Sección Especial: 37th AMASON / Special Section: 37th AMASON
Aurora

# Variations of aurora emissions during substorms at Spitsbergen archipelago

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**ABSTRACT:**

The variations of the intensities of the green 5577 Å auroral emission and the red 6300 Å one will be examined. The dynamics of these emission intensities during substorms, observed over the Spitsbergen archipelago will be studied. Data from simultaneous measurements of the photometer and the all-sky camera from the 2007/2008 winter season installed at the Barentsburg Observatory, plasma and solar wind magnetic field data from the WIND satellite and data from the ground-based magnetic stations from the IMAGE network have been used. It was shown that the precipitation of most energetic electrons occurs at the polar edge of the auroral bulge, and inside the bulge precipitation of less energetic electrons is observed.

**Keywords:** Aurora Emissions, Substorms, Auroral Bulge.

**REFERENCIAS Y ENLACES / REFERENCES AND LINKS**

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## 1. Introduction

The emissions intensities ratio $I_{6300}/I_{5577}$ characterizes the hardness of the precipitating electrons spectrum [1], we used this parameter to make a rough estimate of the electrons energy in the auroral arcs, observed in different parts of the auroral bulge – at the polar edge of the bulge and inside it.

It is known that the substorm development goes on in the next way: the substorm expansion phase begins with the flash of one arc, usually the most equatorial one between the existing discrete auroral arcs. After this the auroral bulge is expanding in all directions, mostly toward the pole, to the west and to the east [2]. At the time of maximal stage of substorms the auroral bulge reaches its maximum width. Further, during the recovery phase, the auroral bulge begins to shrink, its polar edge moves to the equatorward, the South one – to the pole, the bright discrete arcs degenerate into irregular strips and fade [3,4].

The formation of auroral bulge is shown in Fig. 1. The substorm begins with the first UV aurora spot by Polar UVI data. The auroral bulge is the area occupied by bright, short-lived arcs. During expansion phase the auroral bulge expended in all directions and reaches its maximum width and maximum area at the time of substorm maximum stage.

We will consider the variations of auroral emissions at polar edge of auroral bulge and inside of the bulge. It was established that discrete auroral emissions occur at the poleward edge of the bulge [2] that corresponds to higher energy particles and brighter emissions. But it is very small works in which are compared energy particles in auroras at polar edge and inside auroral bulge. For example, such a work, in which was studied the dynamic of polar boundary of auroral oval during substorm on the basis of all-sky camera and spectrograph observations in Mirniy observatory [5]. It was shown that more energetic particles are observed at polar edge of luminosity band.

In our paper, the dynamics of the intensities of the green 5577 Å auroral emission and the red 6300 Å one during substorms will be studied. For this purpose the data from simultaneous measurements of the photometer and the all-sky camera installed at the Barenzburg Observatory have been compared with plasma and solar wind magnetic field data from the WIND satellite and data from the ground-based magnetic stations from the IMAGE network.

## 2. Instrumentation

### 2.1. Photometer

The photometer is a unique device developed at the Polar Geophysical Institute (PGI), Russia, to carry out measurements at the Cap Heer Observatory (Barenzburg, Spitsbergen). The photometer has two channels for the 5557 Å and 6300 Å emission measurement directed towards the zenith. The field of view angle of the device is 6 degrees; the objective focus distance is 40 mm. The sensitivity threshold is 2 R (Rayleighs); the sensitivity threshold with background luminosity is 5 R (Rayleighs). The photometer maintains its work parameters at temperatures down to –40°C and at wind velocity up to 50 $m \cdot s^{-1}$. The device time resolution is 1 s.

### 2.2. All-sky camera

Spitsbergen PGI all-sky camera is a standard KTV H88M02 «VEGA» camera directed towards the zenith. The camera coverage is 180°; the sensitivity threshold is 100 R (Rayleighs), the

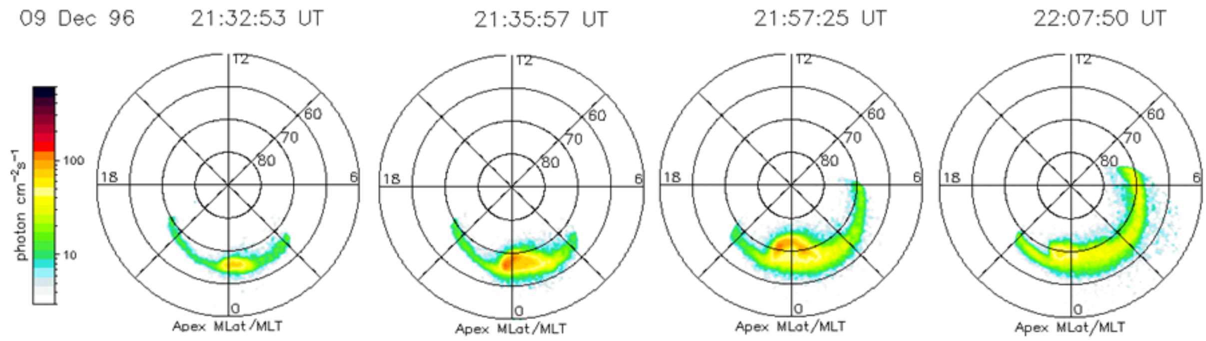


Fig. 1: The example of substorm development by Polar UVI data.

 

angular resolution is 1.25 degrees. The sensitivity maximum of the camera coincides with the green spectral region, and the part of the red spectral region in the registered glow is less than 10%. The all-sky camera maintains its work parameters at temperatures down to –50°C and at wind velocity up to 55 m·s$^{-1}$. The device time resolution is 1 s.

## 3. Data used

We used the following criteria for data selection:

1) Presence of 5577 Å and 6300 Å intensity measurements;
2) All-sky camera observations, presence of aurora and development of a substorm in aurora;
3) Clear sky (no clouds).

Regarding the photometer data, we have examined the periods of simultaneous observations of the PGI photometer and the all-sky camera at Spitsbergen. Spitsbergen PGI photometer data have been used to study the behaviour of the auroral 6300 Å and 5577 Å emissions. Observations have been carried out continuously during one winter season 2007/2008, i.e. the observations were performed during the following period: from 12$^{th}$ December 2007 to 12$^{th}$ January 2008.

As a result, two substorm cases were selected: on 6$^{th}$ January 2008 and on 16$^{th}$ December 2007, during which simultaneous observations of the PGI photometer and the all-sky camera at Spitsbergen were carried out. 67 substorms were observed by the IMAGE network during the observation period (12$^{th}$ December 2007- 12$^{th}$ January 2008), but only 14 substorms were observed by the all-sky camera, and only 2 of them were observed at the time of clear sky. One of these substorms was observed on 6$^{th}$ January 2008 during the solar wind recurrent stream, and the second one – on 16$^{th}$ December 2007, during time period before onset of the recurrent stream on 17$^{th}$ -19$^{th}$ December 2007.

In the following section the study of the 5577 Å and 6300 Å emissions lines intensities and the ratio of these intensities $I_{6300}/I_{5577}$ during substorm on 6$^{th}$ January 2008 are presented.

## 4. Results

Barenzburg is a quite a high-latitude station (LAT = 78°04'), and usually substorms are observed more equatorially, from stations at lower latitudes. However, the substorms sometimes reach higher latitudes, normally during high speed recurrent streams of the solar wind, (e.g. [6-8]). The case of 6$^{th}$ January 2008 is a typical example of observation of a substorm during a recurrent stream: the substorm onset was at auroral zone latitudes (Oulujärvi (OUJ) station, ~61° CGMLat), later it reached Barenzburg and moved further to the pole. Thus, Barenzburg turned out southwards of the polar edge of the bulge, i.e. inside the bulge.

The development of this substorm by all-sky camera data is presented in Fig. 2. By data of the all-sky camera aurora appears in the South of the frame at 21:55:50 UT when the first arc outburst was registered. Then the auroral arcs moved towards zenith, reached zenith at 21:57:50 UT and proceeded with its displacement northwards. At 21:57:50, the polar edge of the substorm auroral bulge was observed over the station, after that it displaced to the pole, and Barenzburg turned out inside the auroral bulge.

Figure 3 (upper panel of the figure) presents the aurora development by data from the Barenzburg all-sky camera from 21:57: 58 to 21:58:58 UT. It is the time period in which auroras was observed in zenith, i.e. at polar edge of the auroral bulge. The two bottom panels present the photometer measurements: the upper graph shows the intensities of the green 5577 Å emission and of the red 6300 Å one, and the lower graph shows the emissions intensities ratio $I_{6300}/I_{5577}$. It is seen that during the appearance of the substorm aurora near zenith, i.e. at the polar edge of the auroral bulge, the green line intensity sharply increased and the emissions intensities ratio $I_{6300}/I_{5577}$ reached a minimum, thus testifying for the precipitation of more energetic electrons. We averaged the values of ratio $I_{6300}/I_{5577}$ for the time period from 21:57:58 to 21:58:58 UT, the average ratio was $I_{6300}/I_{5577}$=0.13, i.e. it is the averaged value obtained for auroras at polar edge of the bulge.

 

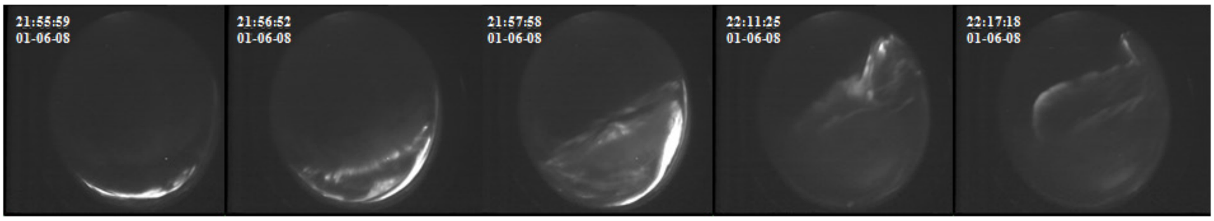


Fig. 2: Presentation of the behaviour of auroras by the all-sky camera at Spitsbergen during the substorm at 21:55 UT.

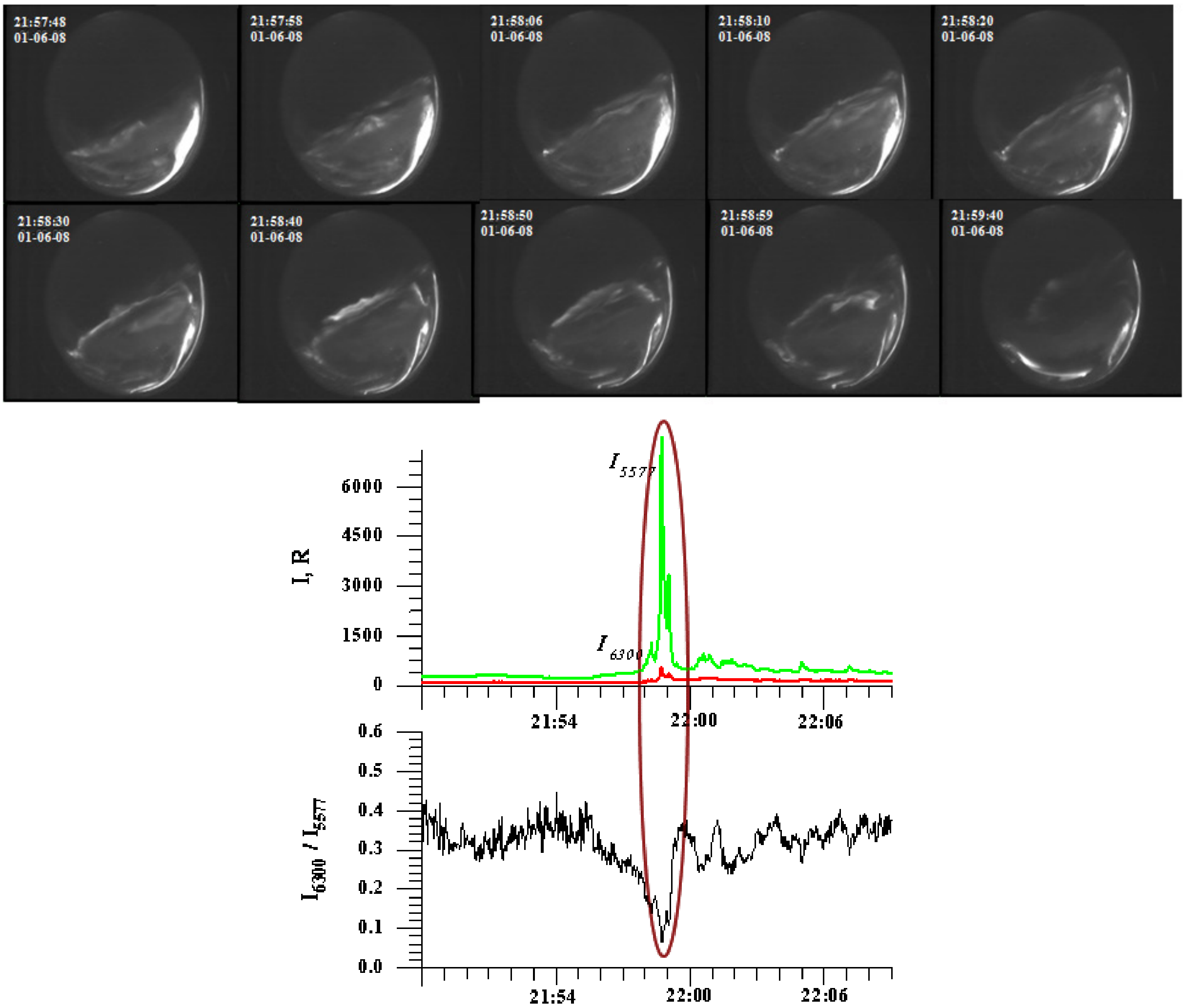


Fig. 3: The aurora dynamics and the variations of the 6300 Å and 5577 Å emissions intensities observed at polar edge of the bulge during the substorm on 6 January 2008 (21:57:58-21:58:58 UT).

Note that after 21:58:58 UT substorm auroras moved poleward, but there were not arcs in zenith. Therefore the photometer, which directed towards the zenith, did not register the increase of the 6300 Å and 5577 Å emissions intensities. We did not consider this time period. The arcs in zenith occurred at 22:10:38 UT, and we selected the following time period for analysis: from 22:10:38 to 22:18:10 UT. The upper panel of Fig. 4 presents the aurora development by data from the Barenzburg station (Spitsbergen) all-sky camera for period: 22:10:38- 22:18:10 UT. The auroras observed inside auroral bulge in this time period. The two bottom panels present the photometer measurements: variations of the 6300 Å and 5577 Å emissions intensities and the emissions

 

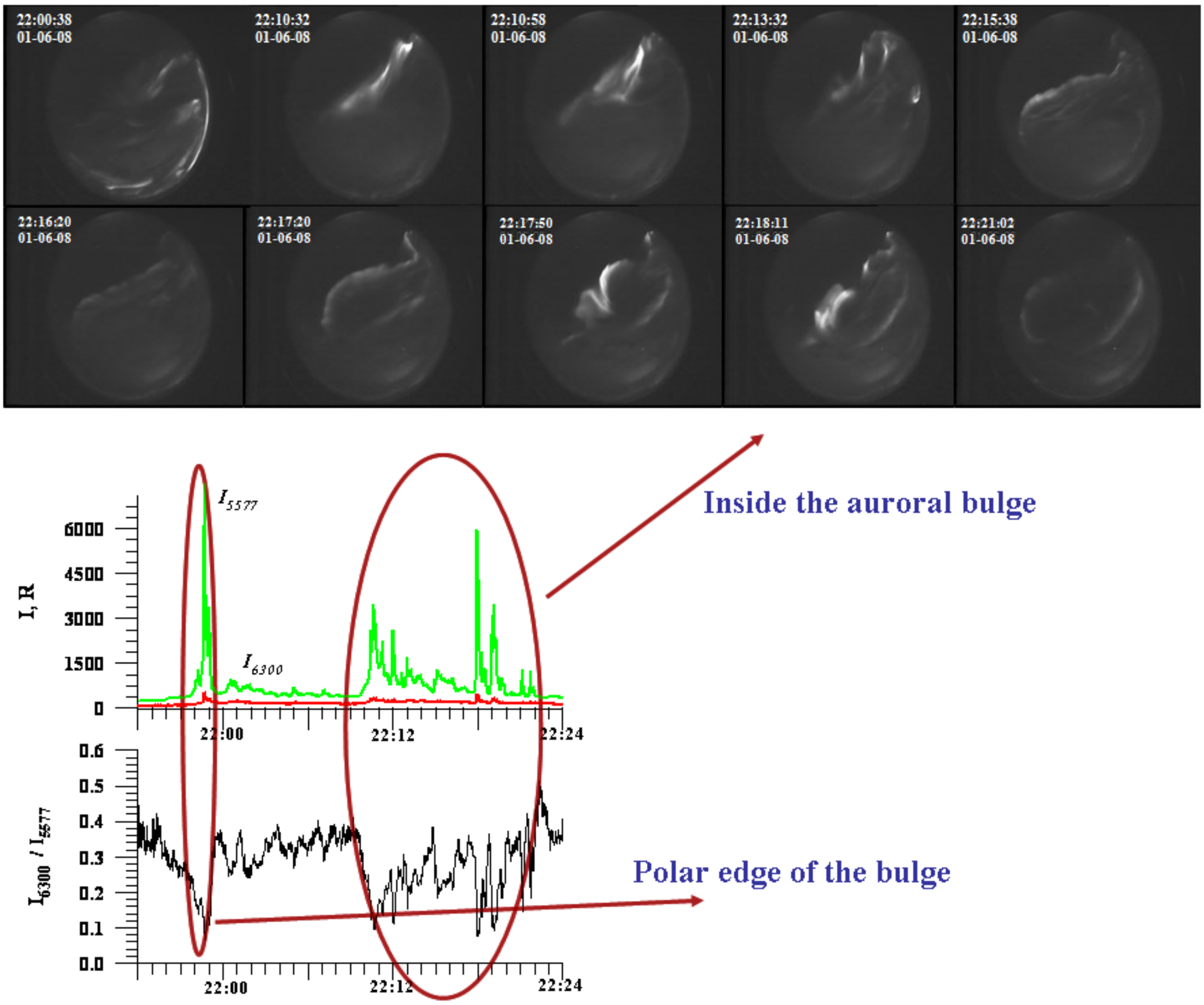


Fig. 4. The aurora dynamics and the variations of the 6300 Å and 5577 Å emissions intensities observed inside of the bulge during the substorm on 6 January 2008 (22:10:38-22:18:10 UT).

ratio $I_{6300}/I_{5577}$. We selected the period of averaging from 22:10:38 to 22:18:10 UT. The average ratio was $I_{6300}/I_{5577}$=0.28, i.e. this is the averaged value obtained for auroras which observed inside of the bulge. It is seen that the value of the ratio of the $I_{6300}/I_{5577}$ inside the bulge is ~2 times higher than to the one at the polar edge of the bulge.

## 5. Discussion

We studied the dynamics of the red $I_{6300}$ and the green $I_{5577}$ line intensities and their ratios $I_{6300}/I_{5577}$ during two substorms, the first of them connected with a recurrent stream of the solar wind. The value of the emission intensities ratio $I_{6300}/I_{5577}$, obtained in this paper (the case of 6$^{th}$ January 2008), is in a good agreement with the result of [9] for this ratio during recurrent streams ($I_{6300}/I_{5577}$ ~0.4). However, authors obtained the yearly means of the of aurora intensity ratio on the base of a large amount of data (aurora observations at the Loparskaya Observatory during 1970-1985). Authors examined the aurora spectral characteristics during long time intervals (during recurrent streams lasting several days). In our work, we examined the dynamics of the aurora spectral characteristics during a shorter time, during substorm development.

We compared the dynamics of auroras emissions and their ratio in different parts of the auroral bulge – at the polar edge of the bulge and inside it. The ratio of the $I_{6300}/I_{5577}$ values inside the bulge to the one at the polar edge of the auroral bulge is ~2. The emissions intensities ratio $I_{6300}/I_{5577}$ characterizes the hardness of the precipitating electrons spectrum. Therefore, the precipitation of the most energetic electrons happens at the polar edge of the auroral bulge, inside the auroral bulge precipitation of less energetic electrons is observed. Our result is in agreement with the paper by [5], in which it was shown, that the energetic particles are observed at polar edge of substorm auroras; their energy is becoming less to equatorward direction.

## 6. Conclusions

On basis of analysis two substorm events we made following conclusion: the precipitation of the most energetic electrons happens at the polar edge of the auroral bulge; inside the auroral bulge precipitation of less energetic electrons is observed.

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