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RECONSTRUCTION OF CHARACTERISTICS OF AURORAL IONOSPHERE AND THERMOSPHERE USING THE METHOD OF OPTICAL TOMOGRAPHY

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Abstract. The ionosphere optical tomography experiment was carried out in the Kola peninsula in February-March 1999 by the Polar Geophysical Institute. The objective of the experiment was to deduce the spatial distribution of the volume emission luminosity, following the arc meridional section. The observation data of three scanning photometers, located almost along the geomagnetic meridian were analized. The two-dimensional images of auroral arc of the 557.7 nm emission of atomic oxygen and 427.8 nm of molecular nitrogen ion was obtained using the tomography approach, based on the theory of stochastic conversion. We have deduced the altitude profiles of the volume emission rate as well as obtained height dependences of ratio of 557.7 nm and 427.8 nm emission intensities. Values of this ratio are within the interval of 6-9, which correlates well with experimental results, obtained during another investigation.

1. The optical tomography experiment

In order to study the spatial distribution of characteristics of precipitating particles and auroral ionosphere, we have performed an optical tomography experiment, in February - March, 1999. Three 4-channel mechanical scanning photometers, designed in the PGI laboratory of "Auroral disturbances of thermosphere" during 1998-1999, were used in the experiment. All photometers have three common channels 427.8 nm, 557,7 nm, 630.0 nm while the fourth channel is either 486.1 nm (H_β) or 320.0 nm (VK). The photometers had been calibrated and brought to the similar sensibility level prior to the experiment.

The scanning photometers were installed in line at the three following geographic positions:

1. $33^0$24',$67^0$34' - testing range in Apatity
2. $31^0$45',$68^0$35' - Verkhnetulomski observatory
3. $30^0$59',$69^0$24' - Korzunovo village

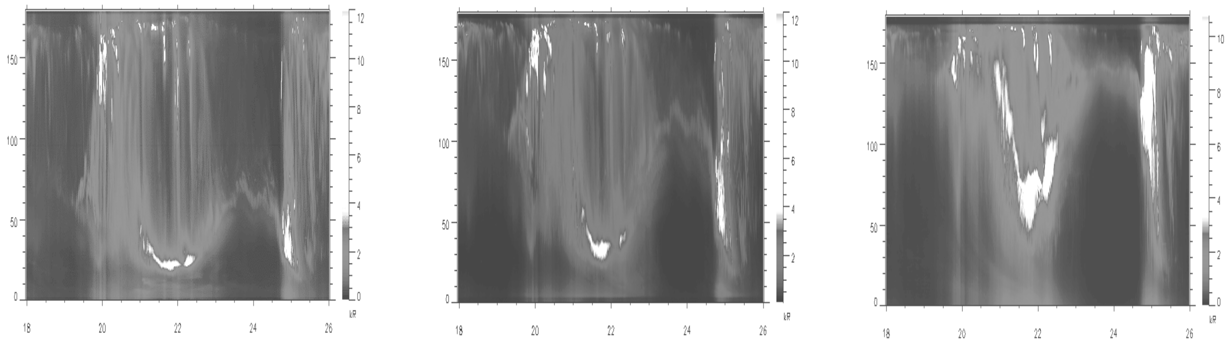
The distance between Apatity-Korzunovo is 226 km. The distances are: between Apatity and Verkhnetulomski - 133 km, Verkhnetulomski - Korzunovo - 93 km.The principal visual line passed via scanners positions in Apatity and Korzunovo with the azimuth of 323.82^0. The scanner sighting line in Verkhnetulomski was parallel to the principal line of sighting, but was shifted about it 8 km westward. All devices were adjusted according to operation azimuths within the error of $\pm 0.25^0$. Scanners' adjustment was verified by star positions, computed using the SCYGLOBE software.

Observations were carried out during moonless periods between February 8 - 22, and March 11- 25, (28 days in all), regardless of the geomagnetic or meteorological conditions, except periods of bad weather, when the Sun was 11^0 below horizon. During February observations, the photometer chain was backed by a TV camera, operating at Verkhnetulomski observatory.

2. Experimental data

During the observation periods, 59 sessions have been performed by all scanning photometers. After the data were sorted out according to favorable weather conditions and presence of luminosity at all three observation positions, the amount of data appropriate for further processing turned out to be rather insignificant. An example of experimentally measured intensity of the auroral emission and 557.7 nm for three observation positions for February 10-11 is given in Fig.1. Time in hours is presented along the X-coordinate, while the angle above the horizon is marked in degrees along the Y-coordinate. It is well seen how the aurora intensity varies with time and the position of aurora about the horizon changes depending on observation sites.

Later on a selection of data was done in order to find a stable and bright enough diffuse arc, visible from all three positions under different angles above the horizon. The period from 23:30 to 00:30 on February 10-11, 1999, when there was observed a diffuse arc, was selected as the most successful one. The magnetogram of February 10-11, 1999, obtained at the Lovozero observatory is presented in Fig. 2. The chosen period is marked by the hatched column. One can see, that it was a quiet period, with no significant variations of the Earth's magnetic field.



Korzunovo Verkhnetulomskay Apatity

Figure 1. The experimental intensities of 557.7 nm emission

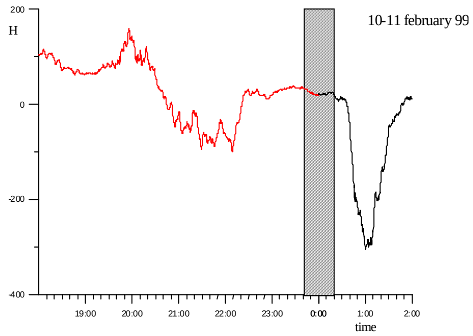


Figure 2. A magnetogram of February 10-11, 1999, obtained at the Lovozero observatory

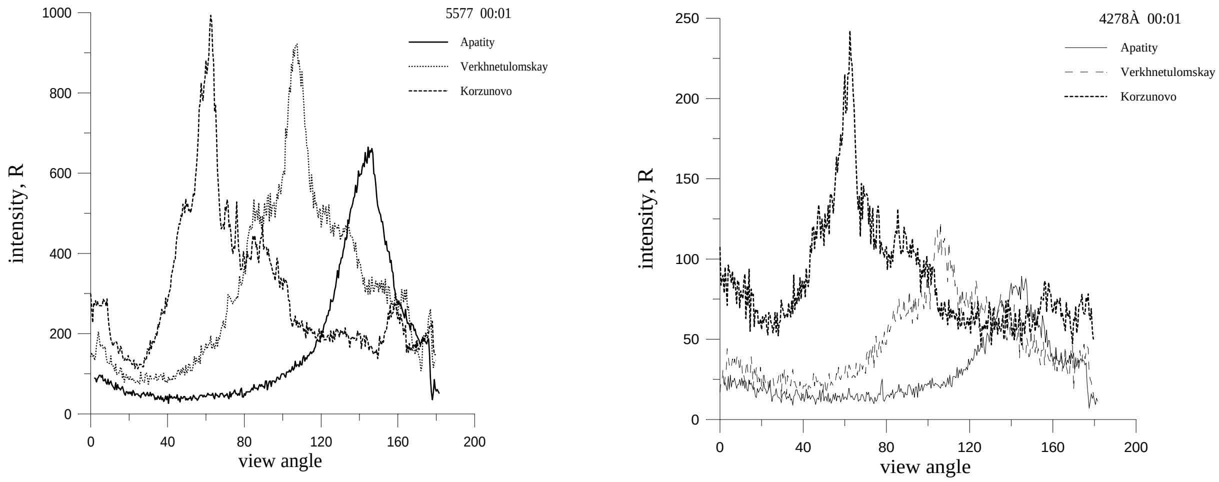
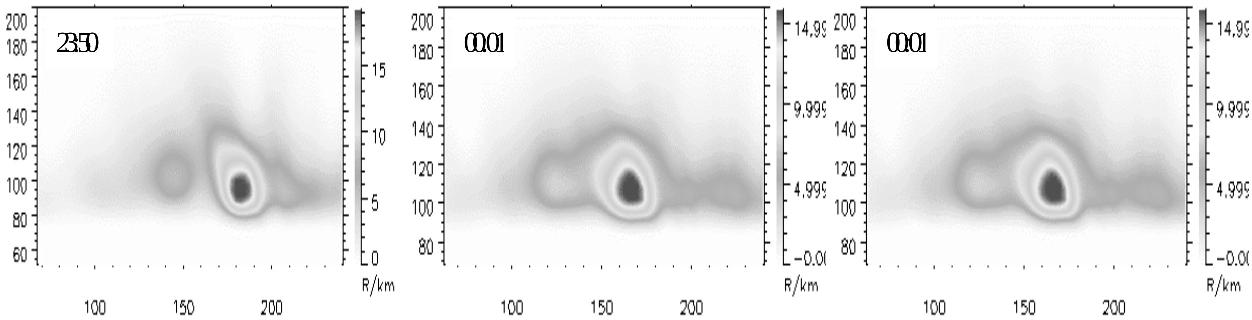


Figure 3. A scannogramm of 427.8 nm and 557.7 nm emission(10-11 February 1999)

When processing the experimental data it is important to obtain the clear emission luminosity (without the background one). For the background luminosity we took minimal intensities, observed during hours, nearest to the processed parts of auroras, on condition there apparently were no luminosity (according to TV-camera data). Examples of obtained scannograms 557.7 nm and 427.8 nm, after the background luminosity was taken away, are given in Fig. 3.

3. Spatial distribution of the luminosity intensity

For the previously selected stable diffuse arc, that occurred at 23:30 - 00:30 on February 10-11 (see Fig.1), the tomography image of altitude distribution of intensity of emissions was reconstructed and presented in Fig. 4 for the emission 557.7 nm for various observation times. The X-coordinate represents altitude in km, while along the Y-coordinate the distance in km is given. The intensity is computed in R/km. The extension of the diffuse arc is about 150 km and the width of the luminosity layer makes ~40 km, while the point of the maximum arc luminosity (the visually determined brightest area) shifts relative to observation positions as the time passes. An interesting fact is that there were observed two arcs at 23:50, one of them of a very low intensity. As the time passes the low intensity arc becomes indistinct and merges with the more intense one.



Figire 4. The tjmography images for 557.7 nm emission intensity

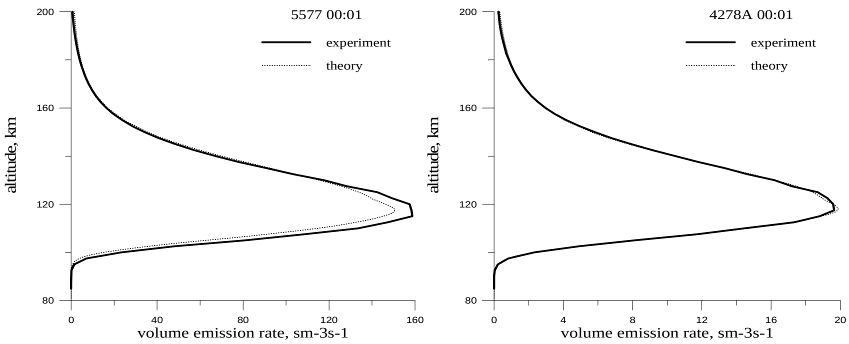
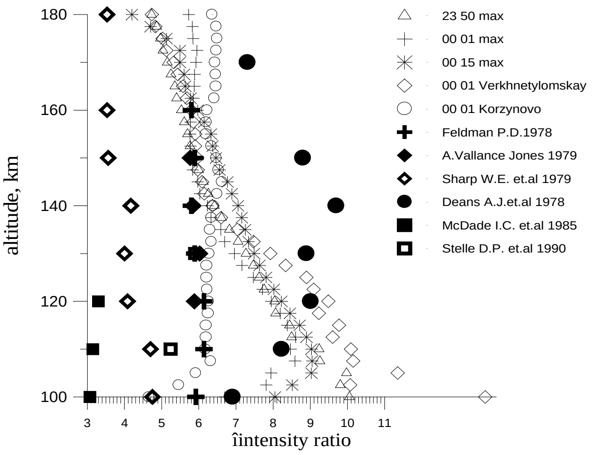


Figure 5. The volume emission rate of 557.7 nm and 427.8 nm



Figire 6. The intensity ratio of emission 557.7 nm and 427.8 nm

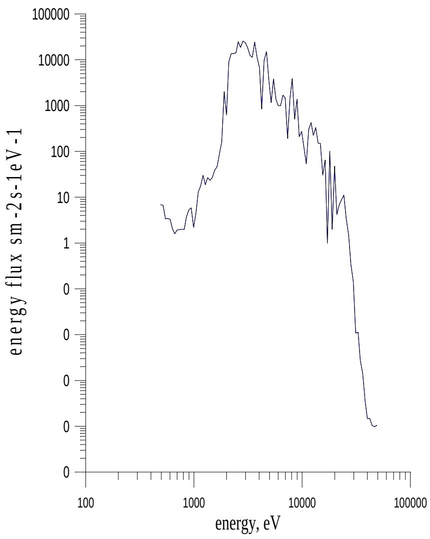


Figure 7. The computed spectra of precipitated Electrons

4. Volume emission rates

Height profiles of the volume emission rate of 427.8 nm and 557.7 nm have been obtained on the basis of the computed tomography images. Fig. 5 presents these reconstructed rates for the maximum luminosity point of the arc and for the observation time 00:01. The volume emission rate of 427.8 nm reaches the value of ~20 cm^{-3} c^{-1}, while the emission 557.7 nm - the value of ~150 cm^{-3} c^{-1}. The intensity ratio of emissions 557.7 nm and 427.8 nm for the maximum luminosity is given in Fig. 6. The value of this ratio is of 6-9 units. The same figure displays ratios of intensities, obtained as a result of rocket observation, performed by other researchers. Almost in all cases , as well as in ours, stable diffuse arcs of various intensity were observed during the winter. As one can see from Fig. 5, our results are within the experimentally obtained interval. The spectra of precipitated electrons were computed from height profiles of the 427.8 nm volume emission rate for the observation time 00:01, using the method, described in Sergienko et al 1996. For these and the following calculations, the model of neutral atmosphere MSIS-86 was used. An example of such spectrum for the maximum luminosity of the auroral arc is given in Fig. 7. Later on, using this obtained spectrum and the model of optical emissions and auroral ionosphere, we developed, there were reconstructed height profiles of volume emission rate of 557.7 nm and 427.8 nm for the maximum luminosity point of the arc marked by the dotted line. As one can see from the figure, the experimental and computed spectra coincided well (within 7%). Unfortunately, the comparison of the experimental and computed results does not give such good results at long distances from the arc maximum (for instance, at distances, corresponding to positions of Korzunovo village and Verkhnetulomski observatory). This may be due to the fact, that at those distances the aurora luminosity is of the same order, that the background one. That is why, taking away the background becomes a problem, which requires an additional solution.

5. Results

Using computer tomography we have reconstructed the spatial distribution of intensities of emissions 557.7 nm and 427.8 nm and have obtained two-dimensional images of the stable diffuse aurora, observed on February 10, 1999. We have established that: a) at a certain moment of time two arcs take place, which corresponds to TV observations; b) the width of the luminosity layer ≈40 km; c) the arc extension ≈150 km;

There was reconstructed the altitude distribution of the volume emission rate of emissions 557.7 nm and 427.8 nm, observed in the diffuse arc on February 10, 1999. There was also obtained the profile of intensity ratios of those emissions. The value of intensities ratio of emissions 557.7 nm and 427.8 nm lies within the interval of 6-9 units, which correlates well with experimental values, obtained by other researchers.

There was reconstructed the spectrum of precipitated electrons and there were equally computed, using the model of auroral ionosphere the height profiles of the volume emission rate of 557.7 nm and 427.8 nm, that correlate well with profiles, reconstructed using tomography.

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