

## TEMPORAL VARIATIONS OF THE EQUATORIAL BOUNDARY OF AURORAL PROTON PRECIPITATION DURING MIDDLE GEOMAGNETIC DISTURBANCE

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### Abstract

There have been studied temporal variations of the (southern) equatorial boundary of hydrogen emission  $H_{\alpha}$  with the intensity of over 200 Rayleighs within a large latitude range ( $67^{\circ}$  -  $56^{\circ}\Phi$ ).

Materials of 2 nights were subject to consideration: December, 28-29 and 29-30, 1970. Conditions for registration of spectra using S-180-S cameras were favorable simultaneously for two stations (slightly overcast weather, satisfactory transparency of the atmosphere) at average magnetic disturbance. Observation stations: Loparskaya ( $\Phi = 64^{\circ}$ ) and Kem ( $\Phi = 60^{\circ}$ ) are located practically on the same geomagnetic meridian which allowed to exclude longitudinal variations of emission  $H_{\alpha}$ .

It is found, that in one event (December, 28-29, 1970, the hourly mean value Dst in the evening time 16-20<sup>h</sup> UT made  $-26$  nT) the equatorial boundary of hydrogen emission  $H_{\alpha}$  underwent wavelike changes in time with the length of wave  $\sim 800$  km and the maximum amplitude  $\sim 350$  km. This phenomenon can testify to the presence in the Earth's ionosphere of a huge undulations of the equatorial boundary of the area of diffuse luminosity of auroral oval. Such phenomena are sometimes found in the integral light by optical equipment, installed onboard DMSP artificial satellite.

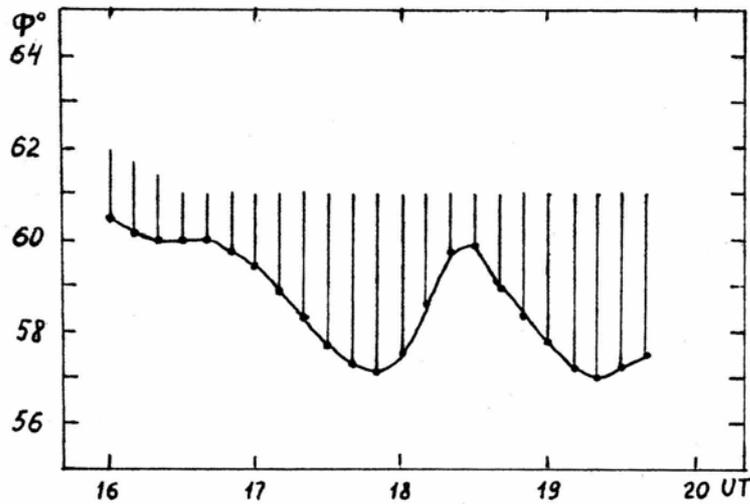
### Introduction

Diffuse luminosity of auroras bordering from the equatorial side the oval of discrete forms, is a well established fact thanks to ISIS-2 artificial satellite [Lui and Anger, 1973]. The equatorial boundary of such luminosity, especially in the evening side of auroral oval, looked smooth enough [Lui et al., 1973]. However, later measurements onboard DMSP artificial satellite by optical equipment in the integral light showed, that sometimes in the equatorial side of diffuse luminosity a large-scale undulations [Lui et al., 1982] is manifested. The amplitude of these wavelike forms measures within the range of 40 to 400 km, whereas the length of wave fluctuates within the limits of 200 to 900 km. In one event it was noticed, that such structures were stretched along the equatorial boundary throughout 3000 km. The image of this auroral undulations when studying consecutive flights of artificial satellite DMSP shows, that such phenomenon remains in space for 0,5 to 3,5 hours. As it was revealed, such wavelike structure is manifested, as a rule, during the maximum of geomagnetic storms development [Lui et al., 1982]. Unfortunately, data about particles flux, which were measured simultaneously onboard the same satellite in the four considered events, did not prove convincing enough to make any certain conclusions about the nature and characteristics of particles flux causing such phenomena. The subsequent studies have allowed to speak about the source which causes such large-scale phenomena. So, in papers [Fedorovich, 1988; Providakes et al., 1989; Mendillo et al., 1989] it is claimed, that these undulations structures are connected with electron precipitation, while other scientists [Yamamoto et al., 1991; Yamamoto et al., 1994; Zhang et al., 2005] believe that these phenomena are caused by proton precipitations. Both groups of authors prove their conclusions and suggest reasons in favour of one concept or another. Unfortunately, satellite data do not provide an unambiguous answer in this respect. Therefore, the purpose of the given paper, based on the ground data base is to make some estimations concerning the agent raising this phenomenon, without concerning the mechanism responsible for occurrence of such large-scale undulations.

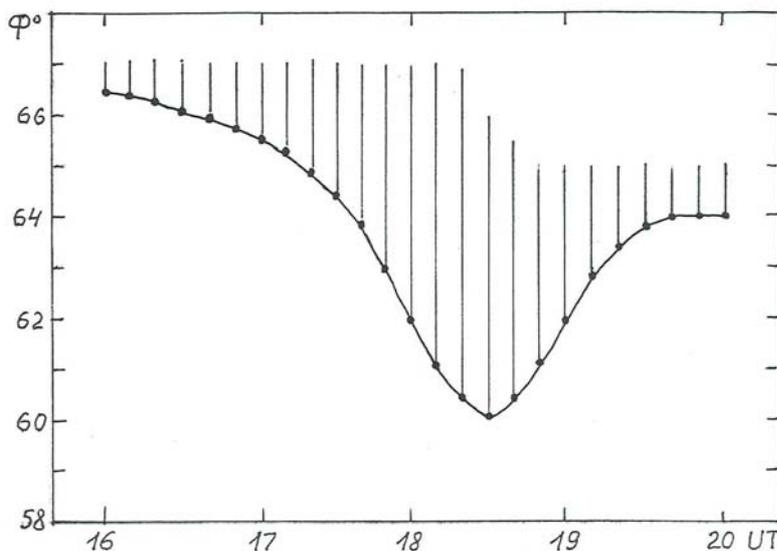
### Methods and results of research

Earlier we [Yevlashin, et al.] showed, that diffuse luminosity in the evening hours equatorward of the oval of discrete forms of auroras is a proton aurora which was determined by presence of hydrogen line  $H_{\alpha}$  in its spectra. Further, it would be expedient to track, whether the equatorial boundary of hydrogen emission undergoes large-scale variations latitudinally. For this purpose patrol spectrographer materials, obtained on December, 1970 simultaneously by 2 stations were used: Loparskaya ( $\Phi = 64^{\circ}$ ) and Kem ( $\Phi = 60^{\circ}$ ) which are located practically along the same geomagnetic meridian. Spectral apertures of devices identified space with a field of vision of  $180^{\circ}$  along the geomagnetic meridian and  $3^{\circ}$  in latitude. It provided the space coverage of  $\sim 10^{\circ}$  along the geomagnetic longitude in the assumption, that the altitude of the luminosity of hydrogen emission made 110 km. The linear dispersion of C-180-S cameras made 25 nm/mm, while the spectral permission was equal to 5 nm. Exposition duration of each shot made 10 minutes. The threshold of detection of  $H_{\alpha}$  emission was equal to  $\sim 100$  Rayleighs. Spectra of two nights were analyzed: December, 28-29 and 29-30, 1970, when conditions for registration of spectra using C-180-S cameras were favorable simultaneously for two stations: Loparskaya and Kem (slightly overcast

weather, satisfactory transparency of atmosphere) at average geomagnetic activity. Observation stations: Loparskaya and Kem are located practically on the same geomagnetic meridian which allowed to exclude longitudinal variations of emission  $H_{\alpha}$ . In the first event of December, 28-29 the hourly average value of Dst-variation made for the evening time 16-20<sup>h</sup> UT – 26 nT, in the second –December, 29-30 Dst =-8 nT. Standardization of the obtained spectra was carried out using an FSR-4 sensitometer. For higher sensitivity the Dn film before shooting was exposed to a bright short-term flash (0,01 сек). The technique of materials processing consisted in the following. Using the sensitometric "wedge" the intensity of hydrogen emission  $H_{\alpha}$  was estimated visually. Then, using spectra of both cameras, the minimum zenith angle was estimated up to which line  $H_{\alpha}$  propagated equatorward with intensity > 200 Rayleighs. Based on the assumption, that the altitude of emission  $H_{\alpha}$  luminosity made 110 km [Murcray, 1966] the latitude of the area to which hydrogen emission extended during the given 10-minute interval was found. In this way, spectraplots were drawn, which presented the distribution of emission  $H_{\alpha}$  depending on latitude and time. Vertical lines in the drawings show the longitudinal extent of emission  $H_{\alpha}$ , and the curve, edging the southern ends of lines, defined variations of equatorial boundary  $H_{\alpha}$  depending on time. Results are presented in fig. 1 and 2.



**Fig. 1.** Temporal variations of the southern boundary of hydrogen emission  $H_{\alpha}$  on December, 28-29, 1970. Vertical straight lines present the longitudinal extent of the given emission.



**Fig. 2.** Temporal variations of the southern boundary of hydrogen issue  $H_{\alpha}$  on December, 29-30, 1970. Vertical straight lines present the longitudinal extent of the given emission.

As we can see in fig. 1, the equatorial boundary of hydrogen emission undergoes undulations variations. It is possible to assume, that such variations are consequences of 2 factors: of an actually existing large-scale formation with undulation structure, permanently "hanging" (as follows from data by DMSP artificial satellite) above the Earth surface and of the effect of daily rotation of spectral cameras along with the Earth during the registration of meridional cross-section of auroras emission. Some elementary calculations show the dimensions of such large-scale formation. If we consider, that a point on equator is circling during the time of the Earth rotation of 24 hours its speed will make  $V_{\text{equ}} = 2\pi \cdot 6400 / 24 \cdot 60 = 30 \text{ km/min}$  [Struve, et al., 1964]. As our analysis of the position of equatorial boundary concerns the latitudes within the range of 60-65° then a point at the Earth's 60° latitude moves following the smaller radius  $\sim 2500 \text{ km}$ . In this event, velocity  $V$  will make the value of  $\sim 10 \text{ km/min}$ . With a 10-minute exposition it will be equal to  $\sim 100 \text{ km}$ . And if we consider that "dip" and "hump" in variations of equatorial boundary make 8-9 ten-minute intervals it will correspond to the wave length of  $800 \text{ km}$ . As follows from fig. 1, the depth of modulation of undulation variations makes  $\sim 3^\circ$  of geomagnetic latitude which corresponds to  $\sim 350 \text{ km}$ . Thus, these values qualitatively correspond to the dimension of the phenomena of large-scale undulation which was found by DMSP artificial satellite

As to the 2 event (December, 29-30), presented in fig. 2 no such undulation variations of equatorial boundary  $H_\alpha$  are observed here.

## **Conclusion**

Studies of temporal variations of the equatorial boundary of hydrogen emission  $H_\alpha$  with the intensity of more than 200 Rayleighs were carried out in a large latitude range during 2 nights: December, 28-29 and 29-30, 1970. In one event of December, 28-29 it is found, that long-period temporal variations of the equatorial boundary were taking place. The wave length of these variations made  $\sim 800 \text{ km}$ , the depth of modulation  $\sim 350 \text{ km}$ . This phenomenon corresponds to the presence of a huge undulation of the equatorial boundary of the area of the auroral oval diffuse luminosity. These events are sometimes found by optical equipment in the integral light, established onboard DMSP artificial satellite. The studies described above, testify that such large-scale structure of the equatorial boundary of diffuse luminosity is caused by the precipitation of auroral protons.

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