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AURORA CHARACTERISTICS DURING THE EARTH`S MAGNETOSPHERE INTERACTION WITH SOME TYPES OF COMPOUND AND SEPARATE SOLAR WIND STREAMS

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Abstract. Based on the ground and spacecraft aurora observations, the spectral characteristics and equatorward boundary position of auroral luminosity are presented in the periods of interaction of the Earth's magnetosphere with the compound streams of the solar wind and separate streams from the coronal holes, flares and heliospheric current sheets. There is no complete mixing of interacting streams from different solar sources. A consecutive change of features in the domination of streams and their geoefficiency takes place in the compound streams of the solar wind and in associated auroral disturbances/auroras. In the extended regions of interaction, the features of both types of streams manifest concurrently. Since the separate streams are structural modules of the complex streams, the characteristics of auroras at the interaction of solar wind compound streams with the Earth's magnetosphere are determined both by separate streams and the region of their interaction.

Introduction

Statistical investigations of the relation of spectral characteristics of auroras to certain types of quasi-stationary and non-stationary streams in the solar wind are presented in [1-3]. It is shown that during the Earth crossing solar wind non-stationary streams, one can often observe red type A auroras with the increased ratio of red emission intensity to that of the green emission (630.0/557.7≥1). As a rule, such ratios are observed under the increased values of solar wind density. The most evident connection of the 630.0 nm emission intensity with the solar wind density is observed at the sign change of the IMF Bz-component. The method of identification of some types of streams at the Earth's orbit is described in [4]. Statistical distributions of aurora equatorward boundary positions for certain types of separate streams in the solar wind are presented in [5, 6]. The purpose of the present paper is to compare the auroral characteristics at the interaction of the Earth's magnetosphere with separate streams from one solar source (the edge of the HSS from CH, flare, HCS) with those at the interaction with compound streams from two solar sources (HCS + the edge of the HSS from CH, flare + HCS).

The edge of the high-speed stream of a coronal hole

Fig. 1 provides an example of passage of the edge of HSS from CH by the Earth's orbit on January 25-26, 1974. In the period of 14-21 UT, the solar wind velocity increased from 500 to 750 km/s, while the density dropped from 22 to 5 cm^{-3}, IMF Bz-component varied from 0.5 to –4 nT, the mean hourly values of AE-index were 600-900 nT. Prior to 19 UT, in the spectrum of auroras one can observe a rather intense red emission, with the ratio 630.0/557.7 reaching 1.5-2.7. Later on, the intensity of the emission 630.0 nm decreased sharply, with the ratio 630.0/557.7 being less than unity. According to DMSP data, the equatorward boundary of auroras reached 56° of geomagnetic latitude.

Flare stream

Fig. 2 refers to a flare stream on October 31 – November 1, 1972. SC was registered on the Earth at 16 54 UT. At 18 UT there occurred a sharp increase in the solar wind density, however it was of short duration. The velocity of the solar wind made 750-650 km/s. The IMF Bz-component varied within a wide range from 10 to –25 nT. The AE-index at 20-21 UT reached the value of 1200 nT. The intensity of the emission 557.7 nm increased sharply at 18-20 UT, whereas the intensity of the emission 630.0 nm remained at a low level (630.0/557.7 ~ 0.2-0.4). The increase of the ratio 630.0/557.7 up to 0.6-0.7 took place at 21 UT and remained nearly unchanged for a long time of aurora registration. However, this increase is related to subsiding of green emission intensity under positive IMF Bz. As evidenced by the DMSP data, the equatorward boundary of auroras reached 55° of the geomagnetic latitude.

The disturbed heliospheric current sheet

In the Earth's orbit, the heliospheric current sheet (HCS) is identified as a boundary of IMF sector structure. Within the HCS, the change of sign of IMF radial component takes place. Fig.3 shows the variations of the solar wind parameters and the behavior of aurora spectral characteristics at Loparskaya station zenith, at the interaction of a disturbed HCS type stream with the Earth's magnetosphere on March 18-19, 1973.

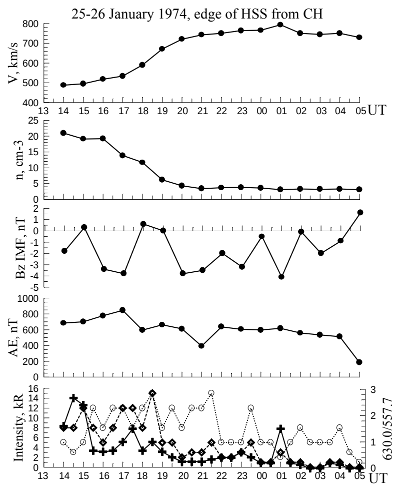

Fig. 1. Solar wind parameters, geomagnetic activity and aurora spectral characteristics at Loparskaya station zenith for the stream of the edge of HSS from CH. Blank circles correspond to 557.7 nm emission, squares refer to 630.0 nm emission, daggers to 630.0/557.7.

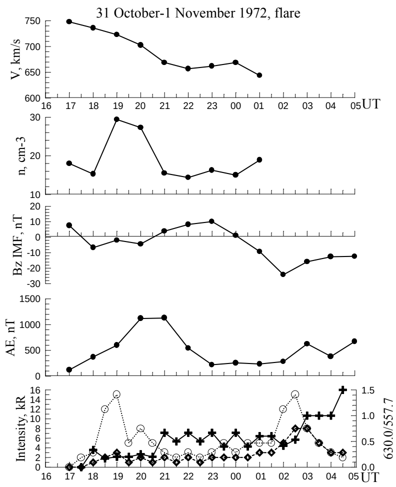

Fig. 2. The same as in Fig. 1 but for the flare stream.

The sign of the sector changed at 22 UT. (In this and following figures the time of HCS crossing is indicated by a vertical solid line). In the time interval studied, the solar wind velocity increased slowly from 350 to 390 km/s, the particle density prior to 21 UT made ~50 cm^{-3}, then it decreased down to ~20-30 cm^{-3}. The mean hourly values of the AE-index were high enough (300-700 nT). The ratio 630.0/557.7 of auroral emission intensities was maximum (1.7) at great values of density in the stream. According to DMSP data, the equatorward boundary of auroras was located at 55^0 of geomagnetic latitude.

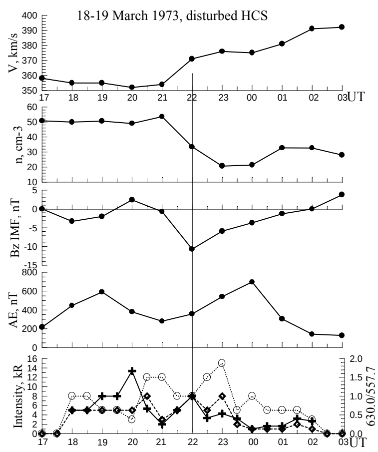

Fig. 3. The same as in Fig.1 but for the stream of disturbed HCS. The time of HCS crossing is indicated by the vertical solid line.

Compound streams

Compound streams in the solar wind are formed as a result of interaction of separate streams from different solar sources. If solar sources on the solar disc are spaced in longitude, the associated streams are sequential and can interact under certain circumstances. In such a time sequence, there will be periods with domination of separate streams and those of interaction of these streams. The HCS occurs in such sequences most often (HCS + the edge of the HSS from CH; the disappeared filament + HCS). If the solar sources are spaced in latitude or located very close to each other, the streams from these sources are most probably mixing in the Earth's orbit. The flare and filament streams are engaged in such events most frequently. However, some features of separate streams can still be found. The compound streams cause the disturbances on the Earth, in which these basic individual properties manifest. If the duration of a complex stream exceeds 40 hours, one can observe a change of auroral disturbance types in the auroral zone, while with shorter duration, a domination of one of the streams can be found [7]. One can also distinguish the properties of the compound streams in auroras by changes in the intensity of spectral lines and in the ratio of emission intensities.

We have studied 57 auroral events related to the compound streams. For these events, the intensity of auroras at maximum of auroral disturbance reaches IBC 2-3. It follows from the spectral observations that the ratio of 630.0 nm emission intensity to that of 557.7 emission makes on the average 0.5-1. This ratio changes in the course of disturbance development. The highest ratios (1-10) refer to those compound streams, in which flare and filament streams with very high solar wind density participate, especially at the Bz IMF sign change. If a stream from other solar source becomes dominating, the ratio drops down to 0.2-0.5. In the interaction of HCS type compound streams with the Earth's magnetosphere, the front edge of the HSS from CH, a flare stream – HCS, a filament stream – the edge of HSS from CH, the equatorward boundary of luminosity at maximum of disturbances in the midnight hours spreads to the geomagnetic latitudes of 55^0 –60^0, with the poleward boundary expanding to 70^0.

Fig. 4 a shows the parameters of the solar wind, AE-index and spectral characteristics of auroras at Loparskaya station zenith on October 28-29, 1983 at the passage by the Earth's orbit of a compound stream of the HCS type + the front edge of HSS from CH. This disturbance is an example of a time sequence with domination of one of the separate streams. The sector sign changed at 22 UT. Before that, the Earth was located in an almost typical left streamer near the HCS, after 00 UT - in a typical edge of HSS from CH, whereas between them there was a region of interaction of those streams, which is signified by an increased temperature, a large value of |B| IMF and its root-mean-square deviation. For this type of stream the gradual increase in the solar wind velocity, a rather fast drop of particle density, the change in the sign of Bz IMF are typical. According to the ascafilms of Loparskaya observatory, the band of diffuse luminosity with discrete arcs embedded, moves from Φ'~67° at 17 30 UT to Φ'~63° at 19 30 UT. In the following period, the auroras are observed throughout the sky, i.e. the equatorward boundary of the luminosity reaches 59°-60° of the corrected geomagnetic latitudes. The intensities of the emissions 557.7 nm and 630.0 nm prior to 21 30 UT are comparable in magnitude, with the ratio of 630.0/557.7 ≥1. As the auroral disturbance develops, green emission prevails, the ratio 630.0/557.7 decreases sharply and makes about 0.4 - 0.6. Thus, because of a rather narrow interaction region of solar wind streams, the auroral characteristics change gradually from those associated with HCS to the ones referring to the edge of HSS from CH.

Fig. 4 b shows the same but for the compound stream of the flare + HCS type on March 8-9, 1970. This auroral event is an example of two partly mixing streams in the Earth orbit: the one from a flare near the central meridian on the solar disc and the disturbed HCS. The variation of parameters in the solar wind and IMF is not appropriate to any separate source. SC was registered on the Earth at 14:17 UT. The change of sign of the sector occurred at 22 UT. First, after SC the Earth gets into a shock layer and then either it passes twice through the HCS or the HCS is multi-layered or distorted. After 18 UT, the density sharply increases from 10 to 50 cm^{-3}, with the stream velocity simultaneously decreasing from 800 to 550 km/s. At 21 UT the parameters of the solar wind restore to the former values. At that time, the IMF Bz component reaches –20 nT, with the AE-index being equal to 1200 nT. The intensity of 557.7 nm emission at Loparskaya zenith is high during the whole period of negative IMF Bz,

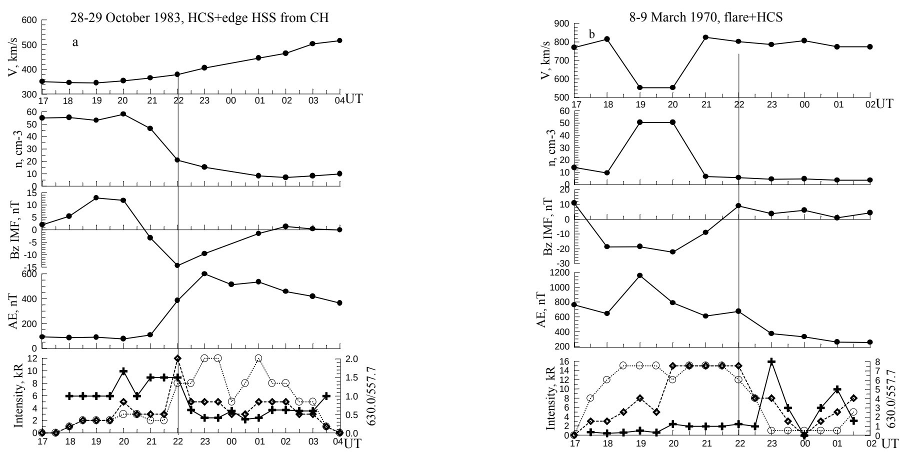

Fig. 4. The same as fig. 3 except for the compound streams: a – HCS+edge of HSS from CH, b – flare+HCS.

whereas the intensity of 630.0 nm emission gradually grows and increases sharply at 20 UT after a jump in the stream density. The ratio 630.0/557.7 becomes ≥1, which is typical for the HCS type stream. For this event, the Earth is staying for a long time in the region of partly mixing solar wind streams (18 -23 UT), with the features of both streams manifesting. In the auroral disturbances, the features of both streams are also displayed, manifesting in a simultaneous increase of both green and red emission intensities.

Conclusions

Thus, we have considered auroral events associated with separate and compound streams in the solar wind. Separate streams have well pronounced properties, with associated auroral disturbances also exhibiting well-defined regularities. A comparative analysis of both types of streams shows that, outside the interaction regions, the features of separate streams are manifested consecutively both in the compound streams and in the auroras associated with them. In the non-extended interaction region, there occurs a gradual change in domination and geoefficiency of streams from different solar sources. If the interaction region is extended, there is a partial mixing of streams, with the features of both types of streams being concurrently observed.

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