OBSERVATION OF THE AURORA ON FEBRUARY 11, 1958, AT THE ROSHCHINO STATION

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ABSTRACT: This paper discusses the results of observations of the aurora display on February 11, 1958 (1:30-4:40 UT) at the Roshchino station ($\Phi \approx 56^o$ N) with an "All-Sky" camera and a patrol spectrograph (dispersion ~ 320 Å/mm, spectral range λ 3900 Å-λ 6600 Å). It was determined that, during the period from 1:30 to 2:30, the spectrum of the aurora contained very intensive forbidden oxygen lines λλ6364, 6300, 5577 Å and 1NGN_2^+ bands. The total energy of the aurora in the visible region of the spectrum during that period reached approximately $2 \cdot 10^{19}$ erg/sec. The ratio was equal to 3.6. During the period from 4:00 to 4:40, when the Earth's magnetic field underwent very strong and rapid variations, the brightest emission in the auroral spectrum was found in the forbidden red oxygen lines. The ratio I_{6300}/I_{5577} reached ~ 72 in this case. The number of N_2^+ ions in the vertical atmospheric column was $3 \cdot 10^{11}$ particles/cm^3. The maximum intensity was observed during the moments of deep negative bays in the horizontal component of the Earth's magnetic field.

The most unusual aurora during the IGY and the following years /87 was observed on February 11, 1958. There have already been many articles [1-17] describing observations of this aurora and explaining it. What was unusual in this aurora was its color, structure, morphology, and spectrum. Against the background of the diffuse emission of a bright-red color, separate forms developed at times: arc, bands, rays (red, yellow, or greenish-white). The emission was observed at many stations located in a large range of geomagnetic latitudes, from $\Phi \sim 65°$ to $\Phi \sim 40°$ (Fig. 1a), i.e., the emission mainly passed through the southern zones of aurorae. Sometimes, according to the data in [14-16], when there was almost no emission in the zone for the maximum appearance of aurorae, there was observed a bright emission at low latitudes (Fig. 1b, 10:20). For a comparison, the values of the parameter L, for the magnetic lines of force entering the Earth's atmosphere at an altitude of 400 km, are plotted on the maps. According to the data of observations with 180°-cameras, the southern boundary of the emission is practically stable, and coincides roughly with the value $L \sim 2.8$.

The inclusion of low-latitudinal spectral observations at various zenith distances, which were described in [2, 6, 11], provided for tracing the southern boundary of the aurora more accurately. In the northern hemisphere, the emission was observed all the way up to a geomagnetic latitude of $\sim 40°$ ($L \approx 1.5$). In the auroral spectrum, the atomic lines OI, OII, NI, and NII are clearly separated. The most interesting feature of the spectrum was the ratio between intensities of the two forbidden oxygen lines I_{6300}/I_{5577}, which reached, at certain moments, values of 10^3-10^4 [11] ($\Phi \sim 42°$N). In a regular aurora, this ratio does not exceed unity in the region of the auroral zone, while, in red, higher forms of aurorae, it may reach several units, but is usually less than 10. Unfortunately, the lines λλ 6300 and 5577 Å were overexposed for many of the observers at high-latitudinal stations on the American continent on February 11, 1958, and it was impossible to make a precise determination of the ratio I_{6300}/I_{5577}. According to observations in Murmansk, it was about 10 [17]. Another characteristic of the spectrum of this aurora was the presence of a very intensive helium emission line λ 10,830 Å [1]. This was the first case when a helium emission was found in an auroral spectrum. Another unusual characteristic was found in the ratio between the populations of the vibrational bands in this sequence: $\Delta v = 2$, $1NGN_2^+$. This ratio was equal to the following: $I_{4709}:I_{4652}:I_{4600} = 100:130:60$ [9], and $I_{4709}:I_{4652} = 1:1.4$ [17]. It is usually 100:50:9 (when the authors exclude the superposable emissions). During excitation by an electron collision from the original N_2 level, the ratios of the intensities for these bands, according to [18], are the following: for $T_{vibr} = 4000°$ K, 100:87:64, for $T_{vibr} = 8000°$ K, 100:127:136. It /88
follows from the studies in [19, 20] that, during excitation by He^+ ions with energies of 150 KeV, the ratio of the vibrational bands $I_{4709}:I_{4652}:I_{4600}$ is equal to 100:100:50.

During the beginning phase of the emission (approximately up to 10:00-12:00[1] on February 11, 1958), the observers at high-latitudinal stations noted the presence of a strong hydrogen emission. At middle latitudes [1], this emission, if it is present in the radiation, is very weak; there is noted an absence of the bands 1PG $2PGN_2$ in the spectrum. Several attempts were made to determine the height of separate forms of the emission appearing during the aurora. According to [9], the beams extended from 90-100 to 400-1100 km, and the red arcs were observed at altitudes of about 400 km. Japanese observers [6, 7] estimated the height of the red arc (around 10:00 UT) at 170-700 km. The temperature, evaluated according to the Doppler expansion of the line λ 6300 Å, was greater than 2500° K during the beginning stage of the aurora [3].

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[1] Here, and later, the time is universal (UT).

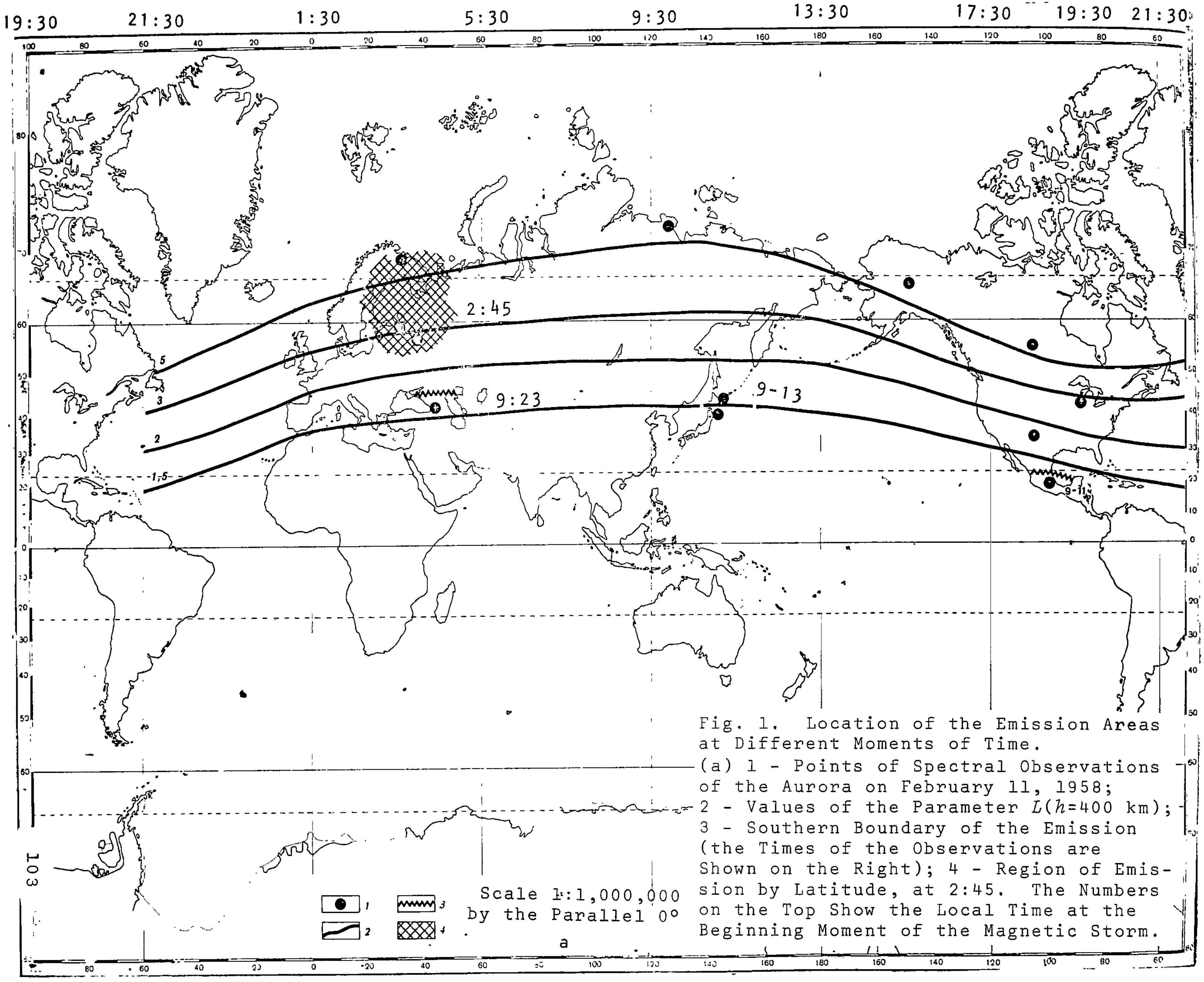

Fig. 1. Location of the Emission Areas at Different Moments of Time.
(a) 1 - Points of Spectral Observations of the Aurora on February 11, 1958; 2 - Values of the Parameter $L(h=400$ km); 3 - Southern Boundary of the Emission (the Times of the Observations are Shown on the Right); 4 - Region of Emission by Latitude, at 2:45. The Numbers on the Top Show the Local Time at the Beginning Moment of the Magnetic Storm.

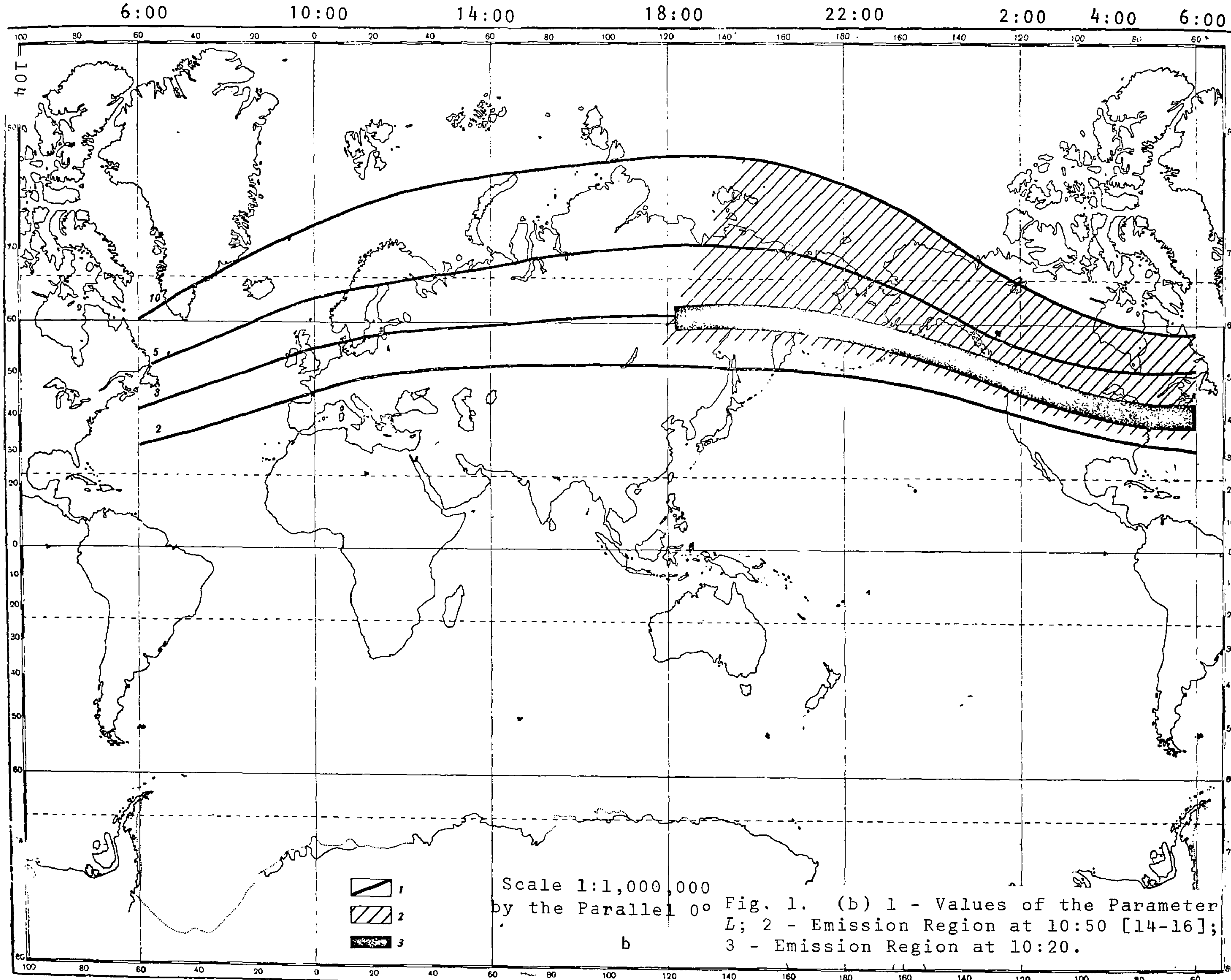

Fig. 1. (b) 1 - Values of the Parameter L; 2 - Emission Region at 10:50 [14-16]; 3 - Emission Region at 10:20.

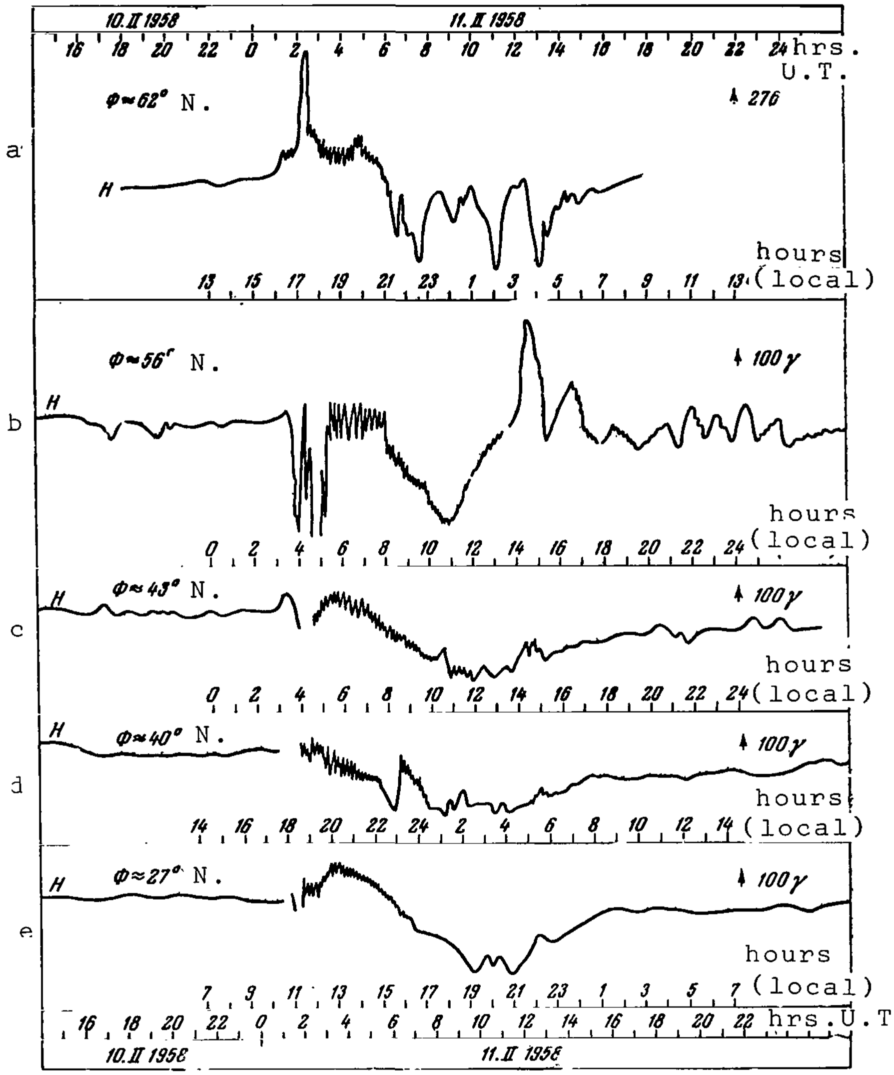

Fig. 2. General Path of the Horizontal Component of the Earth's Magnetic Field *H* Based on Terrestrial Measurements at Various Sites. (a) Voyeykovo (ϕ = 59.9°N, λ = 30.7°E); (b) Odessa (ϕ = 46.8°N, λ = 30.9°E); (c) Kakioka (ϕ = 36.2°N, λ = 140.2°E); (d) Sitka (ϕ = 57°N, λ = 224.7°E); (e) Tucson (ϕ = 32.2°N, λ = 249.2° E). Rapid and Intense Variations of *H* Around 3:00-7:00 UT are Shown Schematically.

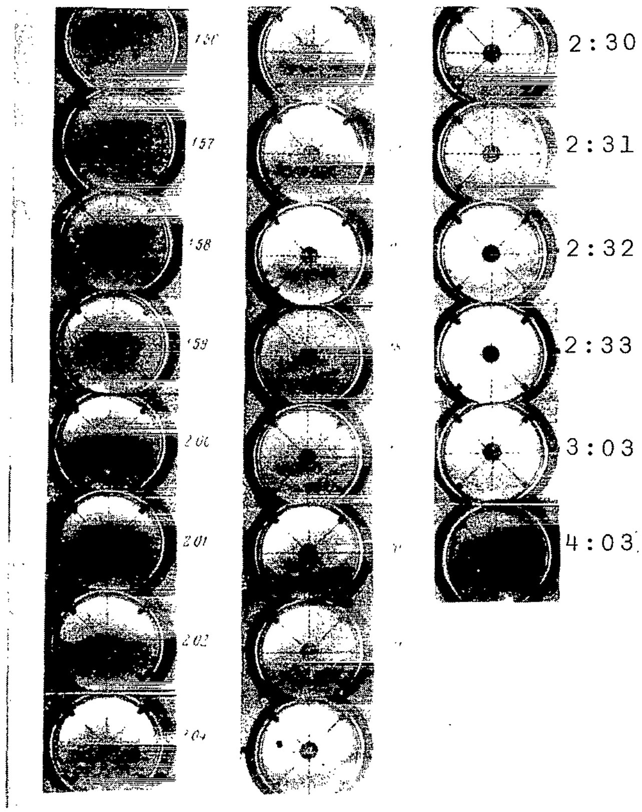

Fig. 3. Examples of Photographs Obtained on the "All-Sky" Camera for Different Times.

The aurora on February 11 followed after strong and multiple flares on the Sun on February 9-10 (scale-number 2^+). The active region passing through the central meridian of the Sun during this period was characterized by a high chromospheric excitation. On February 9, there was observed a dark absorption marking in the meridional direction, and there appeared a facula parallel to the marking [21, 22]. The aurora was accompanied by a number of other geophysical effects. At all latitudes of the Earth, there were observed strong disturbances in the magnetic field, in the ionosphere (strong ionospheric absorption was observed all the way to $\Phi = 30°$), and in Earth-currents. Figure 2 shows the general variation, in time, of the horizontal component H of the magnetic field at various sites. A strong magnetic storm with a sudden and sharp beginning at 1:26 on February 11 overlapped a small (in amplitude) storm on February 10. The magnetic storm on February 11, at all latitudes, was characterized by high rates and large amplitudes for changes in all the elements of the magnetic field. The changes in H sometimes reached 1000 γ. The principal characteristics of this storm were the following: a sudden beginning, large (in amplitude) changes in the field around 2:00, rapid and great variations of the field around 4:00, the potent principal phase of the storm with a decrease in H to 399-500 γ around 10:00-12:00, and a recovery phase. All these characteristics had a planetary nature. At the end of February 11, the magnetic storm began to quiet down. /89

However, there were observed certain differences in the detailed path of the storm for each station. At high and middle geomagnetic latitudes, there were observed several sub-storms during February 11 (Fig. 2) which blurred the general path of the storm. It follows from studies in [14-16] that each sub-storm was accompanied by an expansion in latitude toward the north of the emission region (Fig. 1b). At low-latitudinal stations, the classical path for the development of a storm, with a beginning, principal phase and a recovery phase, was seen more clearly. Very rapid and sharp changes in the Earth's magnetic field were observed on the Earth from 2:00 to 3:00. They differed by the sign of the change in H. For the stations which were located on the morning and day side of the Earth, H decreased (Fig. 2, b, c, and e), while it increased on the night side (Fig. 2, a and d). The storm was accompanied by intensive, short-period, vibrations (the period changed from 1.5 to 40 sec). The storm of February 11 differed from other strong magnetic storms by chaotic strong vibrations with periods of 4-7 sec during the beginning phase which were superimposed by intensive vibrations with periods of 20-40 sec. During the beginning phase of other strong storms, regular vibrations with periods of 10-15 sec were observed [23].

The data on observations of the atmospheric radiation on February 11 mainly related, in time, to the principal phase of the magnetic storm (after 3:00). In this study, as in [17], only the observations of the very beginning phase of the aurora are being examined (1:30-5:00). The observations were conducted at the

Roshchino station (ϕ = 60.2°N, λ = 29.5°E; Φ = 56.6°N, and Λ = 116.8° W) on a patrol spectrograph in the visible region of the spectrum (dispersion ~ 320 Å/mm) and on a 180-degree Stoffregen camera[2]. For the sake of brevity, we will it the "All-Sky" camera. Moreover, visual observations were conducted. A comparison was made between the results obtained for the data on the change in the magnetic field and the results of other authors.

Observations on the "All-Sky" Camera

During the IGY, photographs /90 were made of the aurorae at the Roshchino station with the aid of an automatic wide-angle reflex camera. Exposure of a frame lasted 20 sec, and the frame changed every 40 seconds. The camera was designed so that the top of the photographs corresponded to the direction toward the North, and the center of the frame corresponded to the geomagnetic zenith (Fig. 3). The photographing was done on a panchromatic film of the type D_N.

During the observations on the night of February 10-11, 1958, the sky had no clouds. The photographs from the "All-Sky" camera, as well as the

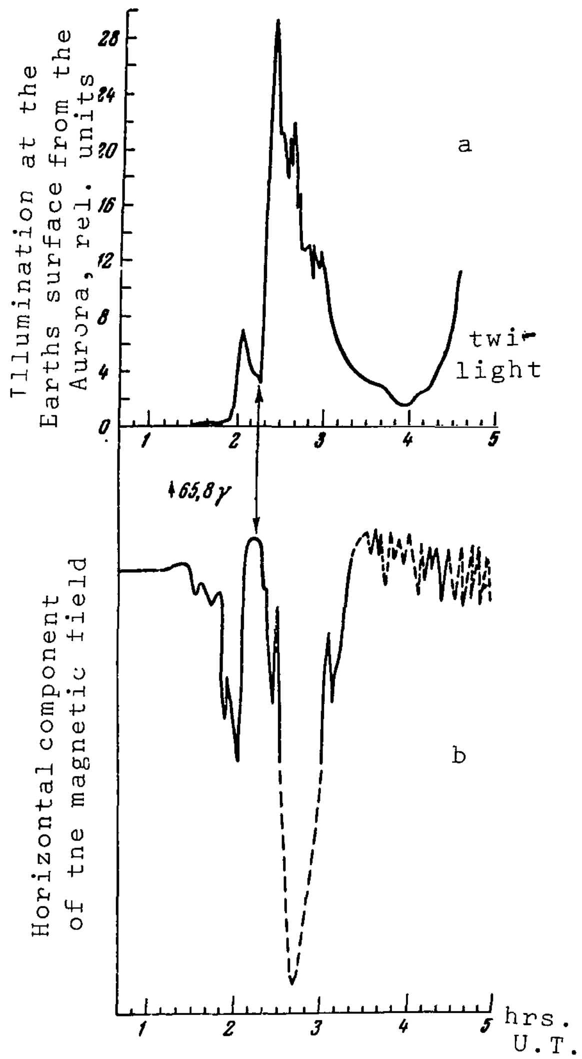

Fig. 4. Comparison of Variations in the Path of the Illumination (a) Toward the Earth's Surface From the Aurora of February 11, in Time (Roshchino Station), and Changes in the Horizontal Component (b) of the Earth's Magnetic Field at the Moment of the Observations (Voyeykovo).

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2 The observations on the camera were made by F. E. Martwel.

visual observations, showed that at the beginning of the night (15:00-21:00, February 10), there was observed an aurora which did not differ at all from the aurorae on other days, i.e., there was observed a characteristic transition from a smooth arc to more active forms - ray-structured arcs, rays, forms of flames. The color of the emission was greenish-white, and the scale-number was 1-2, or sometimes 3. At times there were observed red patches, and sometimes there was a light reddish tint over the entire northern part of the sky. Around 21:00 UT, the intensity of the emission decreased significantly, and then, at 0:00, it died out completely. A weak emission again appeared on the northern horizon around 1:30, and rapidly expanded toward the South. The southern boundary of the emission was clearly outlined (Fig. 3). A sharp flare-up of the emission occurred around 2:00, and, in this case, the area of the emitting sky-region and the intensity of the emission increased. Roughly from 2:30 to 3:00, the entire sky lit up. The region of the emission, in latitude, for 2:45 is shown in Figure 1a, where we used the observations at the station of the Institute of Physics of the Atmosphere at Zvenigorod [1] and at Murmansk [4]. After 3:10, the emission weakened. The visual observations showed that, roughly up to 2:40, the general color of the emission was greenish-white, although there were a large number of bright red patches, red rays, and a red arc. After 2:40, the entire northern section of the sky became bright-red, and remained such until sunrise (5:00). In the red diffusive emission, there sometimes flared up wide red rays and bright red patches, i.e., the emission was not completely diffusive and homogeneous, although, on the all-sky films, there was clearly seen only one sharp form of emission - an arc at the southern extreme of the emission [2:18-2:20).

The time-variations in intensity of the emission (in the visible spectral region) are shown in the upper part of Figure 4, and the lower part shows the change in the horizontal component of the Earth's magnetic field at the moment of the observations (roughly for the same longitude and geomagnetic latitude). Since the entire sky did not light up during the aurora, and the emission was not uniform, it is difficult to obtain the overall emission corresponding to the entire sky from direct measurements of the photographic density. However, the sky was so bright that the corners of the base on which the lower reflector of the camera was fastened are clearly visible in the ascafilms in the reflected light (the arrows in Figure 3 indicate the corners). Therefore, having measured the blackenings on the film corresponding to these corners, and then converting them into intensities, we can obtain the illumination on the Earth's surface from the aurora in the visible region of the spectrum, in relative units. We can see from Figure 4 that the maxima of illumination correspond well with the negative bays of the field. The change in visible brightness of the sky with the zenith distance along the line North-South, for certain moments, is given in relative units in Figure 5. We can see that the northern part of the sky remains brightest during the entire time. Sometimes a uniform intensive emission encompasses almost the entire /91 sky-vault. Figure 6 gives the brightness distribution at the zenith in relative units. We can see here that it repeats the path of the illumination in Figure 4.

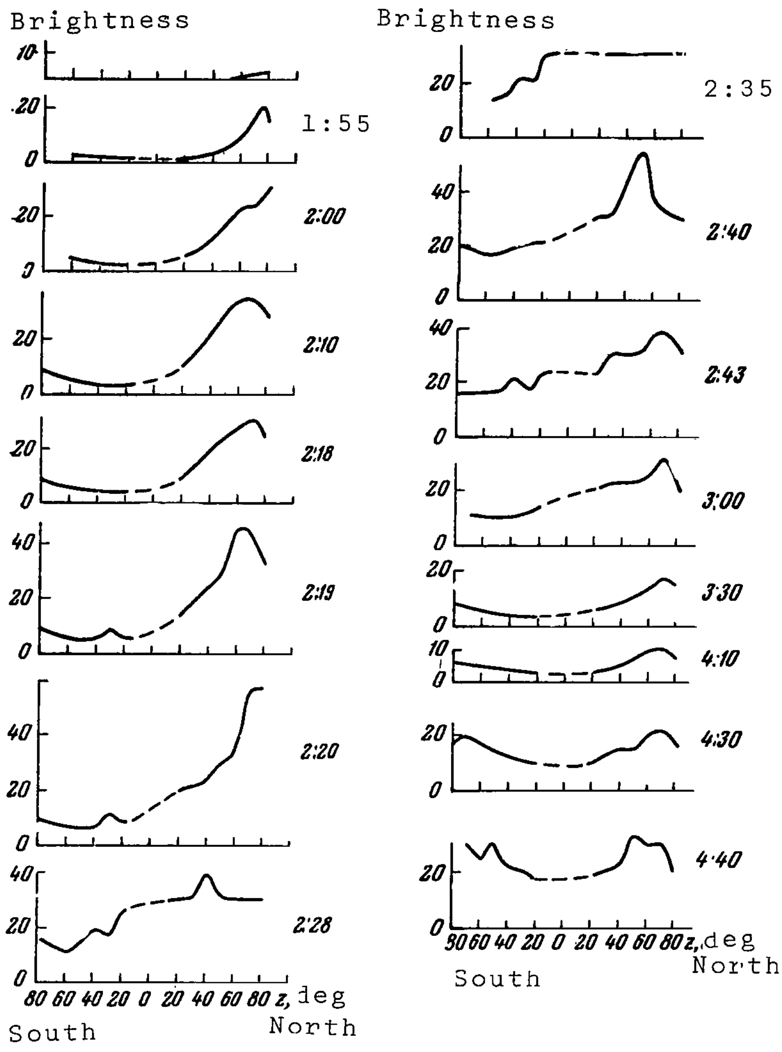

Fig. 5. Visible Brightness of the Sky at Various Zenith Distances, Obtained by the Ascafilms for Certain Moments on February 11. The Brightness is Given in Relative Units.

Attempts were also made to evaluate the intensity of emission /92 in absolute units by comparing the brightness of the aurora with the brightness of the twilight sky. The last frames at 4:30 and 4:40, were obtained during the (morning) twilight. the angles of solar depression during the moments of the observations are shown in Table 1. After 4:00, the scattered light of the Sun was already rather intensive, while the illumination of the aurora decreased greatly (see Fig. 4). Therefore, the intensity of emission at the zenith, for the frames at 4:30 and 4:40 (see Fig. 5), can be attributed to the brightness of the (morning) twilight sky. From the data presented in [24], we have (3600-6600 Å)[3] for the brightness of the twilight

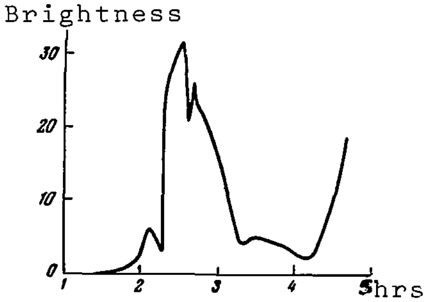

Fig. 6. Time-Variation in Visible Brightness of the Sky at the Zenith at the Roshchino Station (Obtained from Figure 5). The Brightness is Given in Relative Units. The Time is Universal.

TABLE 1. ANGLES OF SOLAR DEPRESSION AT THE MOMENT OF THE OBSERVATION

Time (U.T.), hours	Angle of Solar Depression	Altitude of the Geomagnetic Umbra of the Earth at the Zenith, km
2	27°45′	860
3	20 38	440
4	13 13	180
5	5 50	40

sky at the zenith, for the entire visible range of the spectrum, and 7.5 erg/cm^2·sec for the angle of depression of 8° (frame of 4:40), while it is 3.7 erg/cm^2·sec for the angle of depression of 9° (frame of 4:30). Table 2 gives the values for the brightness of the sky in absolute units for certain moments and certain zenith angles of observation (the absorption in the atmosphere was calculated with the aid of the coefficients from [26]). It was determined (Table 3) that I_{6300} = 0.73, I_{5577} = 0.17, and $I_{1NGN_2} \simeq$ 0.1 of the general intensity.

[3] The spectral region 3600-6600 Å was the range of the spectral sensitivity of the camera (Fig. 1 in [25]).

Observations on the Patrol Spectrograph

Examples of the spectra obtained during the beginning phase of the aurora on February 11 are shown in Figure 7 (the entire period of the observations was not covered by the exposures, since certain frames proved to be unsuitable for analysis). The spectrograph was directed toward the northern region of the sky at an angle of 20° to the hori- /93 zon (roughly the geomagnetic horizon), the spectral interval was 3900-6600 Å, and the dispersion was ~ 320 Å/mm. A panchromatic film was used for the photographing. Absolute calibration of the spectral observations was made with the aid of a constantly-functioning luminophor which was calibrated in absolute units (Fig. 8). Special determinations of the transmittance were not made, while the atmospheric absorption was calculated in the same way as in the case of analyzing the ascafilms, with the aid aid of the coefficients from [26]. Since determination of the intensity was made according to the characteristic curve

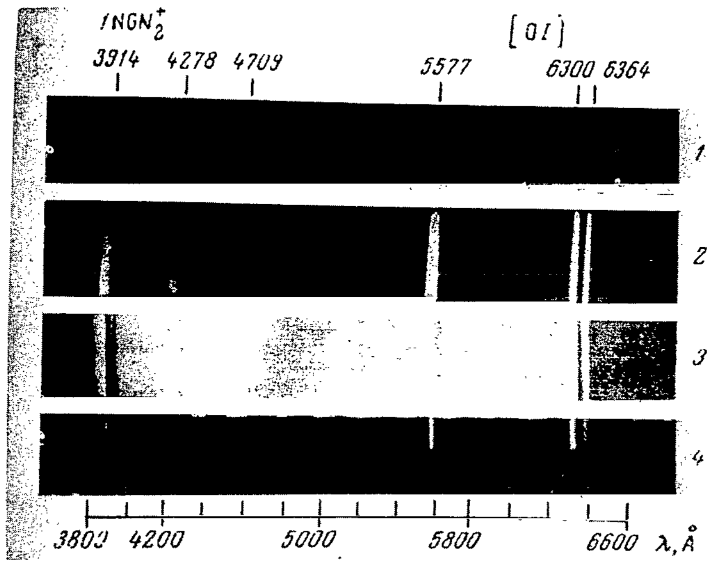

Fig. 7. Spectra of the Emission in the Sky Obtained on the Patrol Spectrograph (Roshchino Station). (1) 21:00-22:30; (2) 1:45-2:30 (The Apparatus was Re-Adjusted); (3) 4:00-4:40; (4) 16:55-3:00. Universal Time.

TABLE 2. TOTAL INTENSITY IN THE VISIBLE RANGE OF THE SPECTRUM, ACCORDING TO MEASUREMENTS OF THE ASCAFILMS (THE TWO VALUES OF *I* RELATE TO TWO ZENITH ANGLES OF 70° and 0°, RESPECTIVELY)

Time (UT)	*I*, erg/cm²·sec	Time (UT)	*I*, erg/cm²·sec	Time (UT)	*I*, erg/cm²·sec	Time (UT)	*I*, erg/cm²·sec
1:55	4,1 0,5	2 20	14,3 6,6	2 40	8,7 12,4	3 30	4,6 2,4
2 00	6,2 1,4	2 28	7,7 14,3	2 43	9,8 11,4	4 00	4,1 1,5
2 10	8,8 2 7	2 35	8,0 15,4	3 00	8,0 8,5		

TABLE 3. ABSOLUTE INTENSITIES OF CERTAIN EMISSIONS

Date	Time of exposures (UT)	I_{6300} Kiloraylelghs	I_{5577} Kiloraylelghs	$\frac{I_{6300}}{I_{5577}}$	I_{3914} Kiloraylelghs	$\frac{I_{3914}}{I_{5577}}$	Forms of Emission
10—11.II 1958	17:15						Patches, Rays, Diffusive arc, Reddish Tint
	19: 00	7	5,8	1,2	—	—	Northern Part of the Sky
	19: 00 21: 00	20	22	0,9	4,4	0,2	Draperis, Diffusive Arc, Patches
	21: 00 22: 30	22	25	0,9	4,9	0,2	Rays, Red Patches, Radial Arc
	1: 45 2: 30	4500	1300	3,5	380	0,3	Sharp Flare-up of the Emission, Red Rays, Red Patches
	4: 00 4: 40	400	5,5	71,5	20	3,7	Red Diffusive Emission, Red Patches
11—12.II 1958	16: 55 3: 00	11	22	0,5	4,4	0,2	Diffusive Reddish Emission
18—19.III 1958	18: 20 18: 40	23	120	0,2	12	0,1	Diffusive Arc
	18: 40 19: 00	140	38	3,7	19	0,5	Red Rays, Red Patches
	19: 00 21: 20	30	75	0,4	23	0,3	White-Green Patches
	22: 45 23: 10	27	68	0,4	6,8	0,1	Homogeneous Arc
	23: 10 1: 20	34	34	1,0	6,8	0,2	Rays, Radial Arc, Draperies, and Red Patches

in the region of overexposures, the accuracy in measuring the relative intensities is low, roughly 35%. The absolute intensities were given with a factor equal to ~2. We can see from Figure 7(b) that, during the very beginning phase of the red aurora on February 11, when rapid and large changes were observed in the Earth's magnetic field (deep, sharp negative bays with a decrease in the horizontal component *H* to ~ 1000 γ), the forbidden oxygen lines and 1NGN$_2^+$ bands are very strong in the spectrum, and no other lines or bands with comparable intensities are observed in the visible region of the spectrum. The hydrogen lines are not noticeable in the spectrum. Within 2-3 hours after the flare-up of the emission, when large and rapid variations in the value of the horizontal component of the field were observed at all sites on the Earth (see Fig. 2), the red oxygen lines λλ 6300 and 6364 Å predominate in the auroral spectrum (see Fig. 7c). A similar development of the spectrum was observed at Murmansk [17]. The absolute intensities of the principal emission in the visible range of the /94 spectrum, and the ratios between certain lines and bands, are shown in Table 3. For a comparison, Table 3 gives the intensities of the same emissions in various forms of the aurora on March 18-19, 1958. We can see that the intensity of the red line decreased on February 11, within 2 hours after the flare-up of the emission, by an order of magnitude, in the same way as did the variation of the overall illumination from the aurora (or the variation of the zenith brightness according to the "All-Sky" camera). The green line decreased during this time by more than two orders. The ratio I_{6300}/I_{5577} reached values greater than 70. During the exposure from 4:00 to 4:40, the ratio I_{3914}/I_{5577} became unusually large, in comparison with the other exposures (February 10-11 and March 18-19). Obviously, this was related to the fluorescence of the N_2^+ ions, since, at the end of this exposure, all the atmosphere above 40 km was illuminated (see Table 1). If this is so, then, considering the value obtained, I_{3914} = 20 kilorayleighs, and taking the coefficient of fluorescence as equal to 0.068 quanta/sec for the band (0,0) 1NGN$_2^+$ [27], we find that the number of N_2^+ ions in the atmospheric column around 4:30 on February 11 was ~ $3 \cdot 10^{11}$ particles/cm^2. We can calculate the total energy release in the visible range of the spectrum during the beginning phase of the emission on February 11 (exposure of 1:45-2:30). The following emissions (erg/cm^2·sec) give the principal contribution:

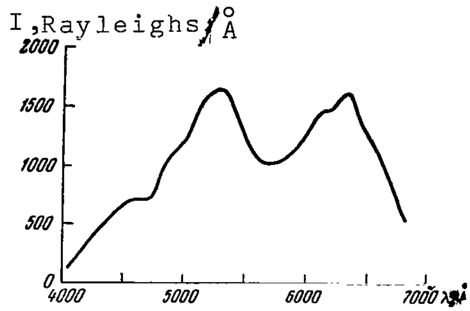

Fig. 8. Absolute Calibration of the Luminophor According to the Data of the Zvenigorod Station.

$$I_{6300} = 14{,}3, \quad I_{6364} = 4{,}7, \quad I_{5577} = 4{,}5, \quad I_{3914} = 1{,}9, \quad I_{4278} = 0{,}59, \quad I_{4709} = 0{,}11.$$

The total energy is ~ 26 erg/cm^2·sec. This value is somewhat higher than that obtained by the photographs of the "All-Sky" camera with the aid of calibrations for the brightness of the twilight sky. Obviously, this can be explained by the inaccuracy in the absolute calibrations. We will maintain further that the total energy release in the visible region of the spectrum at the very beginning stage of the emission was 26 erg/cm^2·sec (with an error of approximately a factor of 2). The appearance of an intensive emission immediately after the beginning of the magnetic storm (1:26) was also noted by American observers [8]. Therefore, we can consider that the emission occurs at all longitudes as well as in the band of the latitude at ~ 15° (see Fig. 1a). From this, we see that the area of the emitting band was /95
equal to $0.6 \cdot 10^{18}$ cm^2, while the total energy release in the visible spectral region at the beginning phase of the emission on February 11, 1958 was $2 \cdot 10^{19}$ erg/sec.

All the available information in the literature on the ratio of the oxygen-line intensities I_{6300}/I_{5577} during the aurora on February 11, according to observations at various latitudes, are compiled in Figure 9. We can see from the figure that the value of the ratio, which remains high during the entire time, varies greatly, reflecting the changes in I_{6300} (Fig. 7b). The maximum values of the ratio are found when large variations are observed in the horizontal component of the Earth's magnetic field (see Fig. 2). From the simultaneous values of I_{6300}/I_{5577} around 4:00-5:00 at various geomagnetic latitudes, and from the fact that the value of this ratio increases with an increase in zenith distance in the direction of higher latitudes [2, 6, 11], we can assume that the maximum emission of the λ 6300 Å line (in the northern hemisphere) was found between the latitudes Φ = 56 and 42°N.

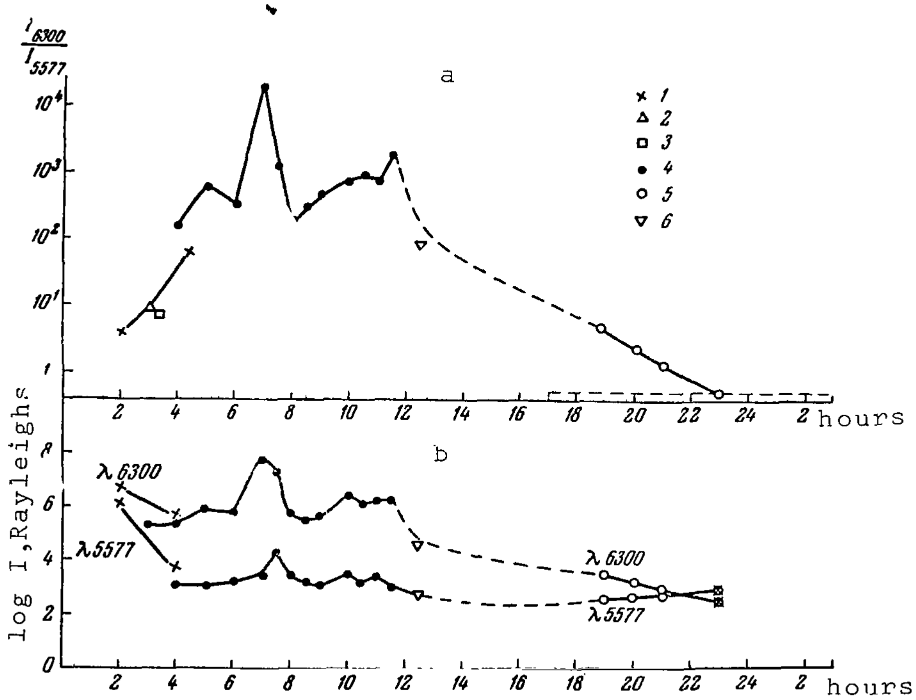

Fig. 9. Change in the Ratio and Absolute Intensities of the Oxygen Emissions. (a) Relationship Between I_{6300}/I_{5577} and the Time (Universal) During the Storm on February 11, 1958, at Various Geomagnetic Latitudes: (1) Φ = 64.4°N; (2) Φ = 63°N [4]; (3) Φ = 64.5°N [19]; (4) Φ = 44.5°N [11]; (5) Φ = 42°N [6]; (b) Change in the Intensity of Emissions I_{6300} and I_{5577} at Various Geomagnetic Latitudes (Same Designations).

Conclusion

Thus, observations of the beginning phase of the aurora on February 11, 1958, at the Roshchino station, showed that, after the sudden beginning of the magnetic storm (1:26 UT), a clear emission rapidly expanding from the North filled the entire sky. The brightness of the emission in the sky varied with time (according to the observations on the "All-Sky" camera). A definite corre- /96
spondence was observed between the maximum emissions and the negative bays in the path of the horizontal component of the Earth's magnetic field (H decreased down to 1000 γ, according to terrestrial measurements). Until 2:30, the forbidden oxygen lines ($\lambda\lambda$ 6300, 6364, 5577 Å) and the $1NGN_2^+$ bands were very intensive in the auroral spectrum (the visible range). (Other emissions with comparable intensities were not observed.) This spectrum shows the solar excitation of the atmospheric emission at relatively high altitudes during this period. The total energy release in the visible range of the auroral spectrum was $\sim 2 \cdot 10^{19}$ erg/sec around 2:30. Within 2-3 hours after the beginning of the magnetic storm (4:00-4:40), when the magnetic field of the Earth underwent intensive and rapid vibrations, the principal characteristic of the auroral spectrum was found in bright red oxygen lines. The intensity of the other emissions did not decrease greatly. The ratio I_{6300}/I_{5577} reached almost two orders of magnitude ($\sim$ 72 times). During this time, the ratio I_{3914}/I_{5577} was unusually high, in comparison with the other exposures. Since the entire atmosphere was illuminated during this time, the principal contribution to the intensity of the λ 3914 Å band can be attributed to the fluorescence of the N_2^+ ions. From this, we found that the quantity of N_2^+ ions in the vertical atmospheric column during the beginning phase of the aurora on February 11 was $3 \cdot 10^{11}$ particles/cm^2. Such a high percentage of N_2^+ ions at high altitudes was also observed during a strong magnetic storm on March 31-April 1, 1960 [25]. A comparison of the data for the observations of intensity of the λ 6300 Å line at various latitudes, and of the ratio I_{6300}/I_{5577}, showed that the value of this ratio remained unusually high during February 11, and that it varied greatly reflecting the course of I_{6300}. The maximum emission of the 6300 line was found at middle geomagnetic latitudes. The lower boundary of the emission extended to a geomagnetic latitide of 40° (L = 1.5, h = 400 km).

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