*"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 89 - 92, 2007*

Polar Geophysical Institute

# SPECTRAL STUDIES OF AURORAS IN THE POLAR CAPS OF NORTHERN AND SOUTHERN HEMISPHERES OF THE EARTH DURING THE IGY, AS WELL AS IN SPITSBERGEN ON THE EVE OF THE IHY

L.S. Yevlashin, S.A. Chernouss, Yu.V. Fedorenko, A.V. Roldugin, O.M. Sharovarova *(Polar Geophysical Institute of the Kola Science Center of RAS, Apatity, Murmansk region)*

**Abstract.** In 1957-59 within the framework of the International Geophysical Year (IGY) (the period of a very high solar activity) spectral observations of auroras were carried out in the USSR at stations of Heiss island, Pyramida (Arctic), Mirny, Vostok (Antarctic), using C-180-S cameras, designed by prof. A.I.Lebedinsky.

Based on a unified programme (photographic film Dn, exposure time 10 minutes, spectral resolution of 5 nm) registrations of auroral spectra were carried out in the dark time of the day in autumn, winter and spring. The films development was centralized and the obtained materials were collected at the World Data Center ICD-B2 in Moscow. The photometric processing was carried out at the Auroral Laboratory of the PGI. There were registered the basic emissions of auroras: 630.0 nm, 557.7 nm, 427.8 nm and 319.4 nm on spectra of auroras with the intensity of I – II IBC points.

At the visual comparative evaluation of intensities of emissions 630.0 nm and 557.7 nm it turned out that the number of spectra, in which the red line 630.0 nm exceeded the green one 557.7 nm more than 2 times and more at all the stations, was very significant (on the average – 60%) This testified of the fact that during that period the number of auroras prevailed in the polar caps, which conventionally could have been referred to red auroras of type A, although, the observers of forms of auroras visually estimated them as light-green ones.

In December-January 2005-2006 (the minimum of solar activity) a spectral camera, designed in the PGI (CCD All-sky spectrograph) was in operation in Spitsbergen (Barentsburg) and allowed to obtain auroras spectra with exposure time of 1 min under the spectral resolution of 0.6 nm. The intensities of emissions 630.0 nm and 557.7 nm for 10 minutes were summed up during the processing. Photometric visual evaluations of the number of spectra, in which emission 630.0 nm exceeded 2 and more times the intensity of emission 557.7 nm proved this number to be very small – 2.5 %. This testified of the fact that during the period of the minimum of solar activity at the Barentsburg observatory, mainly green auroras prevailed.

The reasons of the obtained regularities are discussed as a conclusion.

## Introduction

Characteristics of auroral luminosity in the polar caps of the northern and southern hemispheres essentially differ from the current ones, which are manifested in the auroral zones of both hemispheres. The main distinction consists in that in the polar caps the intensity of integral luminosity and of some auroras is significantly lower than in auroral zones, since the intensity in them is determined by the availability of auroral ovals [Feldstein, 1960; Khorosheva, 1961]. Besides, in the polar caps such specific phenomena are manifested as large regions of red luminosity in the emissions 630,0-636,4 nm [Yevlashin, 1961; Sandford, 1961; Sandholt et al., 1993], whereas in the periods of "absorption in the polar cap" the luminosity is registered predominantly in emissions $1NGN_2^+$ [Sandford, 1962]. Some typical peculiarities are manifested in the regions of "polar cusps", in particular, just recently there were registered splashes of proton auroras there [Henriksen et al., 1985; Frey et al., 2002; Throp et al., 2005].

The Polar Geophysical Institute continues traditions of spectral observations in Spitsbergen, which were started by the Russian expedition in 1899 [Chernouss et al., 2005] and carried out in 1957-1959 during the International Geophysical Year [Yevlashin, 1961]. The goal of this paper is to assess the character of auroral luminosity in polar caps of the northern and southern hemispheres of the Earth during the IGY (The period of very high solar activity) and to compare it with the one, observed in the northern hemisphere polar cap during the season of 2005-2006 at Barentsburg observatory (the period of very low solar activity).

## Data and results

Within the framework of the Program of the International Geophysical Year (1957-1958) and the International Geophysical Cooperation Year (1958-1959) in the Arctic (Pyramida station, $\Phi = 74.5^0$ N, Heiss Isl., $\Phi=71.5^0$ N) and in the Antarctic (Mirny observatory, $\Phi = 77.0^0$ S, Vostok obs. $\Phi = 90.0^0$ S) in the dark time of the day observations of auroras using C-180 and C-180-S [Lebedinsky, 1961] cameras were carried out with concurrent brief visual assessments of the structure of forms, brightness and color of auroras. The photographic film of Dn type, produced by the Kazan Chemical works was used. The films development was centralized and the obtained materials were collected at the World Data Center ICD-B2.

The analysis of spectral data was carried out at the Auroral Laboratory of the PGI [Yevlashin,1961]. Since the observation season of 1957-1958 was a kind of preparatory and, thus, incomplete, only the material of the 1958-1959 season in the Arctic and 1959 in the Antarctic was subjected to scientific analysis. In spectra, obtained with standard 10 min exposition there were usually registered oxygen lines [OI] λ 630.0 nm and [OI] λ 557.7 nm, while sometimes bands of the ionized molecular nitrogen $N_2^+$ λ 427.8 nm and λ 319.4 nm were registered during auroras with the intensity of I – II IBC points. The observation period in the Arctic lasted from November 1958 to February 1959 (the monthly average number of sun spots made 172) and in the Antarctic from May to August 1959 (the monthly average number of sun spots made 173). Due to a large amount of information in spectra there were only carried out visual assessments of the intensities of lines λ 630.0 nm and λ 557.7 nm, which ratio determines to a certain extent the colour of auroral forms (see Table 1).

**Table 1**

**The probability of occurrence of red auroras of type A**

| Station | Geom.lat. | Geom.long. | Years of observation | Total number of spectra analyzed | Number of spectra of red aurora of type A | Percentage of spectra of red auroras of type A |
|---|---|---|---|---|---|---|
| Pyramida | 74.5°N | 130.8°E | 1958-1959 | 1703 | 719 | 42.2 |
| Heiss Isl. | 71.5°N | 155.3°E | 1958-1959 | 698 | 335 | 48.0 |
| Mirny | 77.0°S | 146.5°E | 1959 | 334 | 300 | 90.0 |
| Vostok | 90.0°S | 171.8°E | 1959 | 5600 | 3967 | 70.8 |
| Murmansk | 64.1°N | 126.5°E | 1958-1959 | 6821 | 216 | 3.2 |
| Cape Schmidt | 62.8°N | 132.6°W | 1958-1959 | 726 | 23 | 3.2 |
| Barentsburg | 75.2°N | 113.3°E | 2005-2006 | 905 | 22 | 2.4 |

So, if the intensity of the red line λ 630.0 nm exceeded significantly that of the green one λ 557.7 nm, while its value reaches 10 kR, the human eye registers such forms of auroras as red auroras of type A [Hanna and Anger, 1971]. It is known that as the height of aurora increases, the intensity of line λ 630.0 nm increases relative to line λ 557.7 nm, due to the fact that there is a difference in the life span of initial levels for exciting lines λ 557.7 nm (0.7 sec) and λ 630.0 nm (110 sec) {Chamberlain, 1961]. Since the probability of deactivation processes decreases with the increase of height, line λ 630.0 nm will prevail at the considerable height. Therefore, red type A auroras present luminosity of the atmosphere at the level of F layer.

As mentioned above, visual assessments of the intensities of lines λ 630.0 nm and λ 557.7 nm in spectra of auroras during the season of observations of 1958-1959 showed that at Pyramida and Heiss Isl. Observatories in 1054 spectra the intensity of emission λ 630.0 nm exceeded 1.5 times and more the intensity of the green line, although the intensities of both lines were not considerable (~1-5 kR), which makes on the average 45.1% of all the analyzed spectra.

This large percentage allows us to state that in the polar cap an essential number of auroras can conventionally be referred to red auroras of type A, although, the visual data of observations show, that there had mainly been registered forms of auroras in the form of homogenous arcs and bands of low brightness of light-green colour.

These results agree well with the data of magneto-ionospheric observations, obtained during the same period at stations SP-6 ($\Phi \sim 82^0$) and SP-7 ($\Phi \sim 74^0$) [Feldstein, 1961]. As well known, in the zone of auroras the sources of disturbances in the magnetic field are located in the E region of the ionosphere. A close relationship between the appearance of auroras at the zenith and magneto-ionospheric disturbances in the zone of auroras testifies of the fact that particle flux, stipulating the appearance of auroras in the zone, have energy sufficient for penetrating the E-layer of the ionosphere and causing a noticeable magneto-ionospheric disturbance simultaneously with aurora appearance. As seen from the analysis of magneto-ionospheric disturbances at stations of SP-6 and SP-7, the appearance of auroras is not accompanied by regular generation of sporadic E-layer, while the magnetic field turns out to be more quiet on the average during the appearance of auroras and more disturbed in the periods of absence of auroras.

Similar results, based on the material of C-180-S cameras were registered as well in the Antarctic at Mirny and Vostok observatories (see Table 1).

Some interesting results were obtained during the IGY by a New Zealand scientist Sandford [1961], who photographed auroras in May-July 1958 using an all-sky camera in the Antarctic, at the Scott base ($\Phi \sim -80^0$), while he was using colour film. After coming back home and developing the obtained material, he found that most of the registered forms of auroras were red ones, to which he ascribed type A, although during visual observations in winter time at night he registered them as light-green ones.

In winter of 2005-2006 in Spitsbergen (Barentsburg) there was used a spectral camera of the PGI, similar to the C-180-S camera where a light brightness intensifier with a CCD matrix was used as the light receiver, which allowed to cut down the exposure time to 1 min [Chernouss et al.]. Observations were carried out in December-January, when the average number of sun spots was 28, which testified practically of the minimum of the solar activity.
For the analysis of the obtained material and its comparison with the results of studies during the IGY 1-min intensities in spectra were summed up for a 10- min interval. The visual analysis of intensities of emissions λ 630.0 nm and λ 557.7 nm of those spectra was based on the method, similar to the one used for the IGY spectra processing. All in all 905 such summed up spectra were used for the analysis. It was found that the number of spectra, in which the intensity of emission λ 630.0 nm exceeded the intensity of line 557.7 nm 1.5 and more times, made only 22, i.e.2.4% of the entire number of the analyzed spectra. Thus, one can conclude that the character of luminosity of auroras in the polar cap during the minimum of solar activity changed considerably compared to the period of high solar activity. If during the IGY in the polar cap there prevailed the forms of auroras in which spectra of emission λ 630.0 nm exceeded emission λ 557.7 nm (red auroras), during the years of the solar activity minimum, on the contrary, the prevailing forms of auroras were structural ones, in which spectra emission λ 557.7 nm became prevailing (green auroras).

## Discussion of the results

After such characteristic phenomenon as auroral oval was discovered by the geophysical science [Feldstein, 1960; Khorosheva, 1961], the majority of various characteristics were 'linked' to variations of its borders depending on helio-geophysical parameters. So, Feldstein and Starkov [1968] studied the variations of the near-pole and equatorial borders of the oval depending on the magnetic activity during the IGY (very high solar activity) and in the years of the IQSY (low solar activity). They found that the central line of the auroral oval had shifted towards the pole during the IQSY compared to IGY by $1.5^0$ (from $\Phi = 67.5^0$ to $\Phi = 69.0^0$), whereas the high latitude border under great magnetic disturbances (Q=7) had also shifted northwards by $2^0$ ($\Phi = 73^0$ during the IGY and $\Phi = 75^0$ during the IQSY).

American scientists [Stringer and Belon, 1967] did not find any shift of the maximum in the function of aurora distribution during the IQSY compared to the period of IGY, although they noted a significant widening of the polar flank in such statistic distribution of auroras during the IQSY time compared to the IGY period.
Thus, one can state that the auroral oval, which was built mainly on the basis of analysis of bright green forms of auroras "shrinks" towards the pole during the years of low solar activity compared to years of high solar activity. This appears to be one of the reasons of the fact that the bright forms of auroras in which spectra green oxygen line λ 557.7 nm was prevailing prevailed in the years of low solar activity at Barentsburg station (in the polar cap).

## Conclusion

Based on the materials of aurora observations using spectral cameras C-180-S, which were operating during the IGY in polar caps of the northern and southern hemispheres of the Earth (in the Arctic, Pyramida observatory and Heiss Isl. and in the Antarctic – Vostok and Mirny stations), it was found that the prevailing forms of auroras there were the ones in which spectra the ration of emissions $I_{630.0}$ / $I_{557.7}$ exceeded 2. Those are auroras that can be conventionally referred to red type A auroras. In years of low solar activity, at least at the Barentsburg observatory (Spitsbergen) there prevailed auroras in which spectra the ration o emissions $I_{630.0}$ / $I_{557.7}$ was below 2, i.e. the basic forms of auroras in that region were green auroras. This regularity is explained by the reduction of the auroral oval size during the passage from the years of the very high solar activity to those of low solar activity.

## References

Chamberlain J. Physics of the aurora and airglow // Academic press, 1961, 670 p.

Chernouss S.A., Fedorenko Yu.V., Roldugin A.V., Sharovarova O.M., Yevlashin L.S. CCD All sky spectrograph at Barentsburg (Spitsbergen) and first observing results // Extended abstracts, The 3-d Inter.Conf.Geophys.Res. in Spitsb.Arch., October 03-05, 2006, Murm.-Barents., 2006, p.7-11.

Feldstein Ya.I. Geographical distribution of auroras and azimuths of arcs // Study of auroras, M. AS of the USSR publishing house, 1960, N 4, p.61-78.

Feldstein Ya.I. Magneto-ionospheric disturbances and auroras in the near-pole region // Auroras and night sky luminosity, M. AS of the USSR publishing house, 1961, N 7, p.43-50.

Feldstein Ya.I., Starkov G.V. Auroral oval in the IGY and IQSY period and a ring current in the magnetosphere // Planet Space Sci., 1968, v. 17, p.129-133.

Frey H.V., Mende S.B., Immel T.J., Fuselier S.A., Claflin E.S., Gerard J.-C., Hubert B. Proton aurora in the polar cusp // J.Geophys.Res.,2002,v.107,N A7, 10.1029/2001YA900161.

Hanna P.B. and Anger C.D. Auroral colour variations // Planet Space Sci., 1971, v.19, N. 4, p. 399-411.

Henriksen K., Fedorova N.I., Totunova G.F., Deehr C.S., Romick C.J., Sivjee G.G. Hydrogen emissions in the polar cleft // J.Atm.Terr.Phys., 1985, v.47, N 11, p.1051-1056.

Khorosheva O.V. On the spatial–temporal distribution of auroras in the Arctic in winter 1957/58 // Auroras and night sky luminosity, M. AS of the USSR publishing house, 1961, N 7, p.14-21.

Lebedinsky A.I. Synchronous auroral registration by all-sky camera C-180 and patrol spectrograph C-180-S // Ann.Internat.Geohys.Year, 1961, v.11, p.133-144.

Sandford B.P. Aurora and airglow from colour film observations // Jour.Atm.Terr.Phys., 1961, v.21, N 2/3, p.177-181.

Sandford B.P. Polar-glow in polar cap absorption events // Jour.Atm.Terr.Phys., 1962, v.24, N2, p. 155-171.

Sandholt P.E., Moeh, Budland D., Denig W.F. and Hansen T. Auroral events sequences at the dayside polar cap boundary for positive and negative interplanetary magnetic field By // J.Geophys.Res., 1993, v.98, N5, p. 7737-7755.

Stringer W.J. and Belon A.E. The statistical auroral zone during IQSY and its relationship to magnetic activity // J. Geophys.Res., 1967, v. 72, N 1, p.245-250.

Throp K., Lockwood M., Lanchester B.S., Morley S.K., Frey H.U. Modeling the observed proton aurora and ionospheric convection responses changes in the IMF clock angle: 1. Persitence of cusp proton aurora // J.Geophys.Res., 2005, v.110, A12311, doi: 1029/2003YA010306.

Yevlashin L.S. Red auroras of type A in high latitudes // Geomagnetism and aeronomy, 1961, v.1 N 4, p.531-533.