VISUAL AURORAS OBSERVED AT THE SYOWA STATION–ICELAND CONJUGATE PAIR

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Abstract: Conjugate observations of visual auroras were carried out at Syowa Station in Antarctica and at Husafell in Iceland during the northern summer seasons in 1978. Husafell is located about 50 km poleward from the conjugate point of Syowa Station. Conjugacies of auroras are investigated based on the data of the geomagnetically meridian scanning photometers (5577 Å) in addition to the all-sky cameras obtained at both stations. It is shown that the auroral behavior during the pre-breakup and breakup phases of a substorm as a whole is similar and simultaneous at the northern and southern conjugate stations, while the conjugacy of the auroras during the recovery phase of a substorm and a positive magnetic disturbance is poor.

1. Introduction

Based on the IGY all-sky camera data in geomagnetically conjugate area, DEWITT (1962) illustrated that the auroras show striking similarities in form and motion in both hemispheres. According to BELON *et al.* (1969), DAVIS *et al.* (1971) and STENBAEK-NIELSEN *et al.* (1972), the conjugate auroras are shifted relative to the conjugate point calculated from the GSFC 12/66 model magnetic field. They found that the auroras in the southern hemisphere are shifted toward the west of their northern counterparts before the breakup phase of a substorm, while during the breakups the southern auroras occur to the eastward of their northern conjugates. It is also found that the high-latitude side auroral arcs in the southern hemisphere show an equatorward displacement in comparison with those in the northern one.

From the above observations using the all-sky camera technique, it is difficult to find out the detail differences in the fast variations of auroral luminosity and motion. In addition to all-sky camera, the geomagnetically meridian scanning photometers (5577 Å) were installed at the conjugate pair of stations, Husafell, Iceland and Syowa Stations, Antarctica. The data of the scanning photometer enable us to compare the absolute luminosity and the fast motion of the southern auroras with those of the northern ones.

2. Observation

In the period of August 20–September 27, 1978, simultaneous observations of auroras were carried out at Syowa Station, Antarctica and Husafell, Iceland. According to the 1975 international geomagnetic reference field model, Syowa Station (geomagnetic lat. $-66.4°$, log. $70.1°$) and Husafell ($66.7°$, $70.5°$) make a good geomagnetic conjugate pair. Husafell is located about 50 km north of the conjugate point in the northern hemisphere of Syowa Station (Fig. 1). The geomagnetic local times at both stations are almost equal to universal time (UT), while the geographic local time of Syowa Station (UT+3 hours) is 4 hours different from that of Husafell (UT−1 hour). In the August–September season, the simultaneous night periods for auroral observations at the pair of conjugate stations are restricted to about 3 hours around midnight. In the period of this conjugate campaign, the conjugate auroral data for 15 hours are utilized to study the similarity in auroral form and motion in both hemispheres.

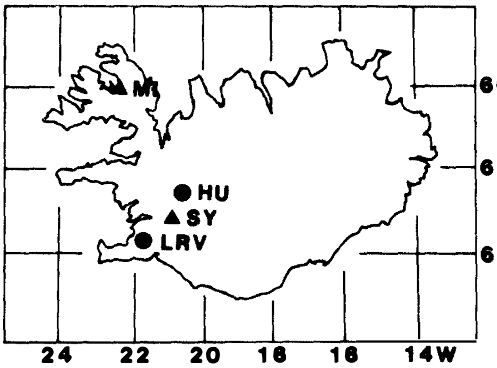

Fig. 1. Locations of Husafell (HU), Leirvogur (LRV) and the geomagnetic conjugate points of Syowa (SY) and Mizuho (MI) Stations are shown in the geographic coordinate. Mizuho is an Antarctic inland station about 300 km geomagnetic south from Syowa.

The equipments for auroral observation at Syowa Station consist of all-sky camera, wide-angle auroral TV and meridian scanning photometer (5577 Å and H_β-line). At Husafell, nearly the same kinds of auroral equipments as those at Syowa Station were installed during the campaign. From the data of meridian scanning photometer, the iso-intensity contour lines of auroral luminosity can be drawn along a geomagnetic meridian (along the abscissa) as a function of time (along the ordinate). The diagrams, such as those shown in Figs. 4 and 6 for example, will be called the meridian-time diagram of auroral luminosity (auroral diagram). An important factor in this diagram is its high resolving power with respect to time because the changes of auroral luminosity and motion are very rapid.

3. Conjugacy of Visual Auroras

3.1. Conjugacy of quiet multiple auroral arcs

Fig. 2 shows the normal magnetograms of Syowa and Leirvogur Stations (ref. Fig. 1). An intense substorm with the geomagnetic H-component decrease of about 500 nT was observed around 2200 UT on September 1, 1978 at both stations. The

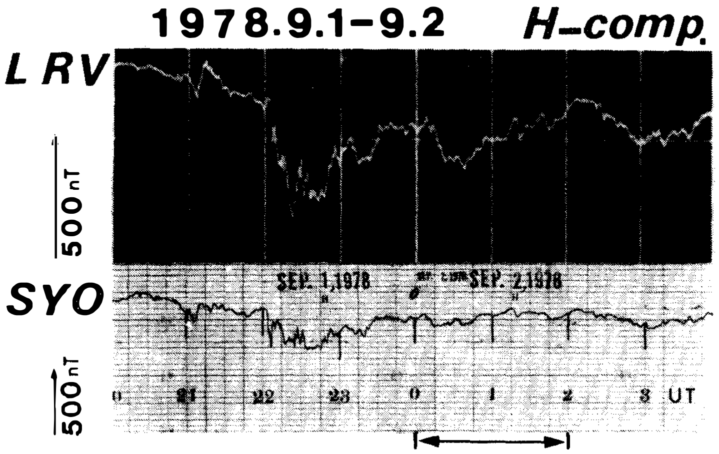

Fig. 2. Normal run magnetograms of Syowa and Leirvogur Stations on September 1-2, 1978.

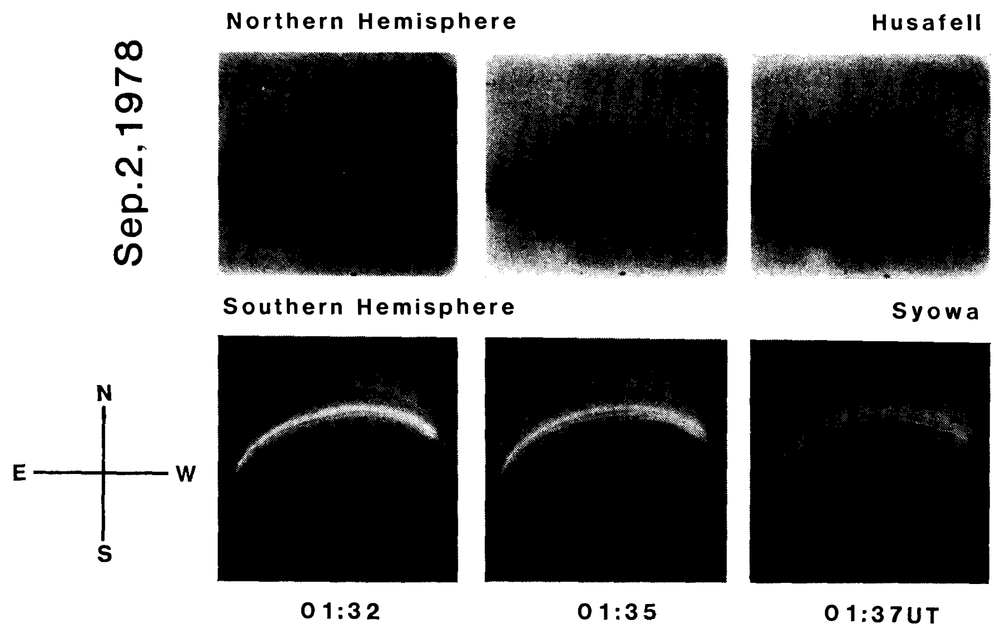

Fig. 3. All-sky photographs by the all-sky TV camera at Husafell and all-sky camera at Syowa Station. Orientation of the photographs; the geomagnetic north is to the top and the west is to the right. Photographs at Husafell are shown in negative.

conjugate auroral observations were carried out from 0000 to 0200 UT on September 2 during a small magnetic bay disturbance observed in the recovery phase of the intense substorm. In this interval, the magnetic disturbance was relatively small (less than 180 nT) and the quiet auroral arcs were seen in the equatorward part of the sky at both Syowa Station and Husafell. Photographs of typical auroras observed by the all-sky TV camera at Husafell and the all-sky camera at Syowa Station are shown in Fig. 3. From 0132 to 0137 UT, multiple auroral arcs were observed simultaneously at both stations. The good conjugacies especially for the locations and the patterns of auroras are clearly seen in these all-sky photographs. Using the data obtained by the meridian scanning photometer, the luminosities and the spatial distributions of auroras are examined in detail between Syowa Station and Husafell. The auroral diagram in Fig. 4 shows that the auroral arcs with the luminosity of about 2–3 k*R*

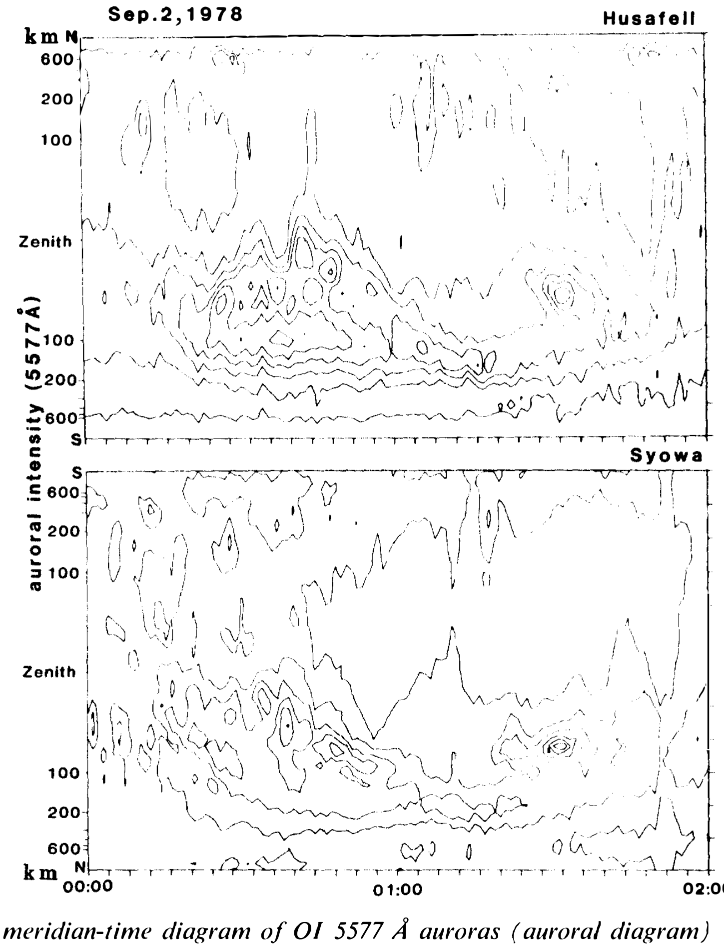

Fig. 4. The meridian-time diagram of OI 5577 Å auroras (auroral diagram) at Husafell and Syowa Stations on September 1–2, 1978. The iso-intensity contour lines of 5577 Å emissions are given in unit of 500 R and the peak luminosity of the contour lines is 4 k R at both observations.

were observed to the equatorward of both observing stations (the southward of Husafell and the northward of Syowa Station) from 0000 to 0200 UT on September 2, 1978. The auroras became weak around 0100 UT and increased again their luminosities up to about 4 k*R* at 0132 UT. Throughout the interval in Fig. 4, it is obvious that the aurorase appear and disappear simultaneously in both hemispheres and changes in motion and luminosity are almost simultaneous.

3.2. *Conjugacy of auroras during a substorm*

Fig. 5 shows the normal magnetograms of September 10–11, 1978 at Syowa and Leirvogur Stations. In the magnetograms, the small magnetic substorm ($-\Delta H \sim 200$ nT) began to start around 2330 UT on September 10. The auroral diagram from 2246 on September 10 to 0140 UT on September 11, 1978 is illustrated in Fig. 6 to show the behavior of the conjugate auroras during the pre-breakup, breakup and post-breakup phases of the substorm. In this auroral diagram, it is clearly seen that the changes in auroral luminosity and motion as a whole were similar in the course of the substorm at both conjugate stations. However, it is also noted in the diagram that the location and the time of the enhancement of conjugate auroras are occasionally different at both observatories. To see the auroral conjugacy in more detail, the auroral diagrams extended along the ordinate (time) are illustrated separately in Figs. 7, 8 and 9 in the cases of the pre-breakup phase (from 2246 to 2316 UT, Fig. 7), the breakup phase (from 2316 to 2346 UT, Fig. 8) and the post-breakup phase (from 2346 to 0024 UT, Fig. 8).

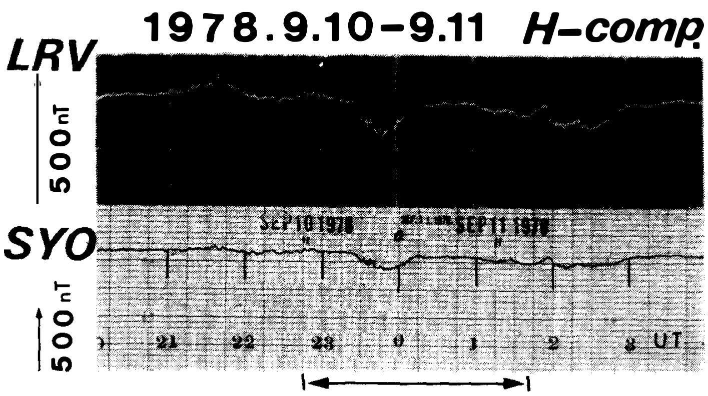

Fig. 5. Normal run magnetograms of Syowa and Leirvogur Stations on Septebmer 10–11, 1978.

Stable auroral arcs in Fig. 7 were found near the poleward regions of Husafell and also of Syowa Station (about 100–200 km poleward away from the zenith). The peak luminosity of these auroral arcs is nearly the same (approximately 7–8 k*R*) but the times of the auroral enhancements are different from each other at both observatories. Three auroral enhancements in luminosity were observed at Husafell around 2246–2252, 2256–2300 and 2303–2311 UT, respectively, while in these intervals the

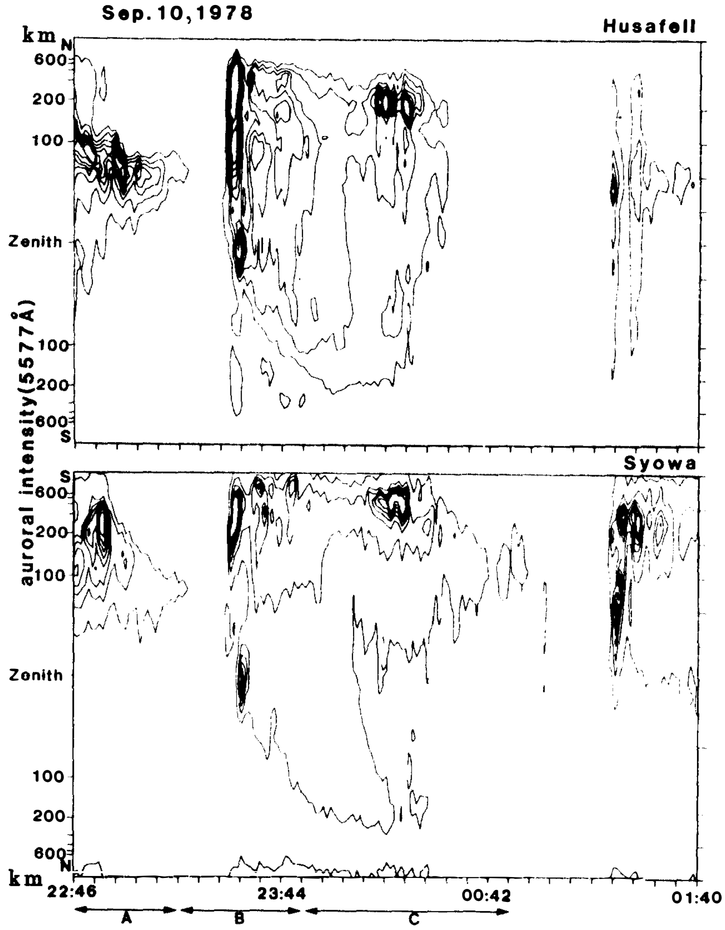

Fig. 6. Meridian-time diagram of OI 5577 Å auroras (auroral diagram) at Husafell and Syowa Stations during the substorm on September 10–11, 1978. The notation is the same as that in Fig. 4.

auroral enhancements were not found at Syowa Station. At Syowa Station, the auroras increased their luminosity around 2252–2256 UT, while the auroral luminosity at Husafell became weak in the period. These results are confirmed by the analysis of all-sky camera photographs taken at Syowa Station and all-sky TV data at Husafell. This example indicates that the auroral arcs are activated alternately in the northern and southern hemispheres. As is illustrated in the auroral diagram of Fig. 8, an auroral breakup occurred simultaneously in both hemispheres at 2330 UT on September 10, 1978. However, the locations of the breakup are different between the northern and the southern hemispheres. At Syowa Station, the breakup is observed about 200–800 km poleward, while at Husafell about 50–500 km poleward from its zenith. Considering that Husafell is located about 50 km poleward of the conjugate point in the northern hemisphere of Syowa Station, the location of the

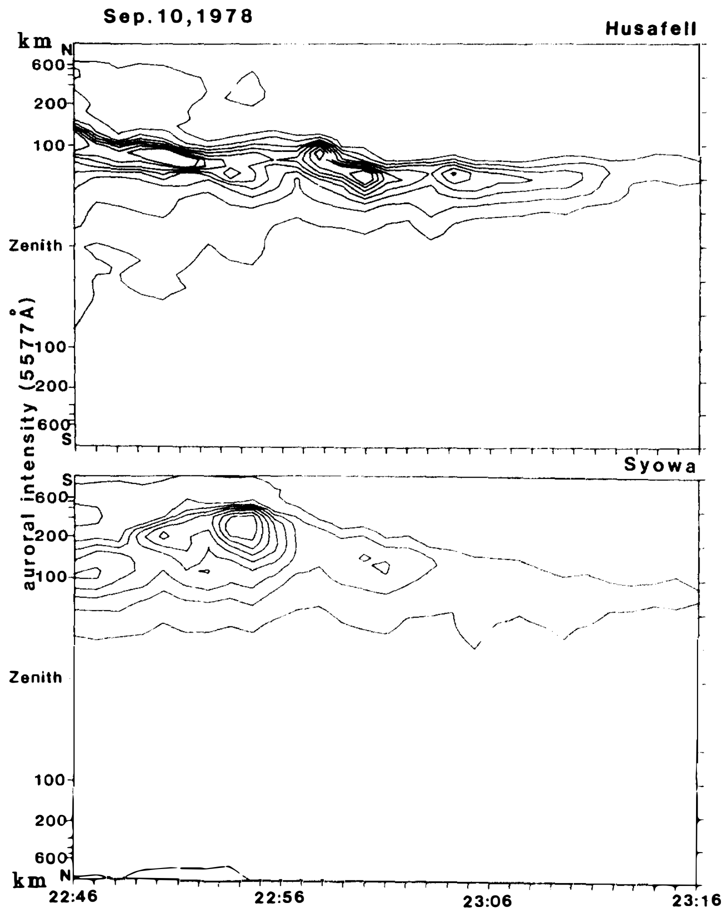

Fig. 7. Expanded meridian-time diagram of OI 5577 Å auroras during the pre-breakup phase of the substorm on September 10, 1978. The notation is the same as that in Fig. 4.

auroral breakup in the southern hemisphere is shifted about 100–200 km toward the pole in comparison with that of the northern auroral breakup. From 2332 to 2334 UT, the bright auroras were observed over the zenith of both observatories. The auroral appearance at Husafell is about 1–2 minutes earlier than that at Syowa Station. Around 2334–2339 UT, the auroral arcs were found at nearly the same location above the poleward horizons of both stations. However, these auroral enhancements show the apparent time lag of about 1 minute or more.

The auroral diagram in Fig. 9 illustrates the auroral display during the post-breakup phase of the substorm. An auroral arc became active near the poleward horizon at Husafell at 0012 UT, became faint for a time and increased again around 0018 UT. On the other hand, the enhancement of auroral luminosity at Syowa Station was restricted to the period from 0014 to 0018 UT. The auroral occurrences indicate that activations of auroral arcs are not always simultaneous in both hemispheres, but show the time differences between the two.

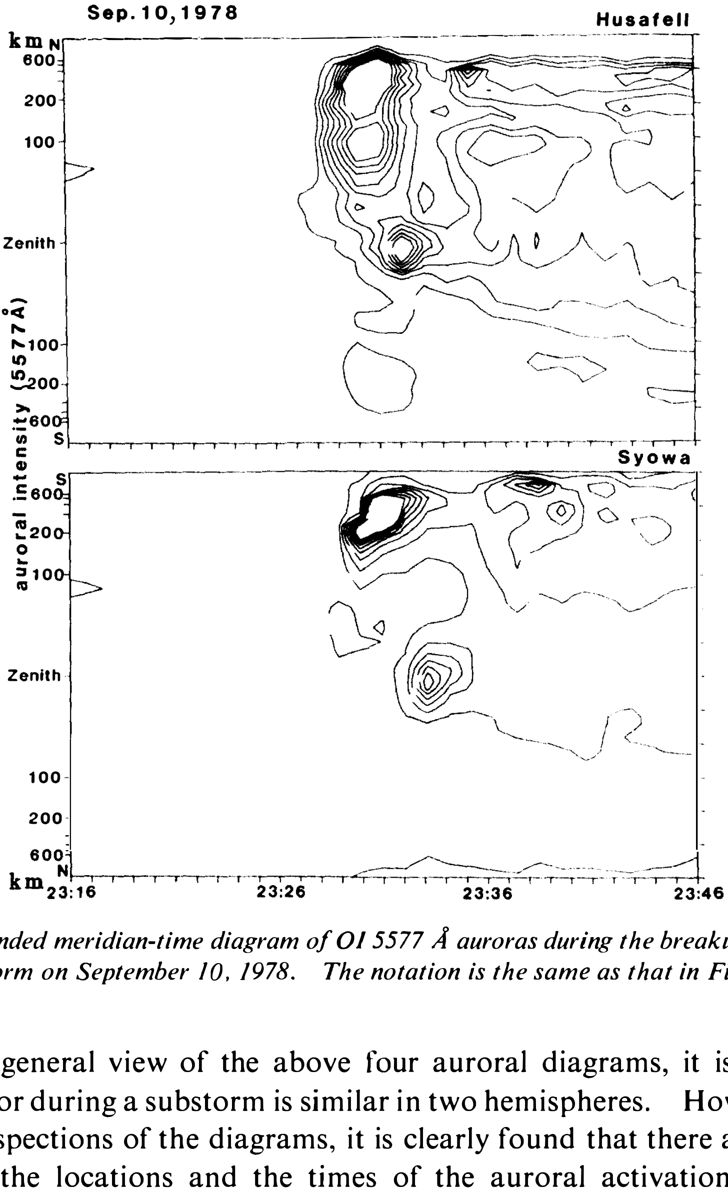

Fig. 8. Expanded meridian-time diagram of OI 5577 Å auroras during the breakup phase of the substorm on September 10, 1978. The notation is the same as that in Fig. 4.

Taking a general view of the above four auroral diagrams, it is said that the auroral behavior during a substorm is similar in two hemispheres. However, through the detailed inspections of the diagrams, it is clearly found that there are remarkable differences in the locations and the times of the auroral activations between the northern and southern conjugate observing stations.

3.3. Conjugacy of auroras during the recovery phase of a substorm

The magnetograms at Leirvogur and Syowa Stations in Fig. 10 show that a substorm with the magnetic *H*-component decrease of about 350 nT began to occur around 2145 UT on September 2, 1978 and lasted for more than 4 hours. Coordinated conjugate auroral observations were carried out during the recovery phase of the substorm. The all-sky photographs in Fig. 11 illustrate that a bright auroral arc was observed above the northern (poleward) horizon of Husafell around 2315 UT. On the other hand, the corresponding bright arc was not detectable at Syowa

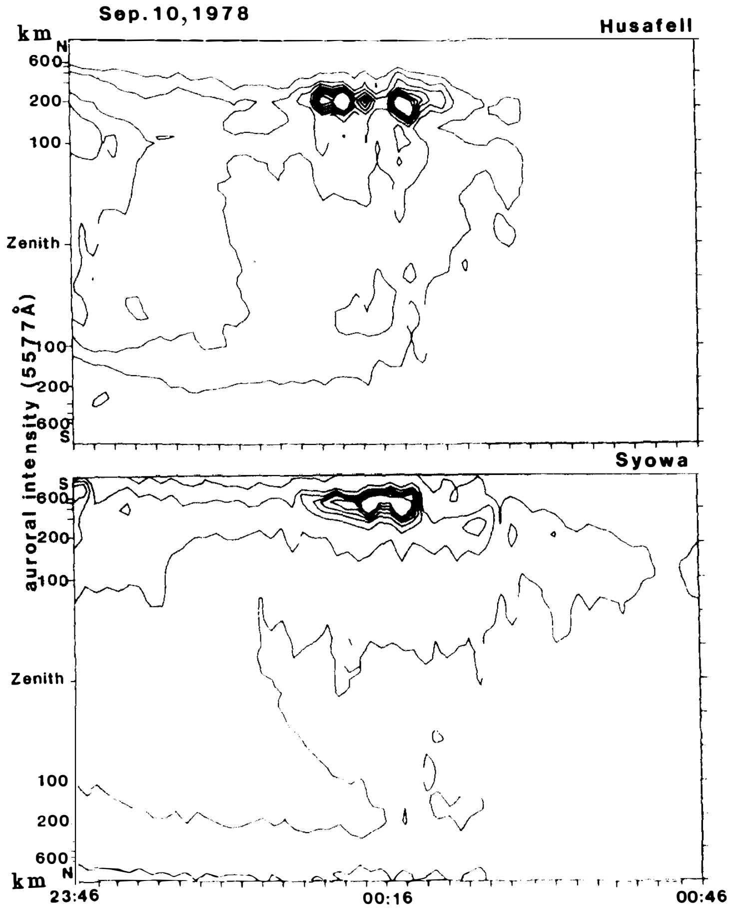

Fig. 9. Expanded meridian-time diagram of OI 5577 Å auroras during the post-breakup phase of the substorm on September 10–11, 1978. The notation is the same as that in Fig. 4.

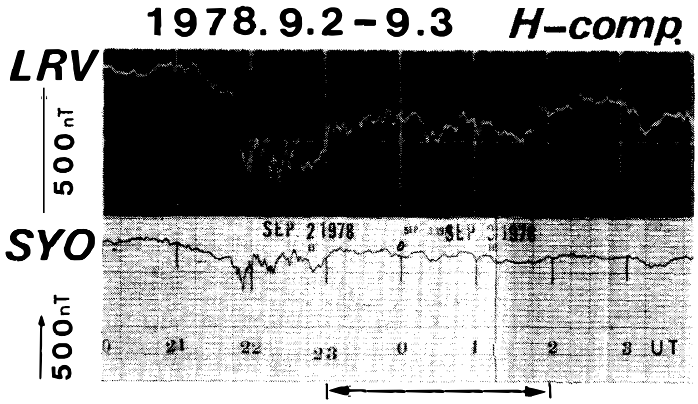

Fig. 10. Normal run magnetograms of Syowa and Leirvogur Stations on September 2–3, 1978.

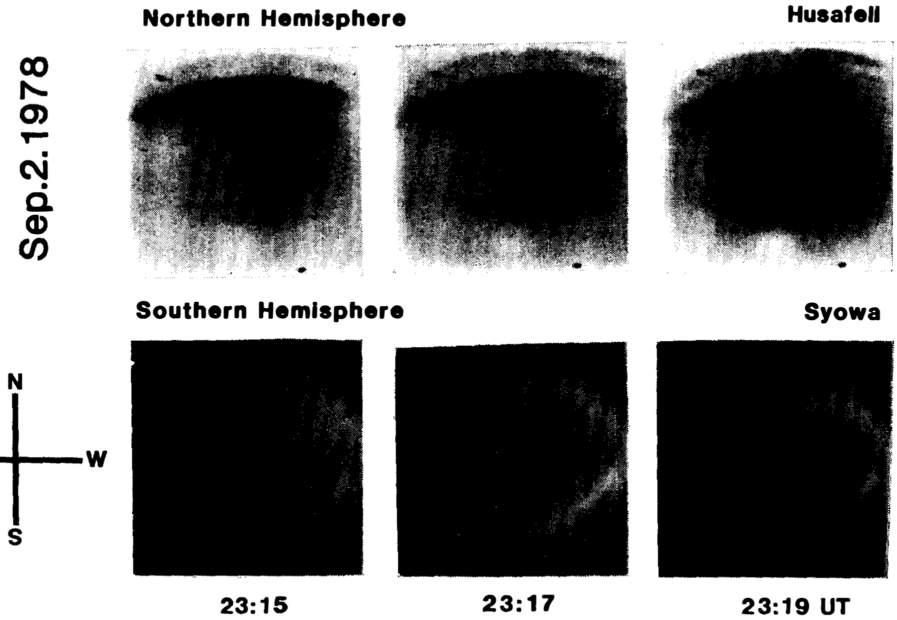

Fig. 11. All-sky photographs observed at Husafell and Syowa Stations on September 2, 1978.

Station, but the northern part of the sky was covered with multiple auroral arcs with diffuse structure. To show the detailed auroral distribution, the auroral diagram in the period from 2300 to 0200 UT is illustrated in Fig. 12. In the diagram, the bright auroras with the luminosity of more than 10 kR are seen about 100–200 km poleward of Husafell from 2300 to 2320 UT, while the conjugate auroras cannot be found at Syowa Station in this period. However, in the all-sky photographs at Syowa Station in Fig. 11, we are able to find out that the bright auroral area exists above the westward horizon of Syowa Station in the period from 2315 to 2319 UT. Because the scanning photometer used in the observation scans from the south to north horizon along the geomagnetic meridian with the aspect angle of 5°, the bright auroras in the west part of the sky are not recorded. If the bright auroras in the westward sky of Syowa Station correspond to the auroras observed in the poleward side of Husafell, it might be said that the conjugate points in both hemispheres are shifted from each other along the longitudinal direction during the recovery phase of a substorm.

3.4. *Conjugacy of auroras during the positive magnetic disturbances*

The magnetograms of Leirvogur and Syowa Stations in Fig. 13 indicate the successive occurrences of the positive magnetic variations. Auroral conjugate observations were carried out from 2250 on September 4 to 0105 UT on September 5, 1978. During the period, a positive bay disturbance with the amplitude of about 100 nT was observed around 2346 UT at both observatories. As is illustrated in the

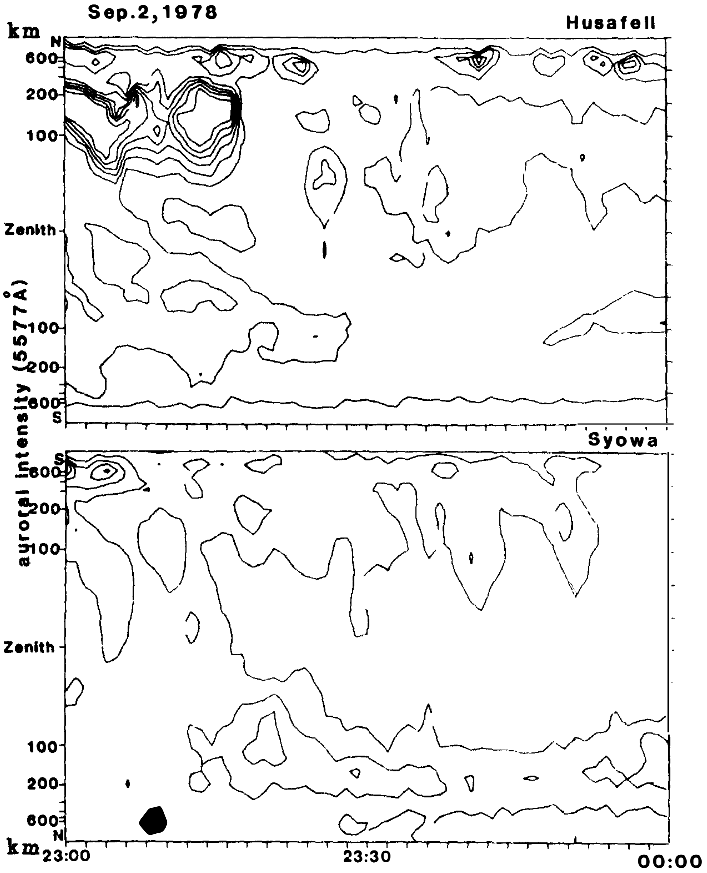

Fig. 12. *Meridian-time diagram of OI 5577 Å auroras during the recovery phase of the substorm on September 2, 1978. The iso-intensity contour lines of 5577 Å emissions are given in unit of 1 kR at Husafell and 500 R at Syowa Stations. The peak luminosity of the contour lines are 8 kR at Husafell and 4 kR at Syowa Stations, respectively.*

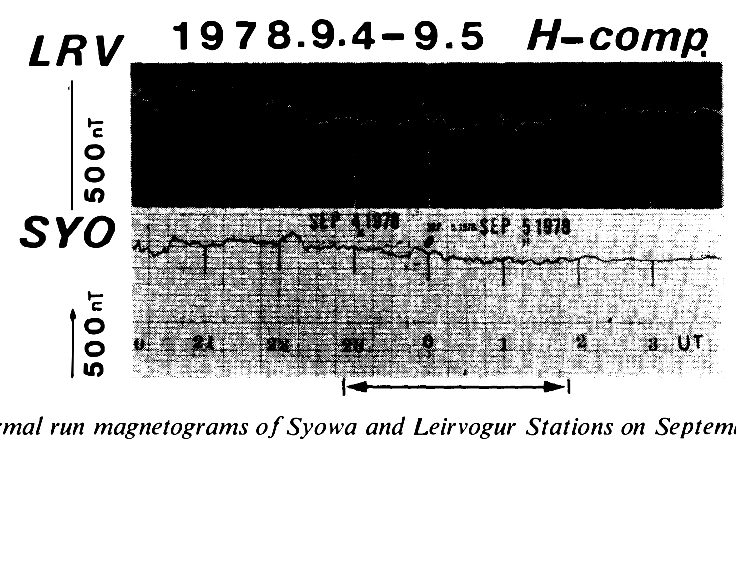

Fig. 13. *Normal run magnetograms of Syowa and Leirvogur Stations on September 4–5, 1978.*

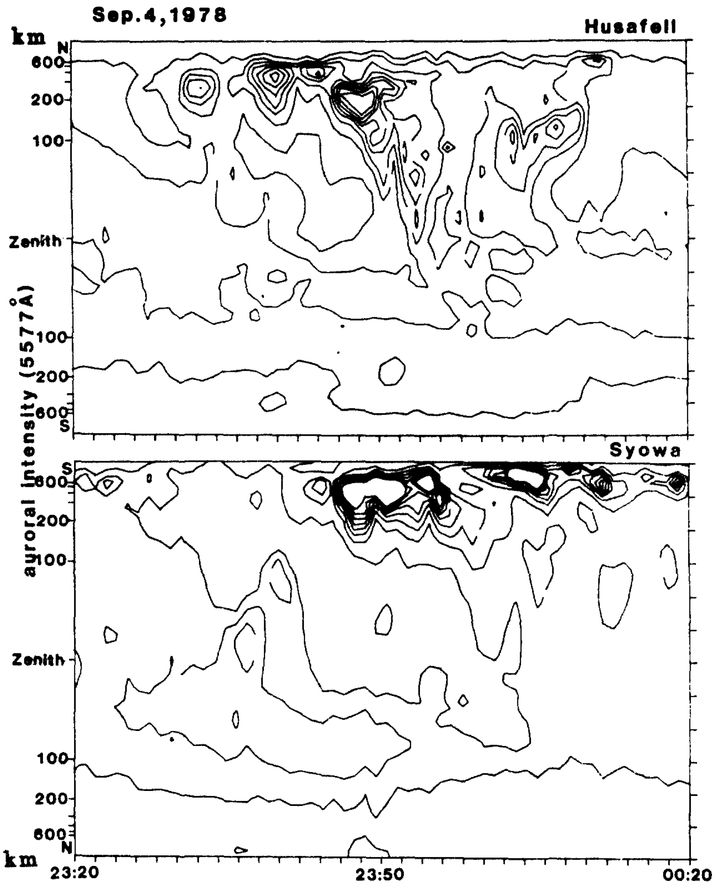

Fig. 14. Meridian-time diagram of OI 5577 Å auroras during the positive magnetic disturbances on September 4, 1978. The notation is the same as that in Fig. 12.

auroral diagram of Fig. 14, in the period preceding the positive bay disturbance, auroral arcs are brightened near the poleward horizon at Husafell, while no appreciable auroras are observed at Syowa Station. When the positive disturbance began to occur at 2346 UT, the auroras increased simultaneously their luminosity in the poleward regions of both observatories. However, the location of the bright aurora at Syowa Station is about 100 km poleward from that at Husafell. A few minutes after the beginning of positive disturbance, the bright aurora begins to expand toward the equator at Husafell. A few minutes after the beginning of positive disturbance, on the contrary to its preceding phase, the auroras are activated above the poleward horizon of Syowa Station, while the auroras at Husafell are not active.

4. Summary

A time sequence of an auroral substorm phenomenon has been divided into three phases, namely the pre-breakup, the breakup and the post-breakup phases (*e.g.* AKASOFU, 1968). In the present study of the conjugate auroras in the course of a substorm, the following characteristics of the auroras are noted.

(1) It has been pointed out that stable auroral arcs are frequently observed prior to an auroral breakup (AKASOFU, 1968; HIRASAWA and NAGATA, 1972). It is found in Figs. 6 and 7 that the time sequence of the pre-breakup auroral arc and their absolute intensities as a whole are similar between the two hemispheres. However, the times of the auroral enhancements are frequently different from each other between the two.

(2) AKASOFU (1964) has pointed out that a stable arc suddenly becomes active and shows a rapid poleward expansion at the onset of an auroral substorm. The auroral behavior shown in Figs. 6 and 8 is consistent with the view given by AKASOFU. The breakup auroras are observed simultaneously and their variations in the luminosity and the motion are generally similar in both hemispheres.

(3) During the recovery phase of an auroral substorm, two types of auroras are found; *i.e.* the auroras in the form of a diffuse or ray (post-breakup aurora) covering the sky where the breakup type auroras have passed poleward and the discrete auroras being located near the poleward boundary of the post-breakup type auroras (HIRASAWA and NAGATA, 1972). From the point of view of the auroral conjugacy, the poleward discrete arc has similar characteristics to those of the stable arcs observed during the pre-breakup phase. The faint diffuse auroras (post-breakup aurora) usually have a good conjugate relationship between the northern and the southern conjugate observatories.

After a severe magnetic substorm, quiet multiple auroral arcs remain occasionally in the equatorward side of the observatories. The auroras are a kind of the post-breakup type auroras and accompanied by the magnetic negative disturbance which shows the gradual decrease and recovery. The multiple auroras have the good conjugacies between the two hemispheres.

(4) On the magnetic quiet days, the successive occurrences of the positive magnetic disturbances are frequently observed during the midnight hours in the polar region. At this time the discrete auroral arcs are frequently seen in the poleward side of the observatory. The conjugacies of the discrete auroras are somewhat different from those of the auroras of the other types and show the complicated relations as is illustrated in Subsection 3.4.

The auroras observed at Husafell in the northern hemisphere are mostly located in the lower latitude side than the simultaneous conjugate auroras observed at Syowa Station in the southern hemisphere. This fact indicates that the actual conjugate relationship between the two hemispheres is somewhat different from the calculated one. From our observational results, the southern conjugate point of Husafell seems to be shifted about 100 km (about 1° in latitude) or more towards the pole from Syowa Station. It is also found that the conjugate points show the longitudinal displacements during the recovery phase of a substorm. However, these examples are too few to make certain the displacement of the conjugate points along the longitudinal direction.

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