52.6	
9	53.8	0.6							53.6	OII (54.1)
	55.1	0.6	55.3	0.6						OII (54.6)
			56.2	0.6	56.9	1.0			57.0	NII (57.0)
10	58.2	2.7	58.6	2.1	58.7	2.3	58.6	1.6	58.5	2P (0−3) (59)
	70.0	0.3					70.5	0.8	70.5	OII (69.9, 69.6)
11	71.8	0.6					72.2	0.7	72.2	OII (72.2),
										V.K. (2−13) (71.7)
	73.3	0.5							73.0	NII (73.1),
										OIII (73.9)
12	76.4	0.6					75.6		75.9	OII (75.9)
	80.6	0.3					78.4		79.1	OII (78.9),
										OIII (81.1)
	82.9	0.3					82.1		82.8	NII (82.3, 82.9)
	84.8	0.3							84.3	OII (84.7, 83.9)
			85.4	0.7					85.5	OII (85.1)
	86.7	0.3							86.4	OII (87.1), NII (87.4)
	94.4								93.5	2P (4−8) (94.8),
										OII (94.2)
	96.1	0.4							95.3	OII (95.6, 96.2, 96.5),
										S. R. (1−19) (95.8)
	99.0								99.7	2P (7−11)
	4100.6	0.3								NI (99.9)
	12.5								4112.0	OII (12.0)
					4119.8	0.5			18.3	OII (19.2)
	20.5				20.7	0.5			21.0	OII (20.6, 20.3)
	22.2									OII (21.5)
	24.8								24.7	NII (24.1),
										OIII (25.5)
	26.5	0.4							●	NO_β (1−13) (27.9)
			4128.3	0.4					30.3	OII (29.3), NI (29.2)
			41.1	0.5					41.0	OII (40.7),
										2P (3−7) (41.8)
	42.2								42.7	OII 42.0, 42.1, 42.3)
	46.2								45.5	NI (45.8), NII (45.8),
										V.K. (6−16) (45.7)
			55.3						56.5	OII (56.5), NII (56.8)
	60.9	0.3							60.0	NII (60.8)
	65.7	0.3							65.7	NI (66.6)
	68.5	0.5							68.5	N_2^+ 1N (3−4) (67),
										NaI (67.8)

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
	69.4	0.5	69.3		69.8	0.6			69.0	OII (69.3), V.K. (3–14) (69.9)
	70.5	0.4	71.2		71.6	0.7			71.5	NII (71.6)
13 {	75.4	0.4			74.5	0.6			74.2	NII (73.5, 73.7), S.R. (2–20) (73.1)
13 {	76.2	0.5	77.1						76.2	NII (76.2)
	80.3	0.4							} 80.2	NI (80.0), NII (79.7)
	81.0	0.4								
14	89.7	0.7	89.3	0.4	90.0	0.5			89.7	OII (89.8)
	94.4	0.5			93.5	0.9	94.4		93.5	OII (92.5), NI (93.5)
			95.6	0.5	95.7	0.8			} 95.8	NIII (95.7)
			96.4	0.6	96.8	1.0				OII (96.3, 96.1)
	99.9	1.5	99.8	1.1	98.9	1.3	4200.2	1.2	99.7	N_2^+ IN (2–3), 2P (2–6) (00.5), NO β (2–13) (00.7)
	4205.4	0.3	4204.6						4205.1	NI (05.7)
	06.4	0.4					06.5		06.1	NI (06.3)
	09.5	0.3			4208.2	0.6	09.3		08.2	NI (09.1)
	12.5	0.4	12.4		11.1	0.7	12.5	0.8	11.6	NI (13.0), S. R. (0–19) (13.6)
	15.6	0.6							15.1	NI (14.7), NO β (2–14) (15.2)
	16.3	0.6			16.0	0.8	16.3	0.8	15.5	NI (15.9), NIII (15.7)
	17.5	0.6	16.9						17.6	OI (17.1)
			18.1						19.1	V. K. (0–12) (18.3)
							20.7	0.8	21.0	NI (20.8)
	36.2	9.8	36.2	str.	36.2	7.4	36.2	6.3	36.2	N_2^+ IN (1–2), NII (36.9, 37.0)
15	41.4	2.7	41.5	0.9	41.7	1.2	41.5	1.3	41.5	NII (41.8)
	76.7	str.	77.1	str.	77.8	str.	76.8	str.	78.0	N_2^+ IN (0–1)
	4303.9								4304.1	OII (03.8), NO β (3–15) (03.1)
			4307.3	0.4					●	NI (05.5)
			08.9						09.0	OII (09.0), NO β (0–13) (09.7)
							4314.6		13.5	OII (13.4), NI (13.1)
16	17.3	0.3	17.9	0.5	4316.9	0.7	17.3		17.8	OII (17.2, 17.7), NI (17.7)
17	20.1	0.4	20.4	0.5			19.0	0.8	19.2	OII (19.9, 19.6), V.K. (1–13) (18.8)
					21.3	0.5	22.4		21.3	NI (22.0), NIII (21.4)
							23.4		} 23.1	
18	24.6	0.3					24.6			NI (24.9), NIII (23.9)
			30.3	0.4					29.4	OII (28.6), NIII (28.2, 30.1, 30.4)

Table 3b (cont.)

Sp. No.	6 λ	6 I	9 λ	9 I	10 λ	10 I	12 λ	12 I	Prev. obs.	Interpretation
19	31.4	0.4	32.0	0.4	31.3	0.6	31.7		31.3	OII (31.8, 31.4)
			33.5	0.5			33.0		}	
20 {	35.7	0.5	35.2	0.5					} 34.5	OII (34.2), NIII (35.5)
20 {	36.9	0.4	36.7	0.5	37.2	0.6	36.6	0.7	37.0	OII (36.9), NI (36.5)
	38.2	0.4	39.2	0.5					39.0	NIII (39.5)
	39.6	0.4			41.0	0.7			41.0	H_γ (40.5), OII (40.3)
	41.3	0.6	41.5	0.6					42.0	OII (42.0)
21	43.7	1.0	44.4	1.0	45.8	1.0	43.9	1.0	43.8	OII (42.8, 43.4, 44.3) 2P (0−4) (43.6)
22 {	47.3	0.5	48.1	0.4	48.1	0.6	48.5	0.8	48.0	OII (47.4), NIII (48.4)
22 {	48.9	0.6	50.0	0.6	50.7	0.6	49.9	0.8	49.0	OII (49.4)
23	51.1	0.9	51.7	0.6	51.5	0.8	51.5	0.9	51.0	OII (51.3)
					52.8	0.6			●	NIII (53.6)
24	58.5	0.7	58.3	0.8	59.4	0.9	58.2	1.9	58.0	OII (59.4, 58.5, 57.3), NI (58.3).
					62.5	0.5			●	
25	67.4	2.6	67.7	1.5	69.1	2.3	67.7	2.5	68.3	OI (68.3, 66.9)
							78.7		78.8	OII (78.4), NIII (79.1)
26	80.0		80.8				80.3		81.3	V.K. (5−16) (80.7), OIII (79.6)
			85.9	0.4	88.4				88.0	NO_β (1−14) (85.7), OIII (85.7)
			96.6	0.5					97.0	OII (96.0)
			4406.0	0.5			4405.8		4405.7	OII (06.0), S.R. (7−24) (06.7)
							11.1		11.4	S.R. (9−25) (11.3)
27	4415.9	1.5	15.4	1.2	4415.5	1.4	15.7	1.4	15.1	OII (14.9)
			16.4		17.2	0.9	16.9	1.3	16.7	OII (17.0), 2P (3−8) (16.7)
			20.0	0.5					●	
28 {	23.3	0.3					23.0		22.6	S.R. (5−23) (22.3)
28 {	25.2	0.3	24.3	0.5			25.2		24.0	V.K. (2−14) (24.0) OIII (24.3)
29	29.0	0.5	28.2	0.6	29.1		27.9		28.8	NII (28.0, 27.2)
					31.0	0.6			}	OIII (30.2)
					31.9	0.7			} 32.6	NII (31.8, 31.5)
			32.8	0.6	33.5	0.5	33.1	0.7	}	NII (32.7, 33.5)
30	34.4	0.6					34.0	0.8	●	OII (34.2), OIII (34.4)
							40.4		40.5	S.R. (11−26) (39.8), OIII (40.1)
	45.7	0.3					45.6		46.0	[G.K. (0−10)]

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
							47.9		48.7	NII (47.0)
	52.3								51.4	OII (52.4)
					56.4				57.7	S.R. (3−22) (55.5)
	65.5				65.6					NII (65.5),
									66.0	OII (65.5, 66.3)
					66.6	0.5				OII (66.3), NI (66.7)
31	67.2	0.3			67.3	0.6				N_2^+ 1N (6−8) (67)
	68.1	0.4			68.6		68.0		67.8	OII (67.8)
	73.5						74.1		●	OIII (74.9)
	77.6						76.7		75.7	OII (77.9, 76.1),
										NII (77.3)
32	83.3	0.3							82.8	OII (82.9),
										OIII (82.8)
	86.2	0.3					85.3		84.6	NI (85.1)
33	87.4	0.4					87.4			OII (87.7)
	88.7	0.3	88.7	0.6						OII (88.2),
									88.2	NII (88.2)
	89.8	0.3	89.7	0.7	90.3	0.7	88.8			N_2^+ 1N (5−7) (89.0),
										2P (2−7) (90.2),
										OII (89.5)
	92.3								91.0	NI (92.4), OII (91.2)
			4506.7	0.4					4506.9	NII (07.6)
	4515.6		17.2	0.4	4517.8	0.6			14.8	N_2^+ 1N (4−6) (15.9)
										NIII (14.9)
							4523.5		23.9	NIII (23.6)
	29.7	0.4								N_2^+ 2N (9−2) (30),
									30.8	OIII (29.7)
34	31.8	0.7	31.0	0.7	30.9	0.6	30.7	0.6		NII (30.4),
										NIII (30.8)
35	33.8	0.6	32.3	0.6	32.6	0.6				
	34.8	0.5			34.1	0.6			32.8	V.K. (3−15) (34.2)
										OIII (34.0),
										NIII (34.6)
	35.9	0.4			36.0	0.5			●	
							38.9	0.6	●	OIII (38.8)
	45.6	0.4	46.4	0.5					47.0	N_2^+ 2N (9−2) (45),
										NIII (46.3)
	51.4	0.4	52.5	0.6			51.2		52.0	NII (52.5)
36	52.8	0.5							53.1	NI (53.4)
	54.4	0.5	55.0		53.1	0.5	53.7	0.7		NI (54.2)
										N_2^+ 1N (3—5) (54.1)
										OIII (55.3)
	55.9	0.4								OIII (55.3)
	59.1	0.4					61.0		●	
			63.3	0.5	63.6	0.6			65.0	NII (64.8)

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
	67.7	0.4			67.3	0.5			●	
	69.0	0.3	68.6	0.4					70.0	OIII (69.5)
37	73.2	0.5	73.4	0.7	73.1	0.7			73.5	2P (1–6) (73.0)
	74.9	0.5	74.9	0.6	74.5	0.7	74.3	0.6		NO_β (3–16) (74.0)
			86.7	0.5					●	S.R. (2–22) (86.6)
			89.1	0.4					89.2	OI (89.9, 89.0)
			91.0	0.6			90.7		91.8	OII (90.9), NO_β (3–16) (90.8)
38	92.2	0.6			92.2	0.7	92.7			
			96.5	0.4	95.1	0.5			96.7	OII (96.1)
	4600.3	0.6	4600.7	0.5	4600.9	0.7	97.0	0.6	4600.1	N_2^+ 1N (2–4) (99.7)
	01.5	0.6							02.0	NII (01.5), OII (02.1)
					03.6	0.6	4602.3	0.6		V.K. (0–13) (03.7)
					08.1				08.0	NII (07.2), S.R. (7–25) (07.7)
39	10.2	0.3					10.4		09.6	OII (10.1, 09.4), NII (09.4)
40	31.0	0.8	29.5	0.8					31.3	NII (30.6)
41	32.4	0.8	32.3	0.7	33.1	1.2	31.7	0.9	33.5	S.R. (11–27) (32.2)
	39.6	1.1	38.2	1.0	38.7	1.1	37.2	0.9	38.7	OII (38.9)
	42.0	1.4					42.2	1.4	42.3	OII (41.8), NII (43.1), NIII (41.9)
	51.3	4.1	49.1	3.8	53.2	4.2	51.1	3.1	51.2	N_2^+ 1N (1–3), OII (50.9, 49.1), NI (51.1)
42	61.7	0.6	61.3	0.7					61.8	OII (61.7)
	62.8	0.8	63.2	0.6	62.7	1.0	62.5	0.9		N_2^+ 2N (6–0) (62)
			68.2	0.7	66.5	0.9			68.0	2P (0–5) (67.3)
	69.5	0.5	69.8	0.6			70.6	0.8		NI (69.8), OII (69.3)
	73.7	0.6	73.2	0.8	71.4	0.9	74.0	0.8	71.5	OI (73.7, 72.8), OII (73.8), S.R (3–23) (72.5)
43	77.9	0.9	76.3	0.8	77.0	1.0			77.4	OII (76.2, 77.0)
	78.7	1.0	78.0	0.9	78.1	1.1	78.1	1.1		NII (77.9)
					79.2	1.2			●	
	4709.1	str.	4709.1	str.	4709.1	str.	4709.1	str.	4709.1	N_2^+ 1N (0–2)
			33.5	0.4					●	NI (31.2, 34.2)
44	51.7	0.3							51.5	NI (50.3), OII (51.3)
			71.0	0.5	69.6				69.9	V.K. (5–17) (71.3)
45	72.5		72.6	0.4					73.3	OI (72.5)
	73.7	0.3			73.5					OI (73.8, 72.9, 72.5)
					80.5	0.6			78.0	NII (79.7), N_2^+ 2N (7–1) (78)
					83.8	0.5			82.5	NII (81.2)

Table 3b (cont.)

	Sp. No. 6		9		10		10		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
			87.3	0.4					87.2	NII (88.1)
	4811.4		4811.2	0.5					4812.0	NII (10.3), NOβ (2–16) (10.0)
							4814.0		13.7	2P (2–8) (14.7), S.R. (9–27) (14.5)
46	15.5		17.4	0.4					16.3	S.R. (2–23) (16.9)
46	20.9	0.3					20.4		●	S.R. (7–26) (21.7)
	35.5						36.1		35.5	V.K. (2–15) (36.2), S.R.(11–28) (35.4)
	35.5						36.1			V.K. (2–15) (36.2), S.R. (11–28) (35.4)
	38.9	0.4					39.0		38.0	NI (37.8)
	45.8	0.5			45.7				45.5	NI (47.4)
			52.1				52.6		●	
	56.0	0.8					54.3		57.0	OII (56.8) Hβ-Doppler band
	57.7		57.4	0.8	57.3	0.9	58.7	1.1		
	63.3	1.0	62.8	0.7	61.4	0.8			61.4	Hβ
					63.5	0.7			●	
	66.6		65.1	0.7	65.6		66.3	0.6	67.0	OII (64.9), NII (67.2)
	69.1	0.3	70.4	0.7			68.4	0.6		NI (68.9)
47	81.1	0.3								NI (81.8), NIII (81.8)
47	83.7		83.2	0.5					82.9	N_2^+ 1N (6–9), N_2^+ 2N (8–2) (82)
47	86.2	0.3			86.2	0.5			86.0	NI (86.3)
48	96.1	0.3							96.4	NII (95.2), NIII (96.7)
					4900.8	0.7			99.2	V.K. (6–18) (99), N_2^+ 2N (8—2) (00.0)
					10.9	0.6			4909.0	
49	4915.2	0.5					4915.4		15.0	NI (14.9)
49	16.8	0.6	4918.4	0.6	16.1	0.6	17.5		17.2	2P (1–7) (16.8)
			32.9						●	
			33.9		33.6	0.6			●	
50	34,8	0.3	36.6	0.7	34.9		36.3		34.7	NI (35.0)
50	41.4	0.3	41.9						42.0	OII (43.0, 41.0)
51	58.8	0.4			56.5				57.0	N_2^+ 1N (4–7) (57.9), OII (55.7)
51	60.7	0.4	59.9	0.5	59.9	0.5	61.8		61.5	V.K. (3–16) (61.1)
51	63.9	0.4								
52	68.0	0.6	65.7	0.5	65.2	0.8	65.7	0.7	66.9	OI (67.4, 67.9)
52	69.4	0.6	70.4	0.6	69.9	0.9	67.8	0.7		OI (68.8)
52	70.8	0.6					69.5	0.6	●	

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
	74.3	0.4			74.5	0.7	73.2		73.3	2P (4−11) (76.4)
53	78.0	0.4	78.2						77.0	S.R. (1−23) (76.4), 2P (4−11) (76.4)
	79.9	0.3							80.2	OI (79.6)
	86.3	0.3	88.1		88.1	0.6			90.0	NII (87.4)
			90.3		91.0	0.6	89.6			NII (91.2)
	93.6	0.3	94.0	0.5	93.0	0.7			95.0	NII (94.4)
							96.1			S.R. (4−25) (96.7)
	97.9	0.9			98.1	0.7			98.7	NII (97.2)
54	99.6	2.3							5001.5	
	5001.1	2.3	5001.3	str.	5001.5	2.7	5001.6	1.9		NII (01.5, 01.1)
	03.9	2.7	03.3	2.3	04.3	2.5			02.9	NII (02.7)
	06.0	2.0	04.5		05.2	2.4	04.7	1.8	04.8	NII (05.1)
	10.7	0.5	11.7	0.6					10.2	NII (10.6, 11.2)
							12.1		14.0	NII (12.0)
					15.7	0.8	16.7	0.6		NII (16.4), N_2^+ 1N (3—6) (14.0)
			17.7	0.8			19.3	0.7	18.8	OI (18.8, 19.3)
55	23.2	0.6	22.1	0.6	21.0	0.7	22.5	0.7	●	1P (12−6) (21), NII (23.1)
	25.1	0.6			24.0	0.9			●	1P (12−6) (25), NII (25.7)
	31.4	0.3	29.2	0.4	31.3	0.7			32.0	1P (12−6) (31)
56	38.0	0.4	36.9	0.4			38.5		●	1P (11−5) (36)
57	43.8	0.3			44.9	0.8	45.6		43.0	1P (11−5) (44), NII (45.1)
			46.4	0.4					46.5	OI (47.7)
			48.1	0.4						1P (11−5) (48)
	52.6	0.3	52.5		51.2	0.7			53.5	1P (11−5) (54), NI (51.6)
							57.0		●	NI (54.7)
	58.1	0.3	59.8	0.5			60.8		59.1	V.K. (0−14) (59.2), N_2^+ 2N (5−0) (60)
	64.8				65.3	0.5			67.0	S.R. (2−24) (64.8)
	67.8		67.9	0.3						NI (67.6)
	72.9								74.1	NII (73.6)
			75.3	0.3	74.8	0.5			78.0	NI (75.9), S.R. (11−29) (75.6)
	76.6	0.3	76.7	0.3						N_2^+ 1N (2−5) (76.6)
			78.7		77.7	0.5				
					86.4	0.5			85.8	O_2^+ 2N (0−11)
			89.7	0.5	88.5	0.6	88.9		89.0	
58	90.1	0.4	91.5	0.5	91.4	0.7	90.1		●	S.R. (5−26) (90.8)
							92.1		93.0	
	93.5	0.4			93.8	0.6	93.2			V.K. (4−17) (92.4)

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
			94.9	0.4						
					5100.2	0.5	98.4		●	
	5102.6	0.4	5101.8	0.5			5102.9		●	
							05.5		5105.0	NII (04.5)
	07.2	0.4	07.8	0.3	06.8	0.5	07.1		} 08.5	
					11.9	0.5				
	15.1						14.7		} 14.0	
							16.3			
			19.4	0.5	20.3	0.6	21.1	0.6	19.0	
	23.0		23.2	0.4					●	
	24.0	0.3			24.9	0.5			●	
	27.0	0.4	28.1	0.4	28.1	0.8	28.0		●	
	30.9	0.4	31.0	0.6	31.2	0.8			32.0	OI (30.5), NI (30.0)
			33.3	0.7	33.2	0.8	32.4	0.7	●	
59	35.9	0.6	35.9	0.7	35.0	0.8	37.4	0.6	●	1P (19—14) (37), NI (37.0)
60	39.4	0.6	40.7	0.7	40.7	0.9	40.1	0.6	39.5	NI (40.8)
	43.8	0.8							●	1P (19—14) (43), NI (45.3)
	47.6	1.4							} 48.1	N_2^+ 1N (1—4) (48.8), NI (48.7)
	48.8	1.3	48.6	1.4	48.8	1.7	49.2	1.2		1P (19—14) (49)
	56.3	0.5			55.6	0.6	55.9	0.6	53.0	1P (19—14) (54), NI (56.3), S.R. (3—25) (55.7)
	58.3	0.5	58.5	0.6	59.9	0.7	60.2	0.6	58.8	OII (59.9)
61	61.5	0.5	62.3	0.6			62.2	0.6		NI (62.8)
			64.6	0.6	65.3	0.7	64.9		66.0	(NI (65.8)
62	69.0	0.4	68.5	0.4	69.2	0.5	69.9		67.5	NI (68.0, 69.6), NII (68.2), N_2^+ 2N (6—1) (69)
			75.7		76.5	0.5	77.3		77.1	NI (75.9), OII (75.9)
	79.0		78.1	0.4	78.6				} 80.0	NI (79.6), NII (79.5)
	80.6		80.0	0.3	81.3		80.4			NI (80.9, 81.5), NII (80.3)
	87.8		88.7	0.3	88.8		88.5		} 93.0	NI (87.1, 89.3), V.K. (1—15) (88.8)
	91.1		91.3		92.3					NI (91.7) (89.3), N_2^+ 2N (6—1) (89), NII (90.4)
	98.4	4.8	97.5	3.1	5200.5	4.0	98.2	4.6	99.5	NI ($^4S_{3/2}-^2D_{1/2}$) (97.1) NI ($^4S_{3/2}-^2D_{3/2}$) (01.6)

Table 3b (cont.)

	Sp. No. 6		9		10		12		Prev. obs.	Interpretation
	λ	I	λ	I	λ	I	λ	I		
	5210.5	0.4	5209.7	0.5	07.7	0.5			5209.3	1P (17–12) (08), [OII (06.6)]
	14.9	0.4	12.8	0.6	13.3	0.7	5212.5		●	1P (17–12) (13)
	17.2	0.5			17.3	0.6	19.0		17.5	NI (18.8)
	28.2	2.3	28.2	2.8	28.2	3.0	28.3	2.2	28.2	N_2^+ 1N (0–3) (28), NI (27.0)
					33.9	1.0			34.0	O_2^+ 1N (7–5), V.K. (5–18) (30.4) 1P (16–11) (33)
	37.5	0.4							●	1P (16–11) (38)
	40.7	0.4			39.1	0.7	39.9	0.6	42.5	O_2^+ 1N (6–4), S.R. (1–24) (41.4)
			42.9	0.6						
					44.1	0.8	44.0	0.6	●	1P (16–11) (44)
	46.9	0.7	46.5	0.7	48.6	1.1			●	
63	51.0	1.0	50.5	1.1	50.4	1.3	49.6	0.7	50.0	O_2^+ 1N (5–3), S.R. (4–26) (49.3)
							52.0	1.0		NOβ (3–18) (52.7)
64	54.6	1.4	55.3	1.5	54.9	1.5	55.4	1.1	55.4	O_2^+ 1N (4–2), 1P (15–10) (57)
	57.6	1.2	57.1	1.5			56.8	1.1	57.0	
							59.0	1.0		
	63.0	0.8	65.0	1.0	62.4	0.9	62.7	0.7	63.0	1P (15–10) (64)
	68.7	0.7			68.2	0.8			70.4	S.R. (9–29) (67.4), 1P (15–10) (69), OIII (68.1)
	70.6	0.6			70.0	0.8	69.6			NOβ (3–18) (70.1)
	5273.3	0.6	5271.8	0.9			5273.4	0.8		NII (72.6), NIII (72.6)
	75.9	0.7	73.9	0.9	5277.4				5275.0	O_2^+ 1N (3–1), OI (75.1), 1P (15–10) (75)
			80.7				81.9	0.6	81.3	O_2^+ 1N (2–0), NI (81.2)
	83.5	0.5			85.0				83.7	O_2^+ 1N (2–0)
			89.3		88.5		88.1		●	O_2^+ 1N (2–0), 1P (14–9) (89)
	91.5				92.2				91.6	O_2^+ 1N (2–0), NI (92.8), S.R. (7–28) (91.8)
	93.9						93.2		●	1P (14–9) (94)
	97.8		96.1		95.7		96.4		96.4	O_2^+ 1N (2–0), NIII (97.9)
			5301.4				5301.2		5301.1	1P (14–9) (00), N_2^+ 2N (7–2) (02)
	5303.8								●	NI (04.8)

Table 3b (cont.)

Sp. No. 6 λ	I	9 λ	I	10 λ	I	12 λ	I	Prev. obs.	Interpretation
09.2		08.8		5310.3		10.2		●	NI (09.5, 10.6)
12.8								15.0	NII (13.4)
15.5				14.6		14.7			NI (15.2), NIII (14.5)
21.8								21.2	NII (21.0)
		23.9		24.9					1P (13−8) (24), V.K.(2−16) (25.0), NI (24.0)
65 { 29.3		27.9						30.9	OI (29.0, 29.6), NI (28.8)
31.7		31.4		29.8		29.8			OI (30.7), 1P (13−8) (30), S.R. (2−25) (32.1)
34.2				35.2				34.5	NI (34.3), N_2^+ 2N (7−2) (34).

The values of K_m and of I_K as a function of K were found from photograms obtained by the Knorr-Albers' photometer. In the case of the spectrograms on Pl. I—a, taken on Kodak 103 a—E plates, the two bands 4278 and 3914 were used. The temperatures obtained by these bands from Plate I—a are given in Table 4a.

Table 4a.

Plate I—a. Kodak 103 a—E.

Band	Sp. No.	1	2	3	4	5	Mean I—a
4278	$T_\varkappa$	252	243	247	245	253	248.0°K
	T_m	231	224	238	231	238	232.4°K
						Mean	240.2°K
3914	$T_\varkappa$	198	237		234	249	230°K
	T_m	224	224		224	231	226°K
						Mean	228°K
						Mean Table 4a	234°K

Table 4—b.

Plate I—b. Kodak 103 a—J.

Band	Sp. No.	7	8	10	11	12	Mean I—b
4278	$T_{\varkappa}$	246	248	244	222	231	238°K
	T_m	242	238	231	220	216	229°K
						Mean	233.5°K
						Total mean	233.7°K

On the spectrograms from Pl. I—b, taken on Kodak 103 a—J, only the band 4278 was used for temperature measurements and the results are given in Table 4—b.

The temperatures from plates Kodak 103 a—E and 103 a—J are practically the same and equal to 234°K or — 39° C.

7. The variability of the spectral composition of the auroral luminescence studied by the "F"-spectrograph. The "F"-spectrograms are mainly used for the study of the variability of the green *OI* line, the red *OI* doublet, the green *NI* doublet, the *H*-lines and their relation to the solar bundles and their behaviour on their way through the ionosphere.

We are not in possession of a photographic plate for high sensitivity for all these features, therefore Kodak 103 a—E was used for the study of the *OI*-lines and H_α and Kodak 103 a—J for the *NI* doublet.

7a. Results obtained with the "F"-spectrograph by the Kodak 103a—E plates. Study of the forbidden *OI*-lines in the aurorae. During the period from September 1957 to February 22. 1960 we obtained with the *E*-plates 89 "F"-spectrograms, which were reproduced on the plates IIa, IIb and IIc provided with explanations in the usual way.

The intensities of the red *OI*-doublet, the H_α-line, the negative N_2^+1N (0—1) band, the positive $N_2$1P (8—5) and $N_2$1P (7—4) bands are measured relative to the forbidden *OI* (5577) line, which is put equal to 100.

The intensities are given in table 5a. The last column contains the remarks regarding spectral features of the auroral luminescence.

In order to make the proper use of these spectrograms we may call to memory some facts regarding the formation and constitution of the solar electric bundles on their way through the ionosphere.

X-rays emitted from sunspot regions produce photo-electronrays which are electrostatically neutralized by solar positive ions, preferably protons. In their way down the atmosphere (ionosphere) the solar electrons and protons may find sufficient atmospheric

Table 5a.

Relative Intensities of forbidden OI-lines, Nitrogen bands and H_α obtained from the "F"-spektrograms (on Kodak 103 a—E) reproduced on Plates II—a, — b, — c.

Sp. No.	N_2^+IN (0—1)	OI $\lambda = 5577$Å	OI $\lambda = 6300$Å	OI $\lambda = 6364$Å	N_2IP (8—5)	N_2IP (7—4)	H_α $\lambda = 6563$Å	Remarks regarding features
1		100	v. st.	v. st.	15	22	2.9	St. Aur. Type A, H_α
2		»	24	11	4.5	6.7		R. L. partly type B
3		»	242	54	2.6	3.9	0.7	Partly type A, Magn. Z.
4		»	31	19	15	21	1.7	A. L., El. ex.
5		»	450	151				R. U. Type A, tow. S.
6		»	51	23				R. L., Mainly El ex.
7		»	195	64				Corona, mixed ex.
8		»	37	16	5.4	8.2	1.5	A. L. Type B, El. ex.
9		»	v. st.	v. st.	7.2	8.6		St. Aur. Type A.
10		»	184	80	7.0	9.0	0.2	Corona, Type A, Mixed.
11		»	v. st.	v. st.	8.2	11	1.2	Type A, high tow. S.
12		»	77	28	6.1	8.1	0.5	Puls. surfaces, tow. S.
13		»	15	6.6	2.2	4.7		A. L. tow. S, El. ex.
14		»	979	257				R. U. Type A, Pr. ex.
15		»	1500	500				R. U. Type A, Pr. ex.
16		»	41	19	4.3	6.4	1.0	We. Aur., El. ex.
17		»	362	132	5.5	9.5	2.6	We. Aur. possibly Type A. Pr. ex.
18	3.4	»	19	7.5	2.7	3.8	0.4	B. through Z., El. ex.
19	5.8	»	7.6	5.2	4.9	5.5		A. L. with R.-structure, El. ex.
20	2.7	»	11	4.5	2.5	3.7	0.6	St. Aur.-ordinary.
21	4.4	»	562	187	5.0	6.2		Ordinary Aur. and Type A.
22		»	103	32				R. L. (2 min. exp.)
23		»	68	19	2.8	4.4	0.9	R. U.
24		»	5.0	2.9	2.2	3.0	0.3	R. L. tow. N and W.
25	4.5	v. st.	21	9.6	5.8	7.9	0.6	A. and D. with R.-structure, vivid Aur.
26	3.2	100	14	6.8	4.2	5.4		A. L., diffuse, tow. S, El. ex.
27		»	14	6.6	3.6	5.4	0.9	A. L. tow. N, El. ex.
28		»	23	8.4	4.1	5.2		A. U.
29	3.8	»	29	15	9.8	13	0.5	D. L. tow. W, mainly El. ex.

Table 5a (cont.)

Sp. No.	N_2^+1N (0−1)	OI $\lambda=5577$Å	OI $\lambda=6300$Å	OI $\lambda=6364$Å	N_2IP (8−5)	N_2IP (7−4)	H_α $\lambda=6563$Å	Remarks regarding features
30	5.3	100	74	32	11	16	1.5	Dif. Aur. tow. SE
31		»	107	42		36	25	R. U. (2 min. exp.)
32	3.0	»	17	9.2	5.8	8.6	1.4	A. tow. N, El. ex.
33	2.2	»	21	9.6	4.4	6.1	0.6	B. tow. W, El. ex.
34	5.8	»	283	94	8.0	15	5.0	Various types, partly Type A.
35	2.5	»	5.5	3.0	2.2	3.4	0.7	Mainly homog. A. in S.
36		»	71	23				Type A and ordinary Aur.
37		»						D. L., El. ex.
38		»	133	34				R. U. tow. SE
39		»	9.8	3.1	1.0	1.1		Mixed Aur. tow. Magn. Z.
40		»	116	29	5.4			We. Aur. type A, partly R. U.
41		»	13	3.9				Homog. B.
42		»	11	3.8	0.7	1.4	0.5	We. dif. Aur., El. ex.
43	2.5	»	23	6.4	1.2	1.9	0.4	Dif. Aur., El. ex.
44	2.1	»	25	8.4	1.4	2.1	0.3	Puls. Spots, El. ex.
45		»	26	11	1.5	2.2	2.2	We. homog. A.
46		»	190	67	2.1	2.3	3.3	A. U. and R., type A.
47		»	15	7.6	2.6	3.7	0.4	A. L.
48		»	66	15				Homog. B.
49		»	353	85				R. U.
50	4.8	»	14	7.2	3.8	6.5	1.8	We. B. in S.
51	11	v. st.	16	9.0	6.3	7.9		B. in S, El. ex.
52		100	1287	429	7.8	10	15	Type A.
53	14	»	v. st.	v. st.	12	14		Type A and partly green R.
54		»	»	»	5.6	5.7		Type A and ordinary Aur.
55	12	v. st.	156	52	5.4	7.9	4.8	Corona — Type A
56		»	v. st.	v. st.				A, D. and various types
57	9.1	100	6.7	2.7	3.2	3.8		A. L. — partly type B
58		»	83	33	5.6	14	7.0	R. U. and fog. surf.
59		»	22	11	10	13		B. and D.
60		»	9.3	6.3	6.4	8.5	0.4	A. L.
61		»	17	9.2	9.3	12	0.3	A. and B.
62		»	17	8.6	5.8	8.5	1.3	We. B. and fog. surf.
63		»	13	6.2	8.0	8.3		We. A. L.
64		»	14	8.9	9.5	11		A. L. with R-struct.
65		»	75	30	6.8	13	4.0	Fog. surf.

Table 5a (cont.)

Sp. No.	N_2^+1N (0—1)	OI λ=5577Å	OI λ=6300Å	OI λ=6364Å	$N_2$1P (8—5)	$N_2$1P (7—4)	H_α λ=6563Å	Remarks regarding features
66		100	247	75				We. R. U.
67		»	31	9.9	5.1	5.6		We. A. L. with R.-structure
68		»	117	57	4.6	6.6	0.8	B. and fog. surf.
69		»	83	33	4.6	6.6	0.8	A. L.
70		»	173	68	3.6	5.6	1.1	R. U. and fog. surf.
71		»	480	185	4.4	7.8	2.4	Fog. surf. type A.
72		»	59	21	3.7	5.9	1.3	A. L. with R.-struct.
73		»	296	119	6.8	12	3.1	R. U.
74		»	29	9.1	3.3	4.1		B. U.
75		»	11	7.0	6.2	8.1	0.3	D.
76		»	6.5	3.4	3.8	5.0	0.2	A. L.
77		»	26	8.8	4.2	5.2		We. R.
78		»	56	22	6.2	7.9		We. B.
79		»	17	7.5	5.0	5.7		A.
80		»	43	13	3.9	5.0	0.2	Fog. Surf.
81		»	34	9.9	4.9	6.0		Dif. surf.
82		»	22	7.1	3.5	4.5		Spots.
83		»	35	14	4.6	6.2	0.4	We. fog. surf.
84		»	33	10	6.0	8.7	1.3	A. L. with R.-struct
85		»	122	53	4.9	6.8	0.7	R. U.
86		»	43	17	5.3	7.8	1.1	We. fog. surf.
87		»	6.8	2.7	2.7	3.6	1.9	A. L.
88		»	17	4.7	2.6	3.5	0.3	A. U.
89		»	30	7.5	3.1	7.6	3.8	We. fog. surf.

ions for the necessary neutralization of the bundles. Thus the solar electron and proton rays are free to move and to be absorbed and stopped independently of each other. As a rule, the proton flux is much smaller than that of the electrons, and the penetrating power much smaller.

The elctrons of the bundle may stop at a height (h_e) at about 100 km, while protons of the same kinetic energy stop at a greater height (h_p), say at 130 km. If such a state could be kept during the exposure, the luminescence from the interval ($h_p - h_e$) would be emitted by the primary electrons and their secondary, and the "F"-spectrograms would show the features, that are typical for excitation by electrons, which means few and mostly weak atomic lines and strong vibrational bands from the dominating gases N_2 and O_2. At the bottom edge of the aurorae the red ($N_2$1P)-bands will be strong, and sometimes strong enough to set up a red band all along the bottom edge of an arc or a band. (Red aurorae of type B).

The electron excitation below (h_p) gives a fairly strong forbidden green *OI*-line (5577), while the forbidden red *OI*-doublet (6300, 6364) is weak or absent.

Above the height (h_p) the red doublet appears strong and the relative intensity increases with altitude [23]. The enhancement of the forbidden red *OI*-doublet is due to proton excitation, and as a rule it is accompanied by hydrogen lines. Very often the red *OI*-doublet dominates the auroral luminescence so as to give it a strong red colour to the top of the longest auroral rays. (Red aurorae of type A).

By the proton excitation the red doublet and the *H*-lines may dominate the auroral luminescence so the relative intensity of bands is extremely small, and they may not appear on the spectrograms, even when the red doublet is highly overexposed [20].

At the height above (h_p) both electrons and protons take part in the excitation process so the features, which are characteristic of the electron excitation will be mixed with the red doublet and *H*-lines. The effect of electron excitation above (h_p), however, will be very small compared with the proton effect.

The types of spectra in auroral luminescence we observe, naturally fall into three groups:

Group E: Spectra excited mainly by the solar electrons.
Group P: Spectra excited mainly by the protons of the bundles.
Group E + P: Spectra from mixed excitation.

It is found that the two spectral types may be selected by means of the relative intensities of the spectral features, listed at the top of Table 5a, combined with the "remarks regarding features" given in the last column.

The classification into groups can also be done fairly accurately by means of the plates IIa, IIb, and IIc combined with the explanation to the plates with its last column "remarks on auroral types".

In Table 6 the numbers of "F"-spectrograms from the three plates (from 1—89) are given for each group:

Table 6.

Classification of "F"-spectrograms.

Group E	II—a	2, 4, 6, 8, 13, 16, 18, 19, 20, 24, 26, 27, 28, 29, 32, 33.
	II—b	35, 41, 42, 43, 44, 51.
	II—c	59, 60, 61, 62, 63, 75, 76, 79, 81, 82.
Group P	II—a	1, 3, 5, 9, 10, 11, 14, 15, 17, 21.
	II—b	34, 38, 40, 46, 49, 52, 53, 55.
	II—c	58, 66, 70, 71, 73, 85.
Group E + P	II—a	7, 12, 22, 23, 25, 30.
	II—b	36, 39, 45, 47, 48, 50, 54, 56, 57.
	II—c	64, 65, 67, 68, 69, 72, 74, 77, 78, 80, 83, 84, 86, 87, 88, 89.

From Table 5a we have calculated the mean relative intensity for each group E, P and (E—P) from the classification of Table 6. The intensities of the various features of the groups are given in Table 7. The green line (5577) is used as a standard and put equal to 100. (n) is the number of spectrograms in each group.

Table 7.

Type of features	*OI* (6300)		H_α (6563)		N_2^+1N (0—1)		N_2 P (8—5)		$N_2$1P (7—4)	
	n	*I*	*n*	*I*	*n*	*I*	*n*	*I*	*n*	*I*
Group E	32	19	19	0.70	11	3.8	30	5.0	30	6.8
Group P	24	675	14	3.57	4	9.1	24	4.9	24	6.9
Group (E+ P)	31	175	18	1.32	4	5.1	28	4.3	28	6.0

We notice that the intensity of the red doublet is about 36 times stronger when it is excited by protons than when it is mainly excited by primary electron rays. The mean intensity of H_α *is about 5 times greater in the proton group than with the group mainly excited by primary electrons. The negative band* $N_2^+ lN$ *(0—1) is 2 1/2 times stronger at the greater altitude of the protons, than further down, where the electrons dominate.*

As the intensity is measured *relative to the green line* (5577), this confirms the result already found in 1923 [3, 19, 13, 16] that the intensity of the negative nitrogen bands relative to that of the green line increase with altitude.

As regards the bands of the first positive group $N_2$1P, we notice the remarkable fact that *the relative intensities, within the limit of possible errors, are the same for the E- and P-group. This means that the luminescence of these bands must be due to excitation by electron rays.* This fact also entails that the green auroral line, is excited by electrons; for if the intensity of the green line were different in the (E) and (P) groups, this would give corresponding intensity-variations to the bands $N_2$1P, because the green line is used as a standard. *The intensity relations show that the green line is due to electron excitation down to the bottom part of the auroral luminescence.*

It has been shown in previous papers that the forbidden red *OI* doublet is excited by protons upwards from the layer (h_p), where the protons of the solar electric bundle are absorbed. The excitation by protons is restricted to the transfer of the double ground state $^3P_{2,1}$ to the metastable $^1D_2$ state, without showing any transfer to the higher metastable $^1S_0$-state.

The results of the intensity distribution shown in Table 7 give us a definite conception of the way in which the forbidden *OI*-lines are excited and of their different appearance in the auroral luminescence.

The results here, briefly stated, lead to the following explanation regarding the auroral luminescence resulting from the metastable ground states of the *OI*-atoms.

When the bundles enter the atmosphere the solar electrons and positive ions (protons) are free to move independently of each other. The electron usually has an energy of the order of 10^4 e. v., which is much greater than that which produces the *E*-layer by soft *X*-rays of energy of the order 1—1.5 10^3 e. v.

The positive rays of the bundle will not essentially influence the passage of the auroral electron rays on their way down the atmosphere until they are absorbed at the lower limit of the auroral streamer, usually at an altitude of about 100 km.

The luminosity per unit length of path for the forbidden lines, will diminish rapidly upwards from the bottom edge of the auroral streamer — at a rate approximately proportional to the density of the *OI*-atoms.

The electrons of the solar bundle on the way downwards to the auroral lower limit, will produce all four metastable states: $^3P_{2,1}$, $^1D_2$ and $^1S_0$ and the corresponding five forbidden lines shown in Table 1.

On account of the fact, shown in Table 1, that the lifetime of the green line ($^1D_2-^1S_0$) is considerably shorter than those of the red doublet, the intensity will be much smaller than that of the green line, even at the lower limit of the aurorae. Further, the ratio of the intensity of the red doublet and other forbidden lines to that of the green line will rapidly decrease upwards.

Now the positive ions of the solar bundle (mostly protons) would be absorbed at an altitude (h_p) above which the mean free path is so great that the protons will have no noticeable influence on the intensity of the forbidden *OI*-lines produced by the electrons of the bundle.

With regard to the *P*-excitation we know from previous investigations that the protons have a great ability to excite the red *OI*-doublet ($^3P_{2,1}-^1D_2$), but the positive ions (protons) have no part in the excitation of the $^1S_0$ — state or in the emission of the green line ($^1D_2-^1S_0$), 5577.

7b. Results obtained with the "F"-spectrograph and Kodak 103a—J plates. Study of the forbidden green doublet *NI* $^4S_{3/2}$ — $^2D_{5/2,\,3/2}$ — 5200.1, 5197.8. Among the forbidden *NI*-lines only the green doublet (cfr. Table 1) can be used by the "F"-spectrograph, and as the sensitivity of the plate Kodak 103 a—E in the region of the green *NI* doublet is small, we have used the 103 a—J plate, which is very sensitive near the forbidden *NI*-doublet. With this kind of plate we have taken, with the "F"-spectrograph at Tromsoe, 61 auroral spectrograms during the year from 9.12. 58—9.12. 59. Reproductions with explanations are given on plates III—a and III—b.

On those plates the spectral features, especially in the most sensitive region near the *NI*-doublet, are often diffuse or too strongly exposed for distinct analysis and accurate measurements. The registrams taken directly from the negatives give better definition of details and more accurate intensities than might appear from the reproduction on plates IIIa, b.

Our results of intensity-measurements from 103 a—J-plates are given in table *5b* for the following features: Six bands of the system N_2^+1N, the lines H_β, the *NII*-group near 5000 Å, and the forbidden green *NI*-doublet.

Remarks on the auroral types corresponding to the features are given in the last column of the explanation to the plates and in Table *5b*.

Table 5b.

Relative Intensities obtained from the "F"-spectrograms (on Kodak 103 a—J) reproduced on Plates III—a and III—b.

Sp. No.	N_2^+1N (0—1)	(1—2)	(0—2)	(1—3)	(0—3)	(1—4)	H_β	NII 5000Å	NI 5200Å	Remarks regarding Features
1	27.7	6.0	11.3	8.0	8.4	6.7	7.7	6.9	14.1	Fog. surf. and A. U.
2	str.	»	8.7	2.7	1.9	0.9	0.9	1.3	1.6	Various forms
3	str.	»	9.7	3.0	1.9	1.0	1.8	2.0	1.7	St. flashes — all forms
4	32.3	»	6.2	6.2	3.2	1.9	5.2	4.7	22.0	Fog. surf. and type A.
5	str.	»	8.3	3.6	1.1	0.5	0.7	1.8	3.1	St. flashes, mainly fog. surf. and type A.
6	str.	»	9.9	4.4	4.1	1.1	1.3	3.1	6.9	St. dif. surf. and type A.
7	str.	»	9.4	3.6	3.0	1.3	1.6	3.2	1.9	St. flash, dif. puls. Aur.
8	str.	»	8.6	4.1	2.5	2.0	3.1	3.9	2.4	Dif. and puls. Aur.
9	30.6	»	6.9	4.6	2.2	1.9	5.0	3.1	9.6	We. A. and dif. Aur.
10	38.6	»	7.0	3.4	1.8	1.9	1.8	3.4	5.7	St. flashes and dif. Aur.
11	—	—	—	—	—	—	—	—	—	Homog. B. and D.
12	43.5	6.0	8.8	4.8	2.5	—	—	—	6.1	V. we. C. and fog. surf.
13	str.	»	11.8	4.9	3.8	2.0	—	4.2	4.8	We. fog. surf. and puls. spots.
14	37.4	»	10.3	4.1	3.1	2.6	—	—	5.0	Homog. A.
15	27.6	—	10.1	4.5	3.1	2.7	—	3.7	4.2	A.
16	29.5	6.0	5.9	3.9	2.5	1.7	—	2.3	26.4	R. U. partly type A.
17	39.8	»	8.1	4.5	2.2	1.8	2.5	2.1	15.2	R. and. fog. surf.
18	36.5	»	8.3	4.5	2.7	2.0	3.5	4.3	18.8	Dif. Aur. type A.
19	47.7	»	12.1	5.6	4.6	2.1	2.8	6.4	11.4	Dif. Aur. and st. A.
20	55.5	»	9.7	4.6	2.1	1.7	—	3.4	7.9	Dif. puls. Aur.
21	35.5	»	9.8	4.9	4.5	2.7	—	4.4	3.7	A. L.
22	37.5	—	—	—	—	—	—	—	21.7	R. U. and fog. surf.
23	str.	6.0	14.9	5.1	4.3	1.6	3.3	4.8	3.9	Var. forms (partly type A)
24	29.9	—	9.3	4.5	—	—	—	—	7.4	R. U. and fog. surf.
25	str.	6.0	17.7	4.6	6.4	2.4	2.9	4.1	1.8	A., D.
26	40.8	»	11.5	6.6	5.1	4.0	4.6	6.2	5.3	Fog. surf.
27	str.	»	11.7	4.0	3.3	1.5	—	2.7	1.3	St. vivid B. and D.
28	str.	»	11.5	4.0	3.3	1.7	—	3.2	1.6	St. B. through Z.
29	str.	»	12.5	5.9	4.5	2.7	—	4.7	3.4	Fog. surf. and homog. A.
30	str.	»	7.9	4.0	2.3	2.0	3.2	2.8	3.5	R. U., B. and fog. surf.
31	35.8	»	10.9	7.5	6.4	4.4	10.5	6.7	18.4	Various forms (partly fog. surf.)
32	str.	6.0	8.7	5.4	3.2	2.6	4.2	4.1	8.6	R.
33	str.	»	13.7	4.3	4.0	2.0	—	3.0	1.8	V. vivid Aur. — A. and R.
34	str.	»	str.	3.5	4.3	1.1	—	2.0	—	Vivid A. with R.-structure
35	str.	»	12.8	3.9	2.8	1.6	—	2.9	1.7	Fog. surf.
36	39.8	»	8.8	6.2	4.0	2.8	6.7	5.7	8.2	We. R. and D.
37	str.	»	10.1	4.5	2.8	2.1	—	—	3.1	B. through Z.
38	str.	»	13.4	4.2	4.3	2.4	2.6	3.7	2.8	A. and D.
39	str.	»	9.9	4.2	3.4	2.3	3.2	3.7	3.5	Fog. surf. and puls. spots.
40	str.	»	10.1	4.5	3.9	2.6	4.2	4.2	3.5	Fog. surf. and homog. B.

Table 5b (cont.).

Sp. No.	N_2^+1N (0–1)	(1–2)	(0–2)	(1–3)	(0–3)	(1–4)	Hβ	NII 5000Å	NI 5200Å	Remarks regarding Features
41	37.7	6.0	12.9	8.5	7.7	6.4	7.9	—	15.1	Fog. surf. and R. L.
42	28.0	»	9.7	4.4	4.3	3.7	—	—	5.2	D, A, type A and type B.
43	str.	»	15.1	4.4	5.1	1.8	—	3.0	1.3	St. A. and D, partly type A
44	38.7	»	9.5	5.1	3.0	—	—	5.3	5.5	R. U, fog. surf. and type A.
45	37.7	—	—	—	—	—	—	—	30.0	R. L., we. fog. surf.
46	32.3	6.0	11.8	9.5	6.2	4.5	9.3	9.3	9.2	V. we. fog. surf.
47	32.4	»	10.4	—	3.2	—	—	—	10.6	We. R. U.
48	45.1	»	15.2	7.0	6.0	4.1	—	5.0	3.2	D., st. A. and we. fog. surf.
49	43.7	»	10.4	—	4.0	—	—	—	4.4	R. U. and fog. surf. towards Z.
50	35.6	»	10.6	—	5.5	5.0	—	—	7.0	A. and fog. surf.
51	44.8	»	12.2	5.5	3.3	3.3	—	—	5.2	We. Aur.
52	38.4	»	8.5	4.6	2.8	—	—	—	4.9	Puls. Aur.
53	str.	»	11.5	4.5	3.4	2.9	—	4.6	4.6	St. A.
54	str.	»	14.3	4.3	3.8	2.5	—	3.3	1.7	D. in st. flash.
55	44.4	»	8.0	4.9	3.4	2.3	—	—	5.4	R. U. towards Z.
56	45.3	»	11.0	6.9	5.7	3.7	6.4	6.3	9.2	D. and fog. surf.
57	35.1	»	7.7	4.1	3.4	2.8	—	—	7.7	R. U. and type A.
58	40.7	»	9.6	—	2.9	—	—	—	—	St. flash — magn. Z.
59	40.7	»	9.5	5.2	3.4	2.6	—	6.0	4.2	B.
60	42.3	»	12.1	6.8	4.6	5.1	6.9	4.7	9.0	We. D.
61	20.8	»	5.8	—	3.3	—	—	—	8.4	We. fog. surf.
Mean values	37.5	6.0	10.4	5.0	3.8	2.6				

In the case of the spectrograms taken on 103 a—E-plates, a fairly good classification was possible by the enhancement of the red $N_2$1P-bands and the strong green line 5577 on the one hand, and the red *OI*-doublet on the other.

When the 103 a—J plates are used, the typical features for electron and proton excitation are no longer so pronounced. The J-plate is in fact insensitive for both the red doublet, responsible for the red aurorae of type *A*, typical for proton excitation, and for the red $N_2$1P bands responsible for the red aurorae of type *B*.

The observers have tried to give a short characteristic of the auroral forms and variations during each exposure and tried to notice the appearance of red aurorae of type *A*.

From the remarks and the auroral photograms we have tried to divide the auroral displays on the two plates IIIa, b into 6 groups according to the expressions used for each group. For each group the mean intensity is calculated for each of the 8 features.

The results are given in Table 8. The character of each group or type is seen in the 1st column.

Table 8.

"F"-spectrograms on 103 a—J plates 1958/59.

Type \ Feature		N_2^+1N 0—1	N_2^+1N 1—3	N_2^+1N 0—3	N_2^+1N 1—4	*NII* 5000	*OI* 5577	*NI* 5200	H_β
1. Red Type A	I_m	9.0	4.5	3.3	1.9	3.5	449	10.8	2.7
	n	9	9	9	8	7	8	9	4
Surfaces 2. Pulsating	I_m	10.0	5.6	4.1	3.2	4.5	287	8.2	5.0
	n	24	18	22	16	14	20	24	10
3. Flash. Puls.	I_m	9.8	4.0	2.6	1.9	3.4	444	3.9	2.2
	n	5	5	5	5	5	5	5	3
4. A.B.D.	I_m	11.2	4.7	3.7	2.6	4.1	421	4.5	4.4
	n	11	11	11	11	9	11	11	4
5. R.	I_m	9.8	4.9	3.8	2.2	3.7	401	6.0	5.5
	n	4	5	5	5	4	5	4	2
6. Various forms	I_m	11.3	4.8	3.8	2.0	4.2	651	7.4	3.9
	n	5	5	5	5	5	5	5	5

As seen from Table 5b, the intensities are given in relation to that of N_2^+1N (1—2) as a standard put equal to 6, and we should expect the relative intensities of the other 4 negative nitrogen bands to be essentially the same for all 6 groups. Taking into account the character of the spectrograms, this conclusion with regard to the intensity distribution of the N_2^+1N bands seems to hold good in a satisfactory way.

Also the relative intensities of the multiplet *NII* (5000) seem to be the same for all 6 groups, within the possible error of measurements.

We notice the great relative intensity of the green auroral line (5577). With the exception of group No. 2 the relative intensity of this line keeps a value not greatly different from those of the other 5 groups with a mean value of 473.

The intensity of group 2 has just a little more than half the value of the other groups.

As this small intensity is based on a fairly large number of spectrograms, it indicates that the small intensity is real, and that the observed surfaces and pulsating aurorae have appeared at great altitudes, for we know that the intensity of the green line (5577) relative to the negative N_2^+1N bands decreases with altitudes.

Our interpretation of the small intensity of the green line in group (2) also agrees with the fact that the forbidden *NI*-doublet at 5200 and the H_β-line are considerably enhanced. From earlier investigations, it was found that the excitation of the *NI*-doublets and the H_β-lines, is caused by positive ions (protons) from the auroral bundles, and that they should only be existent at an altitude greater than (h_p) where the protons are absorbed (cfr. papers 19, 21). A quite marked enhancement of the *NI*-doublet and the H_β-line appears in group (5) where the auroral luminescence is emitted from rays, which means that the emission mainly comes from great altitudes.

It is of particular interest that the greatest mean relative intensity is for group 1, which corresponds to spectrograms for which red aurorae of type *A* have been observed. In these cases we know that the excitation of type *A* is caused by the protons from the solar bundles, and that also the forbidden *NI*-atoms have been enhanced by the effect of protons from the altitude (h_p) and upwards.

The great variability of the *NI*-doublet relative to the other 6 features of Table 8 can be shown in a very direct manner by dividing the spectrograms of *NI*-into the three intensity groups shown in Table 9.

Table 9.

Intensity number	$I \geqq 10$ 11	$10 \geqq I \geqq 5$ 21	$I \leqq 5$ 29
Mean intensity	19	7.2	2.9

In table 9 the second horizontal line shows the strongest intensity group containing 11, and the succeeding other groups 21 and 29 spectrograms respectively.

The upper intensity group is seen to have a mean intensity of more than 6 times the smallest one.

8. Conclusions regarding the analysis of the "F"-spectrograms.

1. By the separation of electrons and protons of the solar bundles on their way down the ionosphere, the electrons, which have the greatest penetrating power will stop at the lower limit of the aurorae (h_e). Above this altitude the atmosphere is excited by electrons from the solar bundles.

Consequently, the electrons will also excite the metastable states of *OI*, *OII*, *OIII* and *NI*, *NII*. In the present case we have only been able to deal directly with the green *OI* line (5577), the red *OI*-doublet (6300, 6364), and the green *NI* doublet (5200, 5198).

Near the bottom edge of arcs, bands and draperies, the auroral luminescence is excited by electrons which produce the forbidden lines of fig. 1. The intensity of forbidden lines, we observe, depends on the atmospheric density in relation to the life time of the metastable state in question.

Usually the lower part of the aurorae appears at altitudes between 80—110 km, and the relation between density of *OI*-atoms and lifetime is suitable for the emission of *the green OI line* ($^1D_2—^1S_0$), which has been excited by the electrons of the solar bundle.

2. Also the other metastable states of Fig. 1, are excited by the electron rays, e.g., the red *OI* doublet ($^3P_{2,1}—^1D_2$) but on account of the long lifetime, the excited atoms will be disturbed by collisions before emission, and the red doublet, at the usual altitudes of the bottom edge of the aurorae, is too weak to be observed.

3. From the altitude (h_p), where the protons stop, and upwards, the red doublet may be excited and emitted with great intensity, *but no corresponding emission of the green line (5577) is found.*

4. *Remarks on the "F"-spectrograms taken on 103 a—J plates:*
   a. The intensity of the green line (5577) relative to the standard band (N_2^+1N) (1—2) is much smaller for group 2 than for the 5 others, indicating the greater altitude of group 2.
   b. The greater intensity of the forbidden doublet *NI* (5200) is shown to be due to proton excitation.
   c. The variability of the forbidden *NI*-line may be very large, compared with that of other features on the *J*-spectrograms.

9. Reaction between protons and the atomic systems OI, OII, OIII, NI, NII by the formation of the forbidden $^1D_2$-doublets. The collision between the neutral *O*-atom and *the proton*, which leads to the excitation of the red doublet emitted from the metastable $^1D_2$-state, differs most essentially from the *electronic* excitation of *OI* already dealt with. We must first of all remember the positive charge of the proton and its great mass compared with that of the electron.

When a proton strikes an *OI*-atom it will attract one of the *OI*-electrons, and try to form a hydrogen atom. This interaction may partly result in the formation and sudden dissociation of a *H*-atom and a *OII*-ion, partly in the transfer of the ground state of *OI* to the metastable state *OI* $^1D_2$, which results in the emission of the red doublet. On account of the catalytic coupling, the lifetime of the $^1D_2$-states is greatly reduced so the probability of the emission of the red doublet is increased. This may account for the enormous enhancement of the emission of the doublet *OI* ($^3P_{2,1}—{}^1D_2$) which is responsible for *the red aurorae of type A*.

The same reasoning may also account for the emission of the other doublets of the forbidden lines from a $^1D_2$ state to its corresponding ground state of *OI*, *OII*, *OIII*, *NI*, *NII*.

The catalytic chemical reaction between *O*-atoms and the protons of the solar bundle which result in the formation of the *D*-doublet from the metastable ground state *OI* $^3P_{2,1}$, has *no influence on the higher metastable state OI* $^1S_0$, *or on the emission of the green line OI* ($^1D_2—{}^1S_0$) *(5577). This leads to the remarkable result that the famous green auroral lines to the remarkable result that the famous green auroral lines are excited by photo-electrons contained in the solar bundles produced by sunspot X-rays.*

It is to be expected that the following corresponding forbidden lines from the upper metastable states behave like the green auroral line in so far as they are only excited by electrons like the following 5:

$$OI\ (^1D_2—{}^1S_0),\ OII\ (^2D_{3/2}—{}^2P_{3/2}),\ OIII\ (^1D_2—{}^1S_0)$$
$$NI\ (^2D_{5/2,\ 3/2}—{}^2P_{1/2}),\ NII\ (^1D_2—{}^1S_0).$$

The electron excitation also holds good for the following transitions $P-S$ and $S-P$. Only the doublets $P-D$ and $S-D$ are excited by protons (cfr. Table 1 (abcd), through a kind of electrochemical reaction ("catalysis in gas-reaction").

10. Spectrograms obtained with the "C"-spectrograph at Oslo from 29.8. 57 to 5.11. 59 and their classification into groups. As seen from table 10 the dispersion or light power of the Oslo-spectrograph "C" is considerably smaller than for the two spectrographs "V" and "F" used at Tromsø:

Table 10.

Scale values (in Å/mm) at different λ, and light power of the three spectrographs.

λ Light power	"V"-spectrg.	"F"-spectrg.	"C"-spectrg.
	F: 1.20	F: 0.65	0.95
4000 Å/mm	40	77	100
8000 Å/mm	188	395	550

On account of the smaller light power or dispersion of the instrument at Oslo, we had to use longer exposures, and this in itself, made it more difficult at Oslo than at Tromsø to obtain spectrograms mainly showing features of one definite type of excitation process. At the same time, the auroral displays appeared more variable and complex towards lower latitudes.

The Oslo spectrograms are reproduced on the three plates IVa, IVb and IVc and are accompanied by explanations in the usual way.

All spectrograms on plate IVa and IVb were taken on Kodak 103 a—E plates.

On plate IVc Nos. 51—61 were taken on Kodak 103 a—E, in the time intervals from 4.12. 58 to 5.12. 58 (5 spectrograms) and 3 spectrograms were taken during the evening 4.1. 59, and 3 on the morning of 5.11. 59.

Particularly for the study of the forbidden NI-doublet $({}^4S_{3/2}-{}^2D_{5/2,\ 3/2})$ (5200.1 —5199.8), we took 11 spectrograms from Nos. 62—72 on Kodak 103 a—J plates.

Classification of spectrograms.

The 61 spectrograms on Kodak 103 a—E plates.

As in the case of the "F" spectrograms we intend to classify the spectrograms in 3 groups: (Table 11)

- *E* those which are mainly excited by electrons.
- *P* those which are mainly excited by protons.
- *E*, *P* those which are excited by a mixture of *E* and *P*.

For the reasons mentioned, hardly any of the Oslo spectrograms can be considered as excited purely by electrons or purely by protons.

Table 11.

E	(group)	a)	2, 3, 6, 11, 17.
		b)	28, 29, 30, 42, 45, 46,
		c)	51, 54.
P	«	a)	4, 8, 9, 10, 12, 20, 22,
		b)	26, 32, 33, 34, 36, 38, 39, 40, 43,
		c)	52, 56, 58, 59, 60, 61.
E + P	«	a)	1, 5, 7, 13, 14, 15, 18, 19, 21,
		b)	23, 24, 25, 27, 31, 35, 37, 41, 43, 44, 45, 47, 48, 49, 50,
		c)	53, 55, 57.

The selected group contains the spectrograms Nos. 1 to 61, taken on Kodak 103 a—E plates sensitive to red. In this case the excitation with electron rays is easily selected by the bands $N_2 2P$, $N_2^+ 1N$ the green auroral-line, and the very small intensity of the red forbidden doublet. These features all appear in the red part.

The *P*-group is characterized by the appearance of the strong red forbidden doublet (6300, 6364), the presence of H_α and H_β or the absence or weakness of strong bands.

The *E*-group excited by electrons shows the following typical features:

Strong vibrational bands, particularly from N_2 absence of Hydrogen lines. Absence of the forbidden red and very often strong doublet.

The *E*-spectrograms come from the lowest part of the aurora, usually from the bottom edge, at the height (h_e).

The *P*-spectrograms, show the forbidden red doublet often with great intensity.

11. Altitude and Temperature of Aurorae on 103 a—E plates. As shown in section 7a the emission results from the transfer from the ground states $OI\ ^3P_{2,1}$ to the metastable state $OI\ ^1D_2$. As we know, the enhancement of the red doublet is due to the protons which enter the atmosphere as part of the neutralized bundle, and the excitation by protons takes place above the absorption height (h_p). This means that the excitation of the *P*-group takes place far above the lower limit of the aurorae, where the electron rays are stopped.

The *p*-excitation is no doubt responsible for the long auroral streams, which are usually present at low latitudes, and indicates the presence of aurorae at great altitudes.

Thus the aurorae belonging the group (p) show us directly the auroral properties at great altitudes.

Table 12.

Absolute Ionospheric Temperatures observed at Oslo with the spectrograph "C"
The Spectrograms used are indicated by the numbers given in the Explanation to Pl. IV—a, —b, —c.

Pl. IV Sp. No.	Date	Band	Temp. °K	Auroral type	Altitude indication
2	23. 9. 57	3914	200	R.	
»	»	4278	267	»	H
11	21.10	»	347	A. L.	L
13	10.12.	»	283	Various forms.	H
16	20. 2. 58	»	283	A., D. L.	L
17	»	3914	245	A. L.	L
19	24. 3.	4278	311	A. L.	L
23	3. 9. 58	4278	302	Corona	H
24	»	»	302	A. U., D., R.	H
25	4. 9.	»	346	A. U., D.	H
26	»	»	326	R. U.	H
27	»	3914	264	Corona, R. U.	
»	»	4278	349	»	H
28	»	3914	258	D. L.	
29	»	4278	333	D. U., R.	H
30	5. 9.	»	347	D.	
31	16. 9.	»	296	D., R. L., A.	L
35	22.10.	»	330	D. with R.-structure	L
37	»	»	320	D.	L
41	24.10.	»	309	Various forms.	
42	25.10.	3914	227	D. L., R.	
»	»	4278	310	»	L
45	4.12.	»	392	D. U. with R.-structure	H
46	»	»	260	B., A.	L
»	»	3914	211	»	
49	»	»	315	A. through Z.	L
»	»	4278	333	»	L
50	»	»	316	R. U.	H
51	»	3914	288	R. L.	
»	»	4278	277	»	L
53	5.12.	»	330	Z.	H
54	»	3914	212	D. L.	
55	»	»	210	Z.	
»	»	4278	273	»	H

Mean H: 318°K
Mean L: 308°K } True temp. about 220° K.

The features of the spectrograms from Oslo usually appear to be too heavily exposed for intensity measurements in the red region which appears in the most important part.

Two bands belonging to the N_2^+1N system are suitable for the test of possible variation of temperature with altitude.

The bands 3914 and 4278 are classified into two groups:

H: those which are taken from long rays (at great height *H*).
L: those which are taken from small altitudes (Low aurorae *L*).

Within the limit of errors the (*H*) and (*L*) groups give the same mean temperatures, although the altitude in the *H* group may be greater by some hundred km.

As we know, the temperatures of the order of 220° can be measured fairly accurately at heights of about 100—200 km. By using long auroral rays, we can also measure temperatures at much greater height. A number of such measurements has been carried out at Oslo and some recent results are given in Table 12.

12. Oslo spectrograms taken with Kodak 103a —J plates. The spectrograms Nos. 62 to 72 were taken at Oslo from 27.3. to 5.10. 1959 on Kodak 103 a—J plates. The properties of these plates are described in connection with plates of the same sort taken by the "V" and the "F"-spectrographs. Their highest sensitiveness is in the region near the forbidden doublet *NI* (5200.1 and 5198 Å). But it is insensitive in the red part which also means it is insensitive to the red *OI* doublet, to H_a and the red $N_2 1P$ bands.

The selection of lines excited by electrons or protons can be done by the following criteria:

Electron excitation: Very strong N_2^+1N and some $N_2 2P$ bands. Absence of hydrogen lines.
Proton excitation: Production of forbidden *NI* doublets and hydrogen lines. *NII* lines.
The N_2 bands are extremely weak or absent.

By using these criteria the following excitation groups are found:

Table 13.

E-excitation:	62, 63, 64, 65, 66.
P-excitation:	68, 71.
(E + P)-excitation:	67, 69, 70, 72.

We notice that the spectrograms excited mainly or partly by protons show maximum intensity of the forbidden *NI* doublet in a similar way as with the excitation of the red *OI*-doublet by protons.

Acknowledgments. I wish to express my sincere thanks to Mr. Steinar Berger for his most able assistance in the auroral spectrographic work carried out with the "V" and "F"-spectrographs at Tromsoe; to Mr. Arne J. Moe for auroral spectrograms taken at Oslo and for his able assistance at Oslo in connection with the treatment of the auroral spectrograms and Mr. Harald Steen for valuable help during the preparation of this paper.

My sincere thanks are also due to "Norges Almenvitenskapelige Forskningsråd" for financial support of my auroral investigations.

LIST OF PAPERS

1. VEGARD, L.: Theory of aurora and magnetic disturbances founded on neutralized solar streams. *Ann. d. Phys. IV*, **50**, p. 583, 1916.
2. — The absorption of electrons and positive rays and structure of aurorae. *Phil. Mag.* **42**, 47, 1921.
3. — The terrestrial and solar corona and the conductive ionized atmospheric layers explained through photo-electric effect of solar X-rays. a. *Phil. Mag.* **46**, 193, 1923. — b. *C. R.* **176**, p. 947, 1488, 1923.
4. — Results of observations from the solar eclipse in Norway, June 29, 1927, and the constitution of the solar corona and sunspots. *Det Norske Vid.-Akad. Oslo, Skr.* I, No. 2, 1928.
5. — *Geof. Publ.* (*G. P.*) Oslo, IX, No. 11, 1932.
6. — Die Corona der Erde und Sonne und ihre Beziehungen zu kosmischen Erscheinungen. *Gerlands Beiträge z. Geophys.* **32**, 288, 1931.
7. — *Phys. of the earth*, ed. by J. A. FLEMING, VIII, p. 573 (written in 1933).
8. — *Ergebnisse d. exakt. Nat. wiss.*, XVII, p. 29, 1938. From the detection of the terrestrial corona it followed that the electric bundles producing the aurorae were due to photo-electrons emitted from X-rays originating from highly ionized matter in the sunspot region and neutralized by positive ions. The properties of such bundles were dealt with in papers 7 and 8.
9. — In 1939 and the following years it was found that the auroral bundles emitted hydrogen showing Doppler effect corresponding to velocities of 2—3 10^8 cm/sec. This proved that the bundles consisted of electrons neutralized by protons. Regarding the discovery of the hydrogen Doppler effect the following papers may be referred to:

9a. — Hydrogen showers etc. *Nature* **144**, p. 1089, 1939.

9b. — and E. TØNSBERG: Results of auroral spectrograms obtained at Tromsø 1941—42 and 1942—43. *G. P.*, XVI, No. 2, 1944.

9c. — *Proc. of the Brussels meeting of the Mixed Commission of the Ionosphere*, July 1948, p. 111.

9d. — *Phys. Soc. Cassiot Comm. Report*, p. 82

9f. — *Trans. of the Oslo meeting of IUGG* 1948, p. 189, 484.

9g. — *C. R.*, **230**, p. 1884, May 1950.

9h. — *Annales d. Geophys.*, **6**, p. 157, 1950.

9i. — *Transact. of the Congr. of IUGG at Brussels 1951.*

9j. — Doppler effects obtained in the years 1940 to Feb. 1950 were treated in *G. P.* XVIII, No. 5, 1952; No. 3, 1951.

10. MEINEL, A. B.: Obtained H_α-Doppler effect in Nov. 1950.
11. GARTLEIN, C. W.: Announces obs. of Doppler-displacement of H_α. *Phys. Rev.* **81**, 103, p. 463, 1951.
12. VEGARD, L.: Paper in "*The threshold of space*", ed. by M. ZELEKOFF, p. 22, New York, London, 1957.

13. VEGARD, L., S. BERGER and A. NUNDAL: *Geofys. Publ.* XX, No. 9, 1958.
14. — Phenomena in planetary and space physics, governed by the "Coronal effect of solar X-rays". *Det Norske Vid.-Akad. Oslo. Avh.* I, 1960, No. 1.
15. — and G. KVIFTE: *G. P.* XVIII, No. 3, 1951.
16. — Doppler displacement of auroral hydrogen lines etc. *G. P.* XVIII, No. 5, 1952.
17. — and E. TØNSBERG: *G. P.* XVIII, No. 8, 1952.
18. — and G. KVIFTE: *G. P.* XIX, No. 2, 1954.
19. — Composition, variations and excitation of the auroral luminescence spectra. *G. P.* XIX, No. 9, 1956.
20. — Recent progress etc. *G. P.* XX, No. 4, 1958.
21. — S. BERGER and A. NUNDAL: Results of auroral observations at Tromsø and Oslo from the four winters 1953—57. *G. P.* XX, No. 9, 1958.
22. — On the origin of the red colour of the aurora. *Nature* **117**, p. 356, 1926.
23. — Vorgänge und Zustände in der Nordlichtregion. Höhenverstärkung der roten OI Linien (6300, 6364). *G. P.* XII, No. 5, 1938.
24. — *G. P.* XII, No. 14, 1940. Great enhancement of the green OI line and even more the red OI doublet towards lower latitudes.
25. — *Zeitschr. f. Phys.* **106**, 108, 1937.
26. — *Nature* **138**, 930, 1936.
27. — *Proceedings of the 3rd meeting at the Mixed Commission of the Ionosphere in Canberra* (Australia), Aug. 1952, p. 135, Bruxelles 1952.
28. — The temperature of the auroral region. *Terr. Magn.* **37**. p, 389, 1932.
29. — and E. TØNSBERG: Continued investigations on the temperature of the upper atmosphere etc. *G. P.* XI, No. 2, 1935.

PLATES

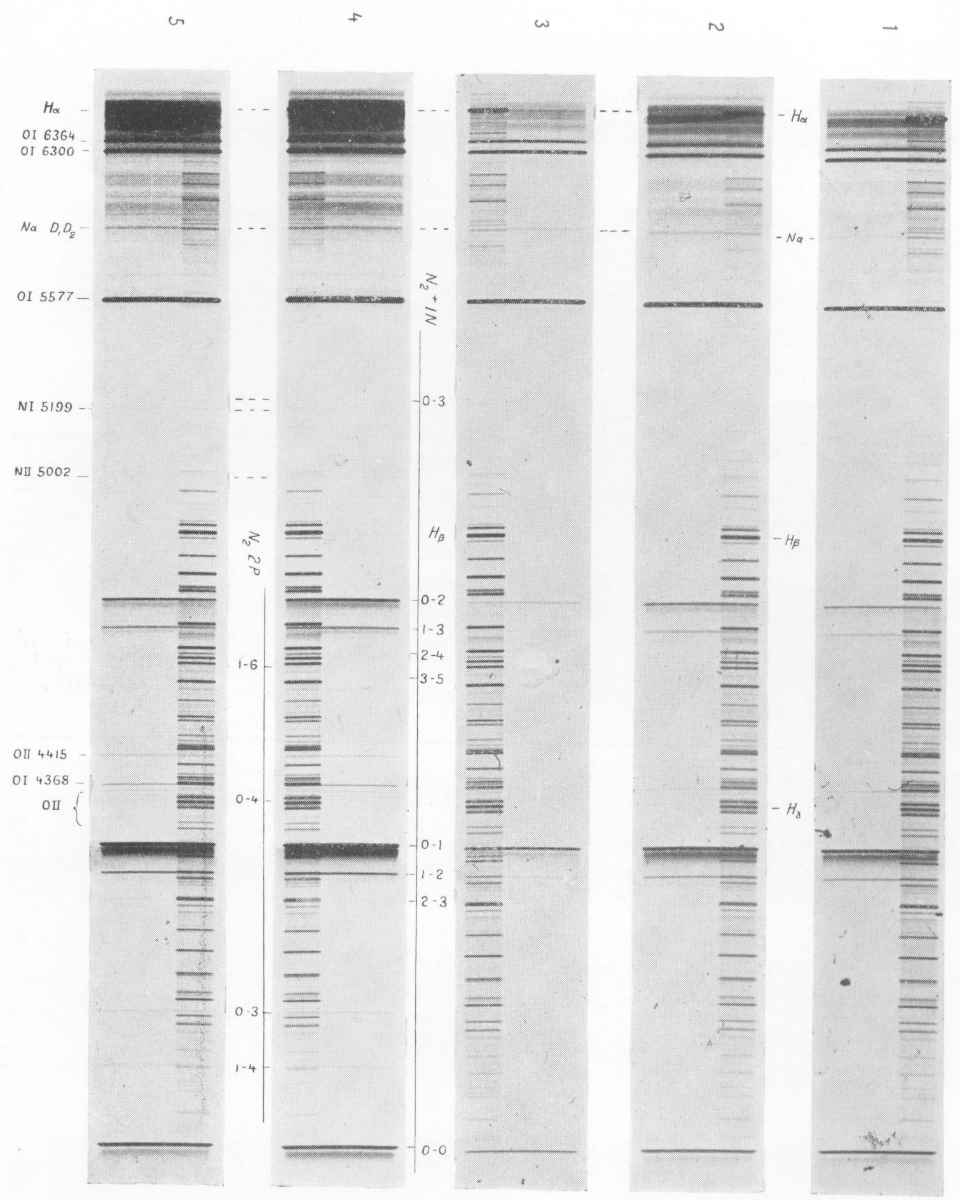
Explanation to Plate I—a.

Spectrograms taken at Tromsø with spectrograph "V".

Sp. No.	Date	Exposure	Direction	Remarks on Auroral Type
1	30.9. —26.11.57	15 h	Magn. Z	Partly type A
2	23.2. —13. 3.58	12 »		Various forms
3	6.10.—11.11.58	10½ »	W—N—E	» »
4	4.12.—17.12.58	11½ »		» »
5	20.12.— 9. 1.59	8 »	W—N	» »

Sort of Plate: Kodak 103 a—E.
Slit: 14/100 mm.

Plate I—a.


5
4
3
2
1
Hα
OI 6364
OI 6300
Na D1D2
OI 5577
NI 5199
NII 5002
OII 4415
OI 4368
OII
N2 2P
1-6
0-4
0-3
1-4
N2+ 1N
0-3
Hβ
0-2
1-3
2-4
3-5
0-1
1-2
2-3
0-0
Hα
Na
Hβ
Hδ

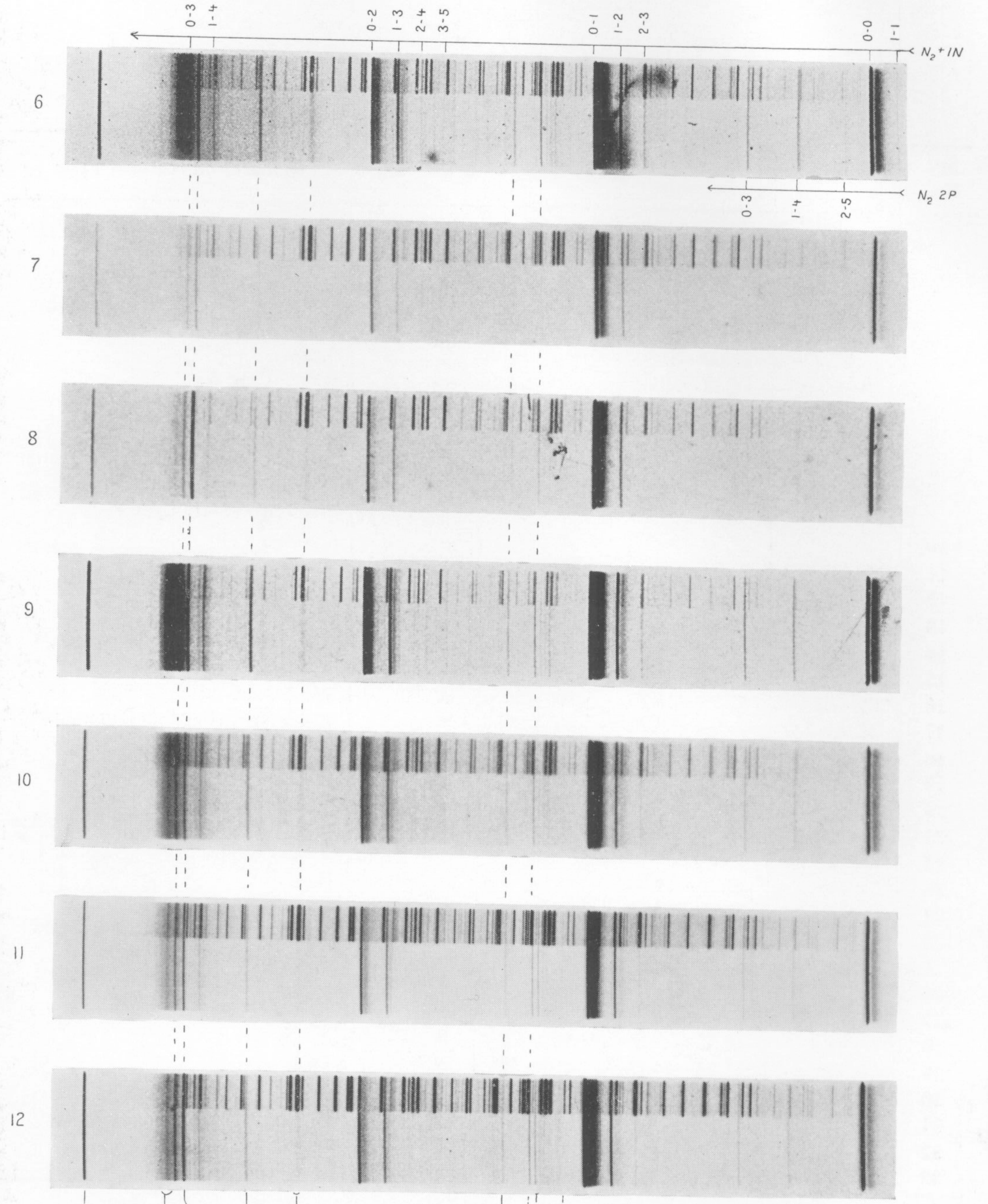
Explanation to Plate I—b.

Spectrograms taken at Tromsø with spectrograph "V".

Sp. No.	Date	Exposure	Remarks on Auroral Type
6	5.3. —12.3. 59	8 h	A., flashes and we. fog. Aur.
7	28.9. — 7.10.	5½ »	B., R and we. fog. Aur.
8	22.10.—31.10.	10 »	Various forms — mainly we. fog. Aur.
9	22.11.— 1.12.	24 »	» » — mainly v. we. fog. Aur.
10	3.12.—24.1. 60	12½ »	» »
11	2.2. — 3.2.	8 »	R., flashes, type A and we. fog. Aur.
12	15.2. —22.2.	12 »	Various forms — mainly we. fog. Aur.

Sort of Plate: Kodak 103 a—J.
Slit: 14/100 mm.

Plate I—b.



N2+ 1N
0-3
1-4
0-2
1-3
2-4
3-5
0-1
1-2
2-3
0-0
1-1
N2 2P
0-3
1-4
2-5
6
7
8
9
10
11
12
OI 5577
O2+ 1N
NI 5201.0
" 5199.5
NII 5005.1
" 5002.7
" 5001.5
" 5001.1
Hβ
OII 4314.9
" 4317.0
OI 4368.3
OII

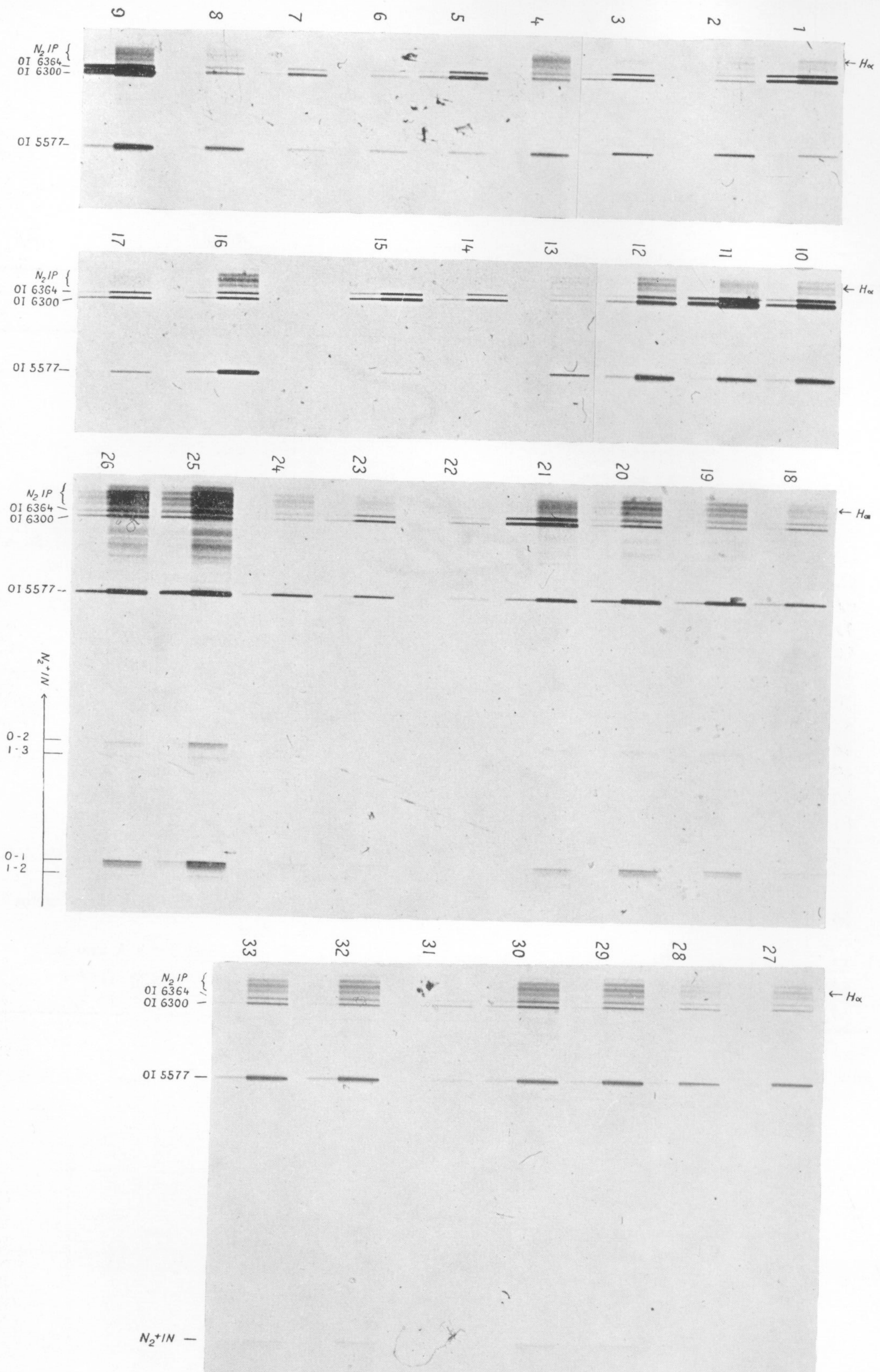
Explanation to Plate II—a.

Spectrograms taken at Tromsø with spectrograph "F".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
1	29.9.57	20.55—21.25		S	Strong red Aur, Type A.
2	30.9.	20.58—21.03			
		21.36—21.37			R. L. Type B.
3	21.10.	21.50—22.05	Magn. Z.		R. U. Type A.
4	25.11.	22.00—22.35	5°	S	A. L.
5	»	22.53—23.05	60°—90°	S	R. U. Type A.
6	»	23.05—23.13		W	R. L.
7	»	23.18—23.32			Corona
8	»	23.56—24.00		S—W	A. L. Type B.
9	26.11.	18.10—19.15			
		21.25—21.29			Strong red Aur, Type A.
10	»	21.32—21.55			Corona, Type A.
11	27.11.	00.31—00.55	50°—80°	S	Red Aur. Type A.
12	»	02.13—02.50	45°	S	Puls. surfaces
13	»	22.22—22.28	5°	S	A. L.
14	»	22.30—22.35			R. U. Type A.
15	»	22.37—22.56			R. U. Type A.
16	22.1.58	21.35—21.55	10°—30°	W	Weak Aur.
17	23.1.	17.24—17.35	10°—30°	W	Weak Aur. (Possibly Type A).
18	27.1.	22.03—22.10			B. through Z.
19	»	22.15—22.20			A. L. with R.-structure
20	7.2.	20.35—20.52			Strong Aur.-ordinary
21	11.2.	18.14—18.47			Red Aur. Type A and ordinary Aur.
22	»	2 m. exp.			R. L.
23	»	23.29—23.39			R. U.
24	»	23.39—23.50		N—W	R. L.
25	»	23.53—00.30		S	A., D. with R.-structure, rapid movement
26	12.2.58	00.30—01.05	2°—5°	S	A., dif. Aur.
27	20.2.	18.45—18.54	25°	N	A. L.
28	»	18.55—19.08	40°	N	A. U.
29	»	21.24—21.29	10°—30°	W	D. L.
30	»	22.46—23.01	20°	SE	Dif. Aur.
31	»	23.03—23.05			R. U.
32	»	22.08—22.20	15°	N	A.
33	»	23.45—24.05		W	Dif. B.

Sort of Plate: Kodak 103 a—E.
Slit: 40/100 mm.

Plate II—a.

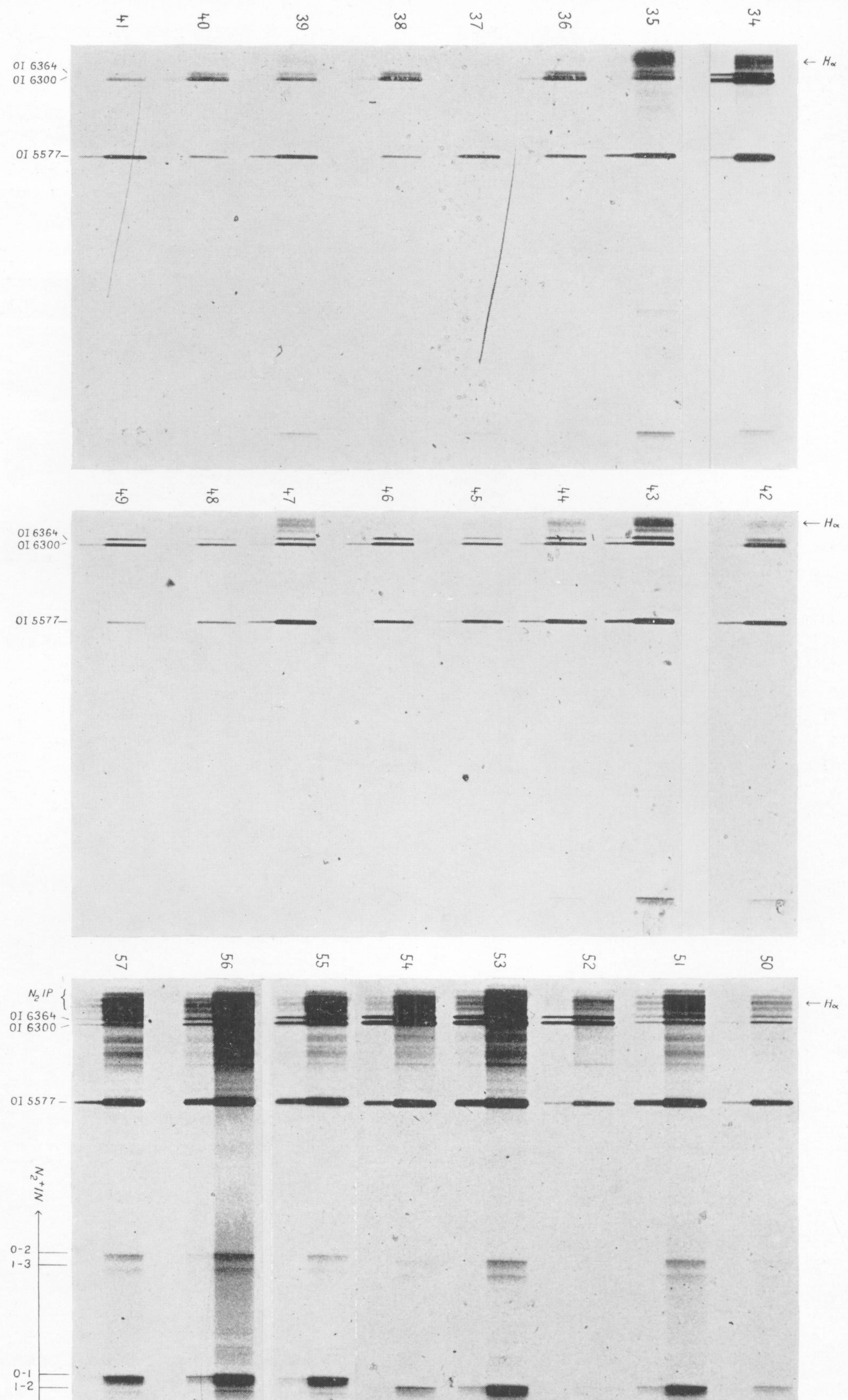


Explanation to Plate II—b.

Spectrograms taken at Tromsø with spectrograph "F".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
34	30.9.58	22.45—23.00	30°		We. Aur. Type A, partly various types
35	3.10.	21.33—21.50	12°	S	Homog. A.
36	6.10.	21.47—22.00	35°	NW	Red Aur. Type A.
37	»	22.26—22.30	60°	N	D. L.
38	»	22.56—23.04	30°—60°	SW	R. U.
39	»	23.10—23.18	Magn. Z		Corona, B.
40	»	23.20—23.32	25°40°	W	We. red Aur. Type A and R. U.
41	15.10.	21.15—21.26	40°	SW	Homog. B.
42	»	22.15—23.20	40°	NE	Weak dif. Aur.
43	7.11.	22.10—22.50	30°—60°	N—NW	Dif. Aur.
44	»	22.56—23.30	45°	S	Puls. spots.
45	11.11.	18.52—19.16	15°	N	We. homog. A.
46	»	19.34—19.50	30°—45°	N	A. U., partly R. and Type A.
47	»	19.45—20.25	7°	N	A. L.
48	»	22.05—22.20	30°	N	Homog. B.
49	»	22.56—23.14	50°	W	R. U.
50	26.11.	19.05—19.10	30°	S	We. B.
51	»	19.17—19.33	30°—60°	S	B.
52	4.12.	18.00—18.40			Red Aur. Type A.
53	»	—			Red Aur. Type A and partly green R.
54	»	23.10—23.50			Red Aur. Type A and ordinary Aur.
55	8.12.	21.15—22.30	Magn. Z		Corona, red Type A and B.
56	20.12.	20.20—21.20		NW—NE	A., D. and various types
57	»	21.23—22.00		N	A. L., partly red Type B.

Sort of Plate: Kodak 103 a—E.
Slit: 40/100 mm.

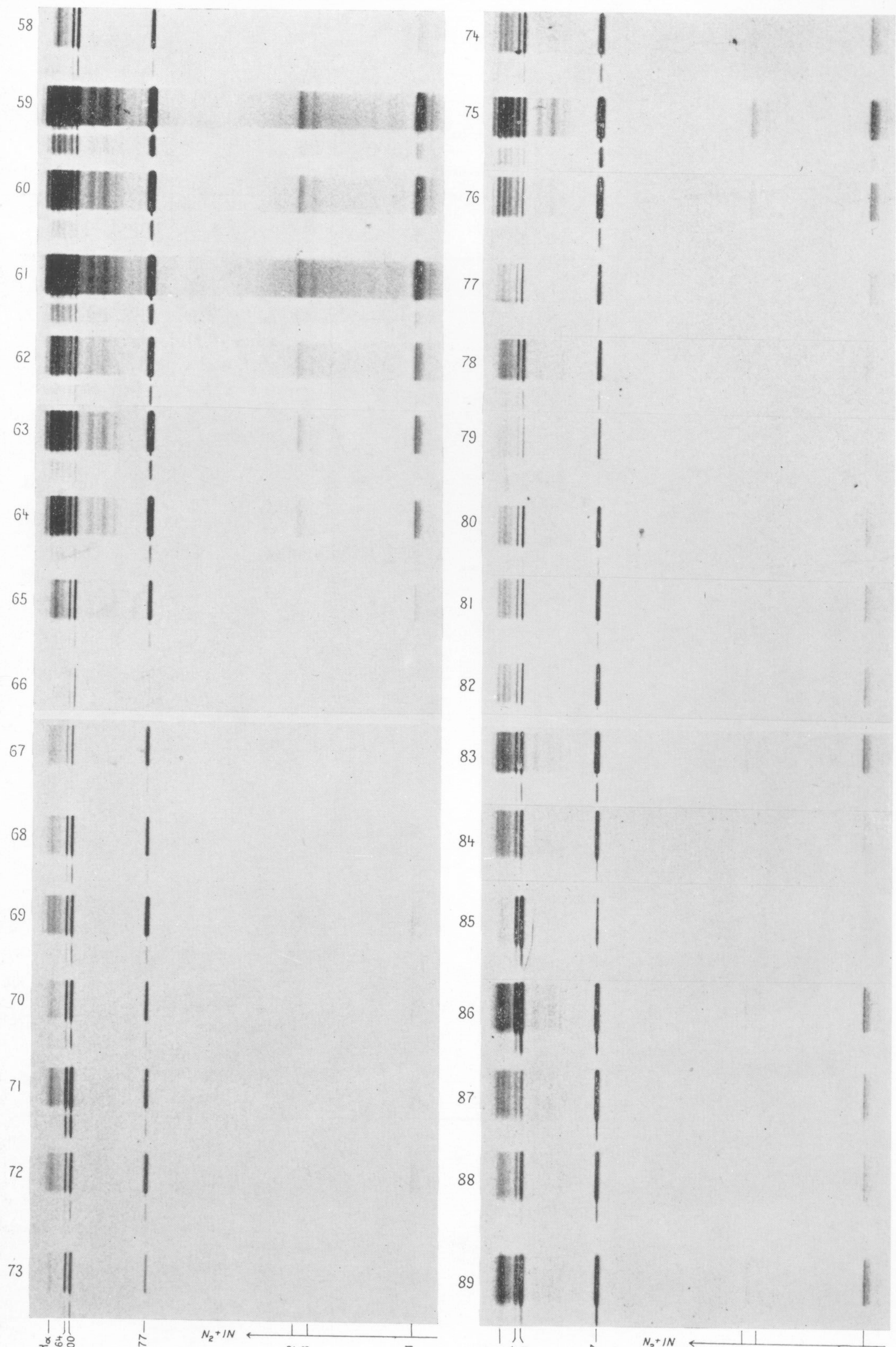

41
40
39
38
37
36
35
34
OI 6364
OI 6300
OI 5577
← Hα
49
48
47
46
45
44
43
42
OI 6364
OI 6300
OI 5577
← Hα
57
56
55
54
53
52
51
50
N2 IP
OI 6364
OI 6300
OI 5577
← Hα
N2+ 1N
0-2
1-3
0-1
1-2

Explanation to Plate II—c.

Spectrograms taken at Tromsø with spectrograph "F".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
58	6.1.60	23.16—23.35		60° N—Z	R. U. and fog. surf.
59	11.1.	20.40—20.55	20°	E	B. and D.
60	»	21.15—21.33	30°	N	A. L.
61	12.1.	20.23—20.40	20°	N	A. and B.
62	»	22.00—22.20	60°	N	We. B. and fog. surf.
63	24.1.	21.00—21.14	20°	N	We. A. L.
64	»	21.26—21.47	20°	N	A. L. with R.-structure
65	»	22.08—22.32		Z	Fog. surf.
66	»	22.44—22.46	45°	N	We. R. U.
67	2.2.	18.41—18.48	25°	NE	We. A. L. with R.-structure
68	»	18.49—19.03		Z	B. and fog. surf.
69	»	{19.31—19.34 20.10—20.14	30°	S	A. L.
70	»	20.15—20.26		Z	R. U. and fog. surf.
71	»	20.27—20.35	17°	S	Fog. surf. type A.
72	»	21.10—21.15	30°	S	A. L. with R.-structure
73	»	21.16—21.24	60°	S—Z	R. U.
74	3.2.	20.18—20.25	60°	S	B. U.
75	»	20.36—20.40	15°	E	D.
76	»	20.45—20.50	45°	N	A. L.
77	»	20.50—21.10		Z	We. R.
78	»	22.06—22.25	45°	S	We. B.
79	»	22.27—22.30	25°	S	A.
80	»	22.31—22.41		Z	Fog. surf.
81	»	22.45—22.54	45°	N	Dif. surf.
82	»	22.54—23.01	70°	S	Spots
83	»	23.01—23.30		Z	We. fog. surf.
84	17.2.	22.03—22.05	20°	S	A. L. with R.-structure
85	»	22.06—22.14	60°	S	R. U.
86	»	22.15—22.40		Magn. Z	We. fog. surf.
87	22.2.	20.36—20.41	25°	N	A. L.
88	»	20.48—20.56	35°	N	A. U.
89	»	21.00—21.28		Z	We. fog. surf.

Sort of Plate: Kodak 103 a—E.
Slit: 40/100 mm.

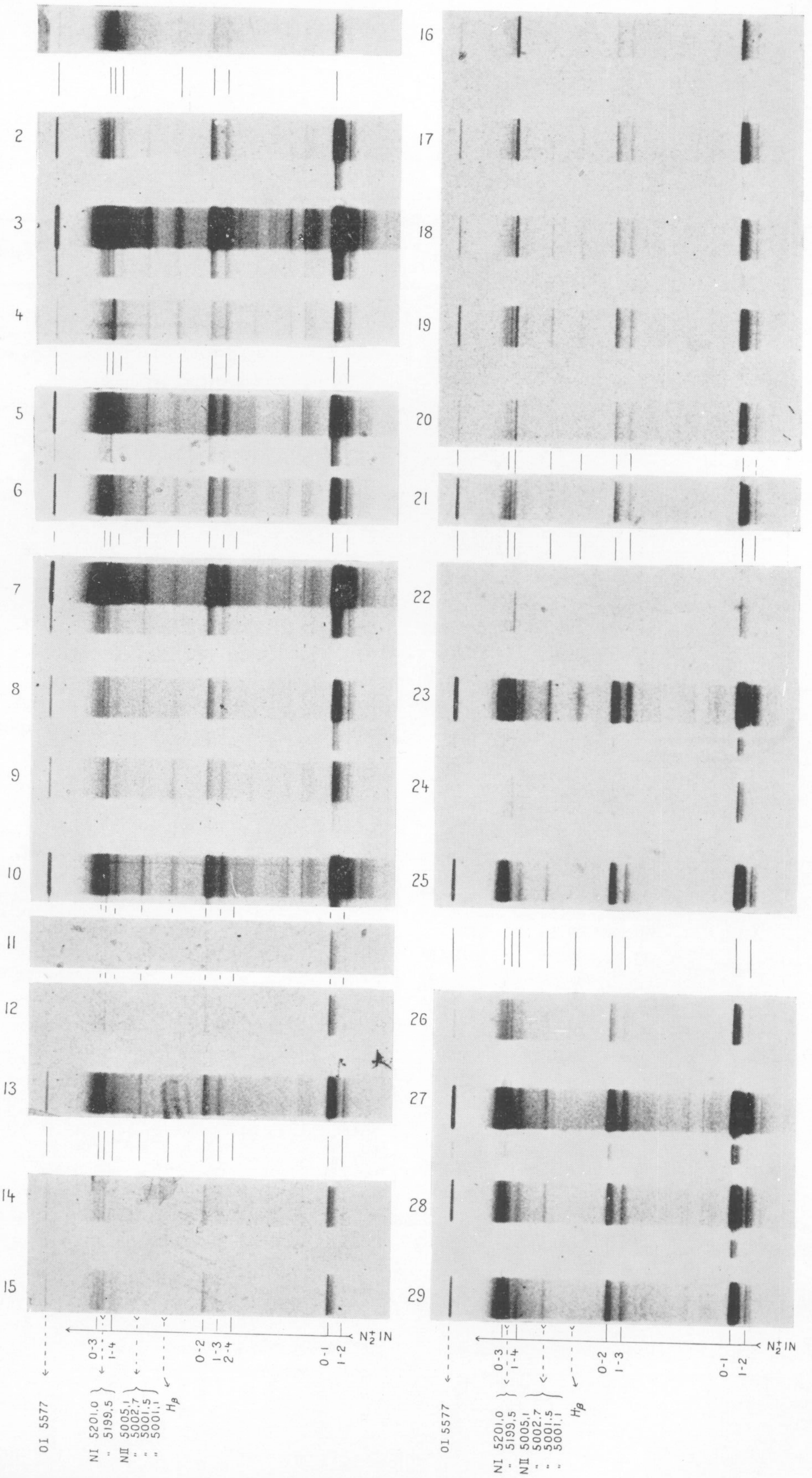

58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
Hα
OI 6364
OI 6300
OI 5577
N_2^+ IN
0-2
1-3
0-1

Explanation to Plate III—a.

Spectrograms taken at Tromsø with spectrograph "F".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
1	9.12.58	21.05—23.50	10—30°	N—W	Fog. surf. and A. U.
2	15.12.	20.30—22.00	30°	E—N—W	We. A, fog. surf. and B. through Z.
3	17.12.	19.00—21.05			St. flashes — all forms.
4	»	22.35—01.20		S—E	Fog. surf. and type A.
5	9.1.59	18.05—22.15			St. flashes, mainly fog. surf. and type A.
6	»	22.45—01.00			St. dif. surf., we. fog. Aur. and type A.
7	5.3.	20.25—23.00			St. flash (20.55—21.15), dif puls. Aur.
8	»	23.00—23.45			Dif. and puls. Aur.
9	11.3.	20.55—22.35	30°	N	We. A. and. dif. Aur.
10	12.3.	20.10—22.50			St. flashes (E, W and Z) and. dif. Aur.
11	22.10.	19.30—19.38	30—45°	S—E	Homog. B. and D.
12	»	20.00—20.27		Magn. Z	V. we. C. and. fog. surf.
13	»	20.35—22.00			We. fog. surf. and puls. spots.
14	»	22.28—22.41	15°	W	Homog. A.
15	23.10.	19.50—20.40	10°	N	A.
16	30.10.	19.00—20.00	30°	E	R. U, partly type A.
17	»	20.05—21.18	45°	E, W	R. and fog. surf.
18	»	21.40—22.30	10°	S	Dif. Aur. type A and green R.
19	»	23.20—00.15	5°	SW	We. dif. Aur, partly st. A.
20	31.10.	00.20—01.15	60°	S	We. dif. puls. Aur.
21	»	17.43—18.35	5°	N	A. L.
22	»	18.35—19.40		Z	R. U. and fog. surf.
23	»	19.40—20.40	5°	S	A, D, dif. spots and type A.
24	»	20.40—21.35		Magn. Z	R. U. and fog. surf.
25	5.11.	19.50—20.25	10°	NE	A. and D.
26	»	20.45—21.50	15°	NE	We. fog. surf.
27	14.11.	16.50—17.20	30—45°	W	St. vivid B. and D.
28	»	17.20—17.50			St. B. (60° in S. — Z, — 45° in N—Z)
29	18.11.	19.55—20.45			Fog. surf. (45° in S) and homog. A. (20° in N).

Sort of Plate: Kodak 103 a—J.
Slit: 4/10 mm.


2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
OI 5577
NI 5201.0
" 5199.5
NII 5005.1
" 5002.7
" 5001.5
" 5001.1
Hβ
0-3
1-4
0-2
1-3
2-4
0-1
1-2
N2+ IN

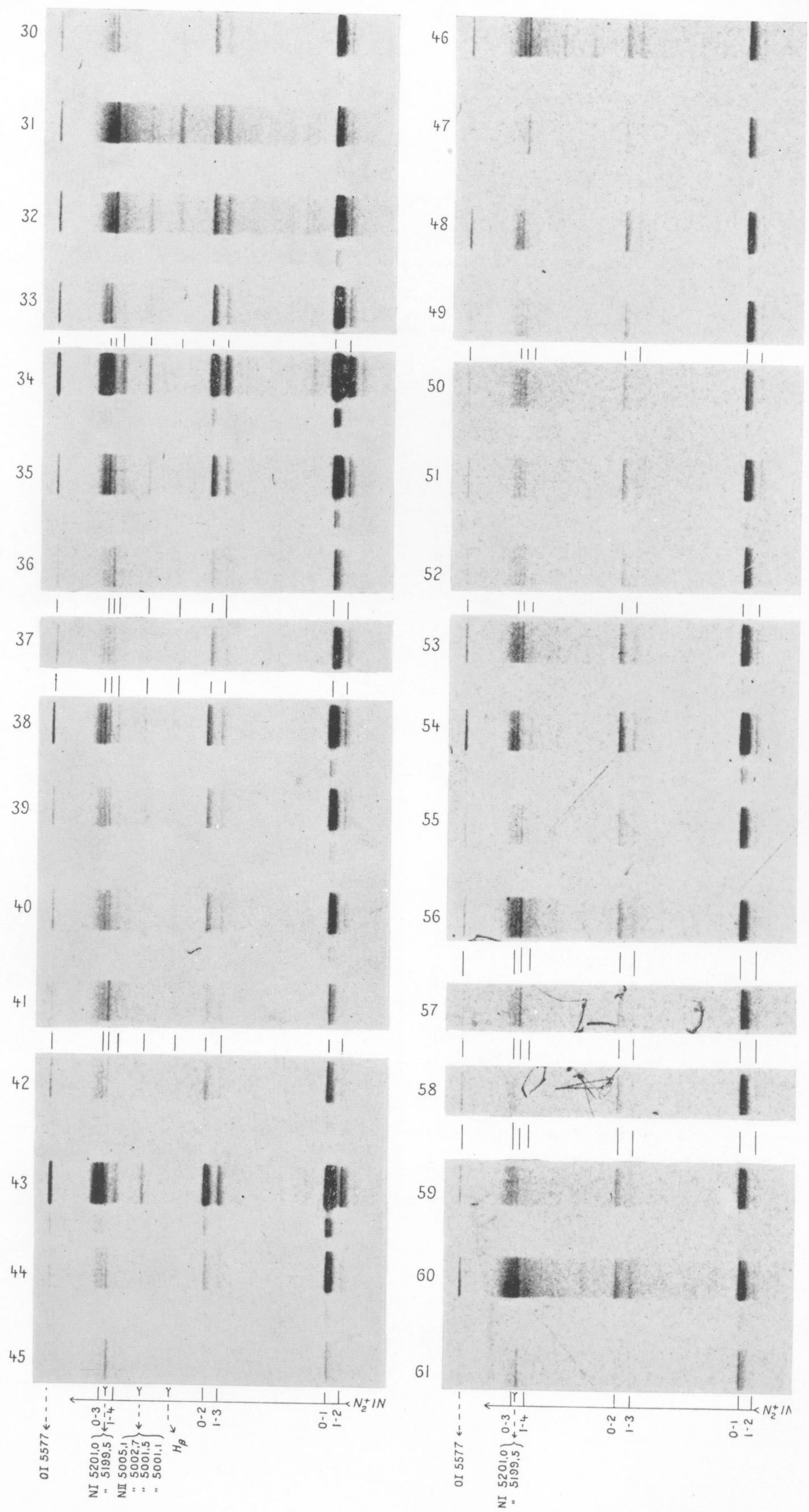
Explanation to Plate III—b.

Spectrograms taken at Tromsø with spectrograph "F".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
30	22.11.59	21.45—22.25		Magn. Z	R. U., B. and fog. surf.
31	»	23.55—01.15	10—30°	SW—S	Various forms (partly fog. surf.)
32	23.11.	01.25—01.50	45°	S—W—NW	Flashes of R.
33	»	20.20—20.40	10—20°	S	St. flashes of A. and R.—. vivid Aur.
34	»	20.40—21.05	20°	N	St. vivid A. partly with R.-structure
35	»	21.05—22.05	25°	SW	Fog. surf.
36	29.11.	17.00—18.00	10°	W—NW	We. R. and D.
37	»	19.55—20.50			B. (60°N—Z.)
38	»	20.50—21.30	20°	W	A. D.
39	»	21.30—22.35	30°	SW	Fog. surf. and puls. spots
40	»	22.35—23.45	20°	S	Fog. surf. and homog. B.
41	»	23.45—24.50	10°	NW	Fog. surf. and R. L.
42	30.11.	18.22—18.55	10—20°	W, E	D, A, type A and type B
43	»	18.55—19.22	10—30°	S, W	St. A. and D, partly type A.
44	»	19.22—20.40		Z	R. U., fog. surf., puls. spots and type A.
45	»	20.40—21.40	20°	N	R. L. and we. fog. surf.
46	»	21.40—23.20	10°	S	V. we. fog. surf.
47	»	23.20—24.25		Z—30°E—Z	We. R. U.
48	1.12.	18.20—18.55	10°	N	D., st. A. and we. fog. surf.
49	»	18.55—20.25		Z	R. U. and fog. surf.
50	»	21.00—22.50	10°	N, W, SW	A. and fog. surf.
51	2.12.	00.13—01.15	45°	SW	We. Aur.
52	»	00.35—02.55	30—45°	S	Puls. Aur.
53	»	17.35—18.50	30—40°	N—W—SW	St. A.
54	»	18.55—19.12	20—40°	E, W	D. in st. Flash.
55	»	19.12—19.55		60° N—Z	R. U.
56	»	20.15—21.10			
		21.40—22.10		NE	D. and fog. surf.
57	3.12.	22.10—23.20		60° S—E	R. U. and type A.
58	8.12.	21.57—22.16		Magn. Z	St. flash.
59	»	22.17—23.35		45° N—Z	B.
60	»	23.40—00.55	10°	E	We. D.
61	9.12.	00.55—02.30		60° N—Z	We. fog. surf.

Sort of Plate: Kodak 103 a—J.
Slit: 4/10 mm.

Plate III—b.

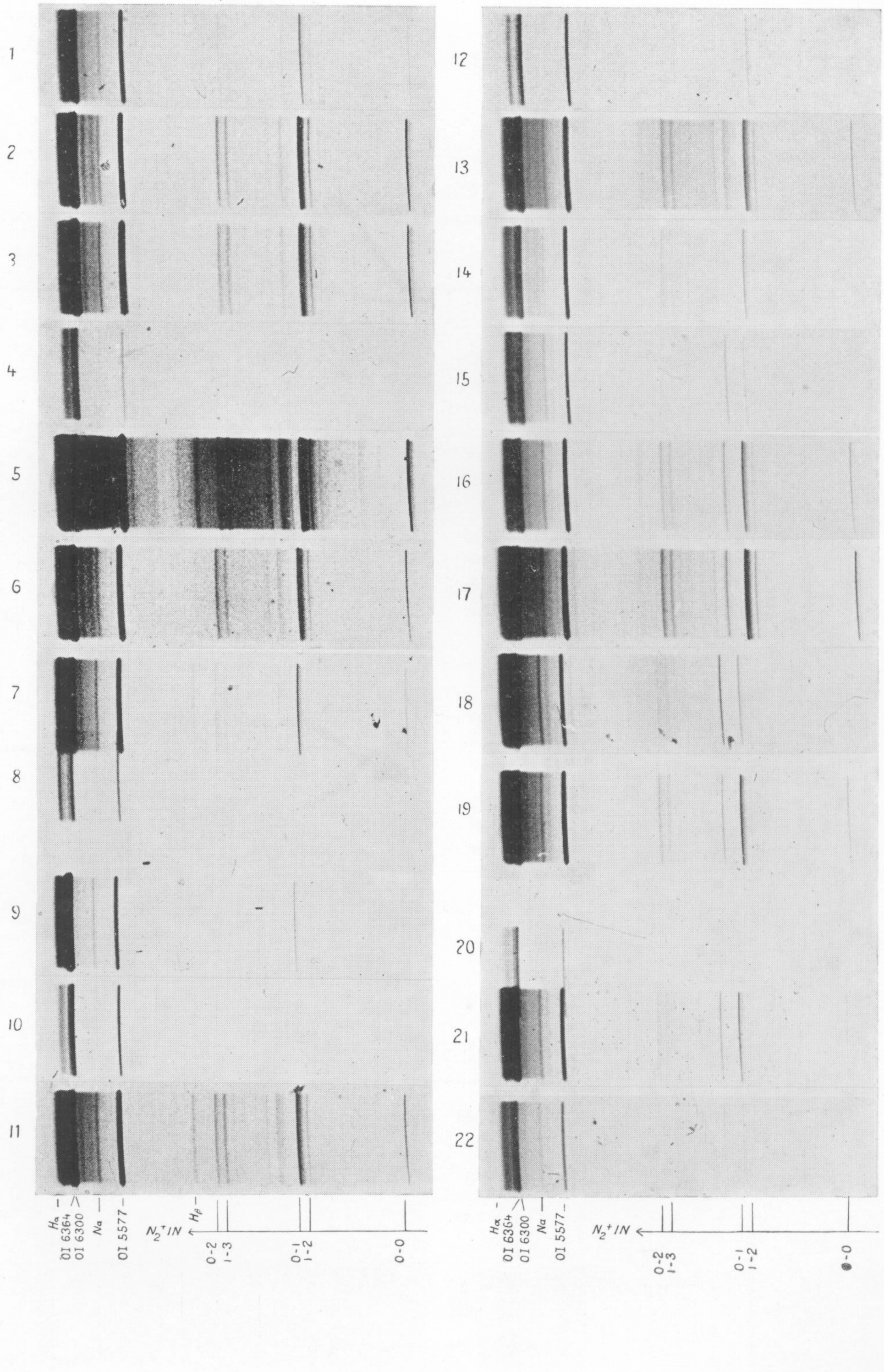

30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
OI 5577
NI 5201.0
" 5199.5
0-3
1-4
NII 5005.1
" 5002.7
" 5001.5
" 5001.1
Hβ
0-2
1-3
0-1
1-2
N2+ IN

Explanation to Plate IV—a.

Spectrograms taken at Oslo with spectrograph "C".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
1	29. 8.57	22.30—24.30		N	A.
2	23.9.	21.27—22.40	30—35°	N	R. and D.
3	30.9.	00.03—00.50	70°—Z	S	R. U., partly red.
4	1.10.	22.40—22.55			
		23.10—23.30	27°	NW	Very weak A.
5	13.10.	22.55—02.03	15°	NW	Quiet A.
6	14.10.	02.03—03.00	25—28°	NW	A. with R.-structure
7	20.10.	21.20—21.45			
		21.57—22.04	20—24°	NW	Weak A.
		22.27—23.26			
8	»	21.10—21.20	17°	NW	Weak A.
		23.26—24.03			
9	21.10.	00.10—00.17		N—W	Red surface and red R. U.
10	»	00.35—00.50	22°	NW	D.
11	»	21.58—23.15	30—35°	NW	Weak red A. with R.-structure
12	22.10.	00.10—00.17	60°	N	R.
13	10.12.	23.10—24.05	25—30°	N—NW	R., red surface and B. with R.-structure.
14	11.12.	00.22—00.25			
		00.50—01.05		N—NW	B. with R.-structure, red surface and weak A.
15	9. 2.58	21.15—22.05	15°	NW	Very weak A.
16	20. 2.	20.30—21.45	20—30°	N	A. with R.-structure and D.
17	»	21.45—24.30	15°	N	Dif. A, partly st. R. and D.
18	22.2.	21.30—24.30	15—20°	N	A. with R.-structure and D, partly very weak.
19	24.3	22.45—24.13	15—20°	NW	Weak A.
20	25.3	10 m. exp.	15—20°	NW	Very weak A.
21	»	22.32—24.00	20°	NW	Weak A.
22	26.3	00.07—00.45	17°	NW	A.

Sort of Plate: Kodak 103 a—E.
Slit: 13/100 mm.

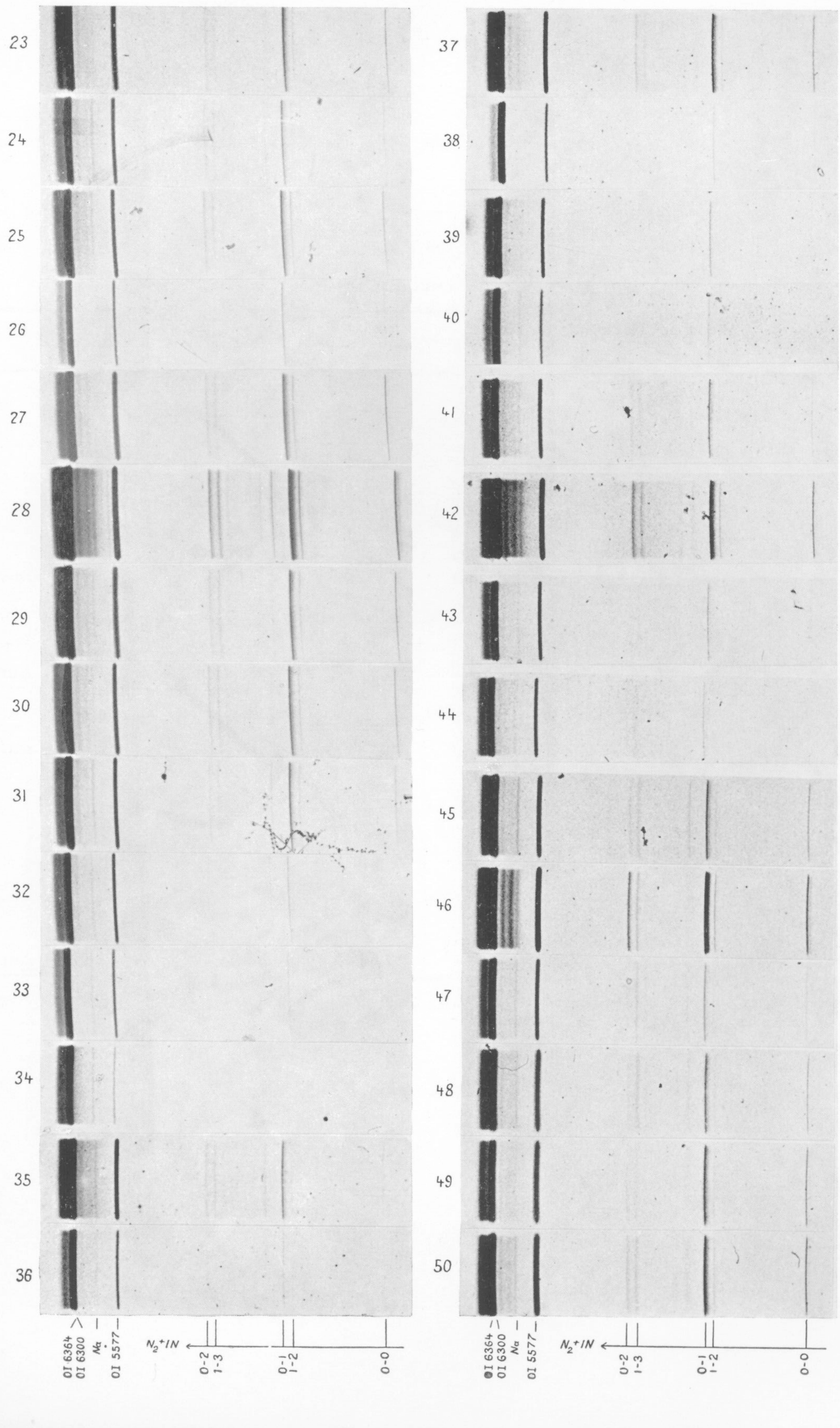

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Hα
OI 6364
OI 6300
Na
OI 5577
N2+ 1N
Hβ
0-2
1-3
0-1
1-2
0-0

Explanation to Plate IV—b.

Spectrograms taken at Oslo with spectrograph "C".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
23	3.9.58	22.46—23.37	Z.		Corona, quiet aur.
24	»	23.46—01.00	40—50°	N—NW	D., R., A. U., partly red aur.
25	4.9.	01.05—02.05	35—45°	NE	A. U., D., partly red aur.
26	»	02.09—02.50	73°	NW—NE	R. U.
27	»	22.07—22.47	Z.		Corona red aur., R. U.
28	»	22.53—23.43	34—37°	S	D. L.
29	»	23.45—24.45	72°	S—W	D. U., R.
30	5.9.	00.48—01.20	28°	NW	D.
31	16.9.	21.39—22.52	28°	N—NW	D. L., R. L., A.
32	»	22.53—24.07	17—22°	N—NW	Various forms.
33	17.9.	00.08—01.18	33—40°	NW—NE	A. U. with R.-structure, D.
34	20.10.	23.06—23.53	10—20°	NW—NE	D. with R.-structure, partly flashes.
35	22.10.	21.55—22.25	24°	N	D. with R.-structure.
36	»	22.34—23.16	50—80°	N	R. U., partly red aur.
37	»	23.17—23.32	26°	N	D., partly red aur.
38	»	23.33—23.50	65—72°	E	R. U., partly red aur.
39	23.10.	00.25—01.06	45°	NW	D., (3 min. exp. tow. red corona.)
40	»	01.08—01.52	45°	N	D. with R.-structure.
41	24.10.	23.15—23.51	70°	NE—E	Various forms.
42	25.10.	00.09—00.49	20—30°	N—NE	D. L., R.
43	»	00.52—01.27	30—40°	N	D. U., with R.-structure and various forms.
44	»	01.29—01.59	40°	NW—NE	Flashes, A., B., partly red aur.
45	4.12.	18.48—19.45	42—58°	NW	D. U. with R.-structure.
46	»	19.46—20.00	10—18°	N—NE	B. and A.
47	»	20.01—20.41	38°	NW	R. U. reddish and various forms.
48	»	20.43—21.45	Z.		Various forms.
49	»	21.46—22.15	Z.		A. through Z, reddish.
50	»	22.16—22.58	55—60°	NE—E	R. U. red.

Sort of Plate: Kodak 103 a—E.
Slit: 13/100 mm.


23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
OI 6364
OI 6300
Na
OI 5577
N2+ 1N
0-2
1-3
0-1
1-2
0-0

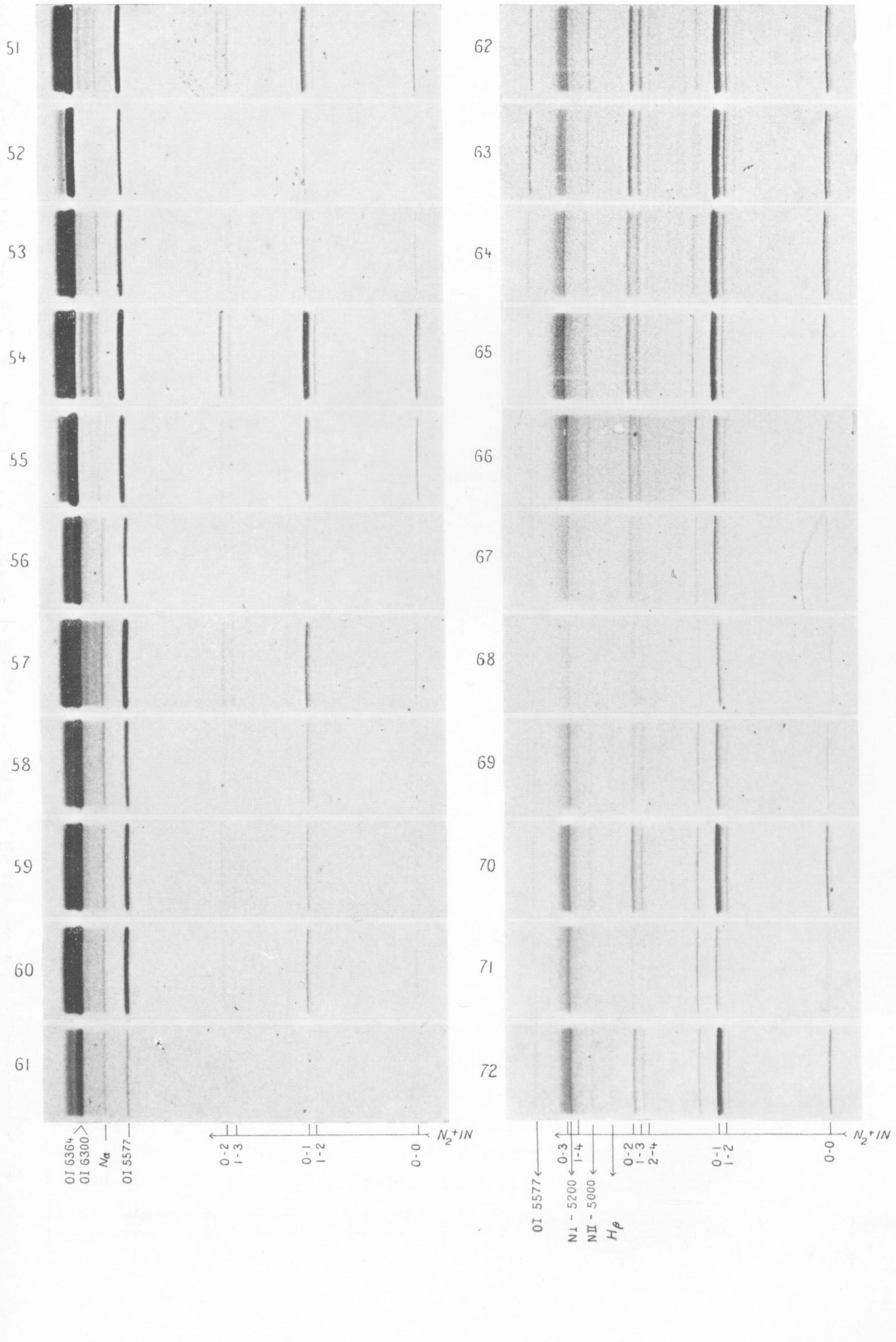
Explanation to Plate IV—c.

Spectrograms taken at Oslo with spectrograph "C".

Sp. No.	Date	Interval of Exposure	Height	Direction	Remarks on Auroral Type
51	4.12.58	23.07—23.24	20°	E	R. L., st. red Aur.
52	»	23.26—23.47	62°	W	R. U., st. red Aur.
53	»	23.49—00.44		Magn. Z	Corona — partly red.
54	5.12.	00.45—01.10	25—40°	NW—NE	St. D. L.
55	»	01.11—02.05		Magn. Z	St. puls. Aur. — partly red.
56	4.11.59	20.03—21.15	30—45°	NW—N	Homog. A. and R. U.
57	»	22.15—23.15	12—30°	N	St. A.
58	»	23.23—00.23	30—40°	N	A. U., R. U. and various forms-partly puls.
59	5.11.	00.24—01.04	20°	N	Various forms — partly A. U.
60	»	01.07—01.47	15°	NW	R. L., flashes and puls. surf.
61	»	01.48—02.28	40°	N	R. U. puls. —partly reddish Aur.
62	27.3.59	21.47—22.17	30°	NE	A., D. L. and B.
63	»	22.19—22.47	30—40°	NW—N	D. with R.-structure and st. surf.
64	»	22.48—23.48		Z	Puls. corona
65	»	23.50—00.45	40—50°	NW—N	D. puls. Aur.
66	23.9	22.00—23.15	20°	NW—N	Various forms
67	»	23.16—00.00	20°	N	We. A. U. and various forms.
68	24.9	00.10—00.30	30°	N	R. U. puls.
69	25.9	21.30—22.20	20—25°	N	We. A.
70	»	22.20—23.10	20°	NW—N	R. L. and st. flashes
71	»	23.10—00.25	25—40°	N	R. U. and various forms.
72	5.10.	21.25—22.25	20—35°	N	A. With R.-structure and dif. Aur.

Sort of Plate: Sp. No. 51—61: Kodak 103 a—E.
Sp. No. 62—72: Kodak 103 a—J.
Slit: 13/100 mm.

Plate IV—c.


51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
OI 6364
OI 6300
Na
OI 5577
0-2
1-3
0-1
1-2
0-0
N2+IN
OI 5577
0-3
1-4
NI - 5200
NII - 5000
Hβ
0-2
1-3
2-4
0-1
1-2
0-0
N2+IN