H_β EMISSION DURING AURORAL BREAKUP

T. OGUTI, H. FUKUNISHI, T. TOHMATSU and T. NAGATA*

Geophysics Research Laboratory, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan

Abstract: The behaviour of H_β emission is examined at the onset and in the course of auroral breakup, on the basis of meridian scanning data of photometers for H_β and green line along with all-sky photographs obtained at Syowa Station, Antarctica in 1971.

The result shows that an auroral breakup starts at the poleward boundary of the pre-existing hydrogen arc, that a global breakup frequently starts when an electron auroral arc comes into contact with the pre-existing hydrogen arc, that the enhancement of H_β takes place in the region bounded by the westward travelling surge, the poleward shifting arc and the pre-existing hydrogen arc with a spatial negative correlation between electron aurora and hydrogen emission, and that the behaviour of a local breakup is substantially similar to that of a global breakup though it has no "contact" of electron aurora.

Introduction

Dynamic morphology of aurora during an auroral breakup has been extensively examined by AKASOFU (1964, 1965), on the basis of the Alaskan network of the all-sky camera, and his results are now widely accepted. In his reports, however, no information of hydrogen emission is included.

Recently, EATHER and JACKA (1966), MONTBRIAND (1971) and FUKUNISHI (1973a) studied hydrogen emission in aurora. Their result showed that the enhancement of hydrogen emission is associated with the breakup of an electron aurora especially in the dawn sector, and that the hydrogen arc shifts poleward following the poleward expansion of the electron aurora, in the course of breakup.

However, there remain several points still unravelled. The first point is the initiation region of auroral breakup. AKASOFU's result shows that an auroral breakup starts at an auroral arc that is located near the equatorward edge of the entire (electron) auroral display. However, multiple diffuse arcs frequently exist near the equatorward edge of the auroral display, and it has not yet been clarified which of these multiple arcs develops into breakup of aurora.

The second point is the condition or configuration of aurora which would result in breakup. AKASOFU in his early report (1964) mentioned that the auroral arc comes to lower latitudes before breakup. HIRASAWA and KAMINUMA (1970) also referred to this phenomenon, as the equatorward shift of aurora seems to be a signal of a growing stage of auroral activity. On the other hand, SNYDER and AKASOFU (1972), stressed that the equatorward shift of aurora is not a signal of a

*At present: National Institute of Polar Research.

growing stage but is a general feature of aurora both before and after breakup.

The third point is the spatial and temporal relation between electron aurora and hydrogen emission during breakup. Though the global behaviour of hydrogen emission in aurora is known by the results of MONTBRIAND (1971) and FUKUNISHI (1973a), details of the relation between electron aurora and hydrogen emission are not yet clear enough to construct an acceleration model of auroral electrons and protons.

In this note the detailed behaviour of aurora at the breakup are examined with the aid of the meridian scanning photometer records of 5577 Å and H_β emissions and those of all-sky camera obtained at Syowa Station (geomagnetic coordinate $-69.6°$, $77.1°$), Antarctica.

Onset Region of Auroral Breakup

In order to locate the region where an auroral breakup starts, we examined the all-sky photographs of aurora along with the data of the meridian scanning photometers of 5577 Å and H_β emission during auroral breakups. For example, the all-sky photographs covering the auroral breakup of 2353, May 18, 1971 are reproduced in Fig. 1a, and the corresponding meridian scanning photometer records are shown in Fig. 1b with 5577 Å (electron) data at top and the H_β (proton) data at bottom.

Before the breakup the electron aurora consists of a sheet seen near the poleward horizon and several diffuse arcs located northward (equatorward) from the zenith. The comparison with the proton photometer record shows that these diffuse arcs are located on the poleward slope of the hydrogen emission region.

At the onset of the breakup (at 2353) a new sheet aurora appears to the east of the station along the poleward edge of the hydrogen emission region. (Or, an electron arc situated along the hydrogen edge is rapidly intensified.) Notice that it is not the equatorward edge of the diffuse electron aurora that becomes excited. Then, the activated sheet aurora quickly extends westward along the poleward border of the hydrogen emission region. The speed of the westward extension is of the order of 10 km/sec. About one minute after the onset, the intensified electron arc begins to split and the rapid poleward expansion of the activated region follows.

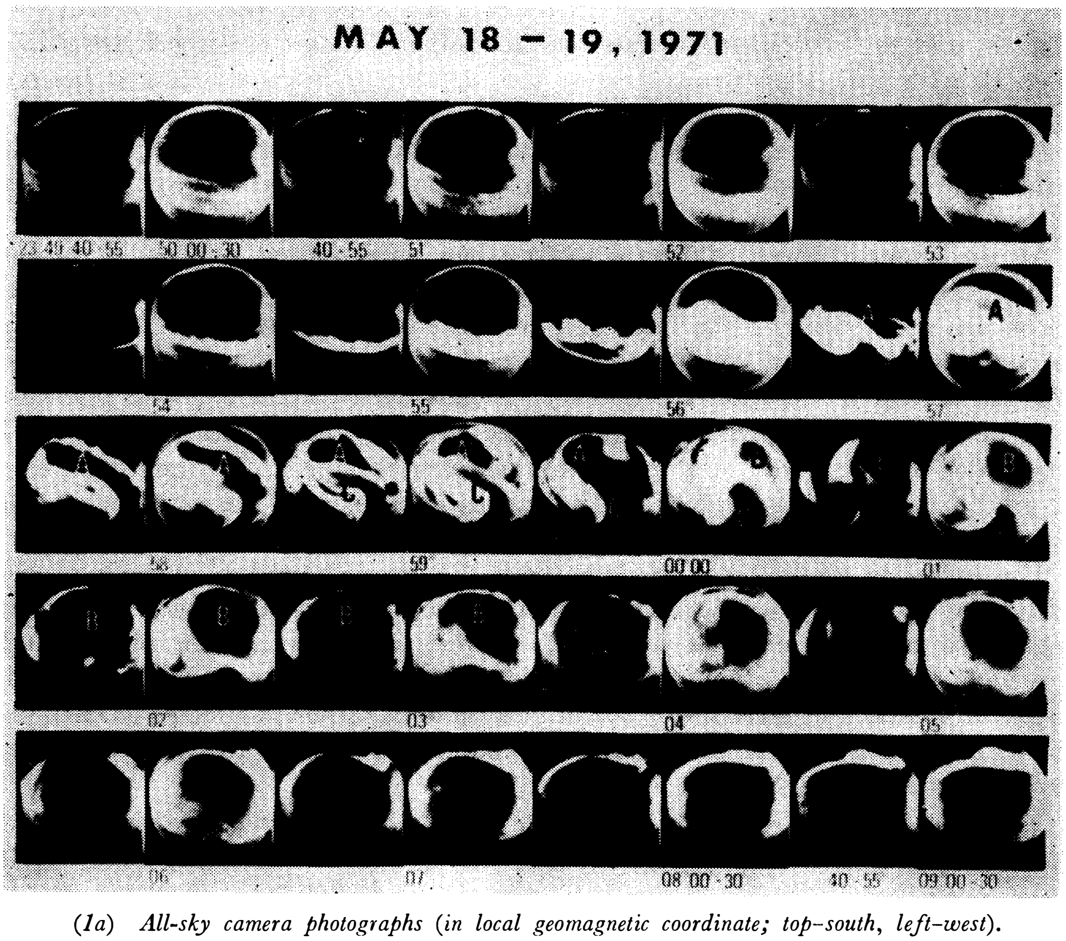
The initiation of the breakup along the high-latitude boundary of the hydrogen arc and the subsequent westward extension of the newly-created (or, intensified) sheet aurora as noted in Fig. 1 seem to be a very common feature of breakups observed in the dusk to midnight sectors. During the process, the high-latitude electron aurora in the dusk sector sometimes remains rather unaffected as exemplified in Figs. 1 and 2, until the poleward expanding front of the newly created electron aurora approaches it.

The poleward and westward expansion of the electron aurora is immediately followed by the expansion of the hydrogen region. The drift of electron aurora seems always to precede the drift of the hydrogen region; or in other words, the electron aurora seems to appear at the fringe of the expanding hydrogen region. In order to illustrate the development of electron aurora and associated hydrogen emission, more clearly in real space than the all-sky photographs, they are shown in Fig. 1c in linear scale reproduced from the all-sky photographs and the records of meridian scanning photometers. The distribution of hydrogen emission is represented by the dotted area in a somewhat schematical manner. The coarsely dotted area indicates the region of H_β brighter than about 3 R/Å, and the densely dotted area indicates the region brighter than about 6 R/Å.

Strictly speaking, the meridian scanning data bring forth no information on the longitudinal extension of the hydrogen region. However the longitudinal extension, as well as the longitudinal motion, of the hydrogen region reasonably deduced from the dynamic feature of electron auroras as will be shown later.

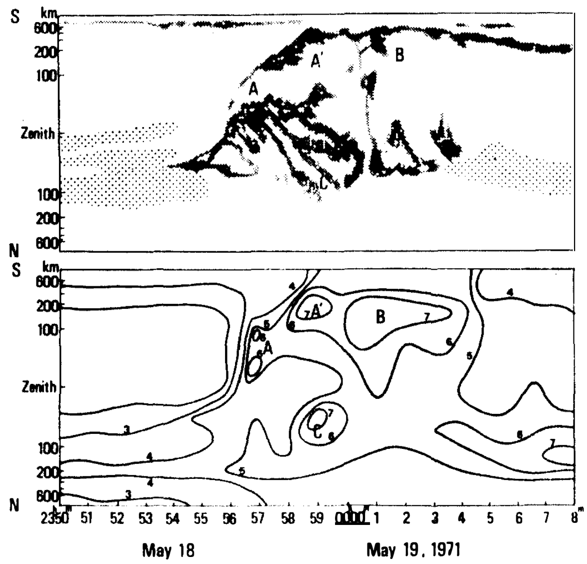
Condition or Configuration of Aurora Resulting in Breakup

The aspect of aurora leading to breakup is one of the important points of the breakup research. AKASOFU (1965) mentioned that aurora disappears in high latitudes, and HIRASAWA and KAMINUMA (1970) said that aurora's equatorward

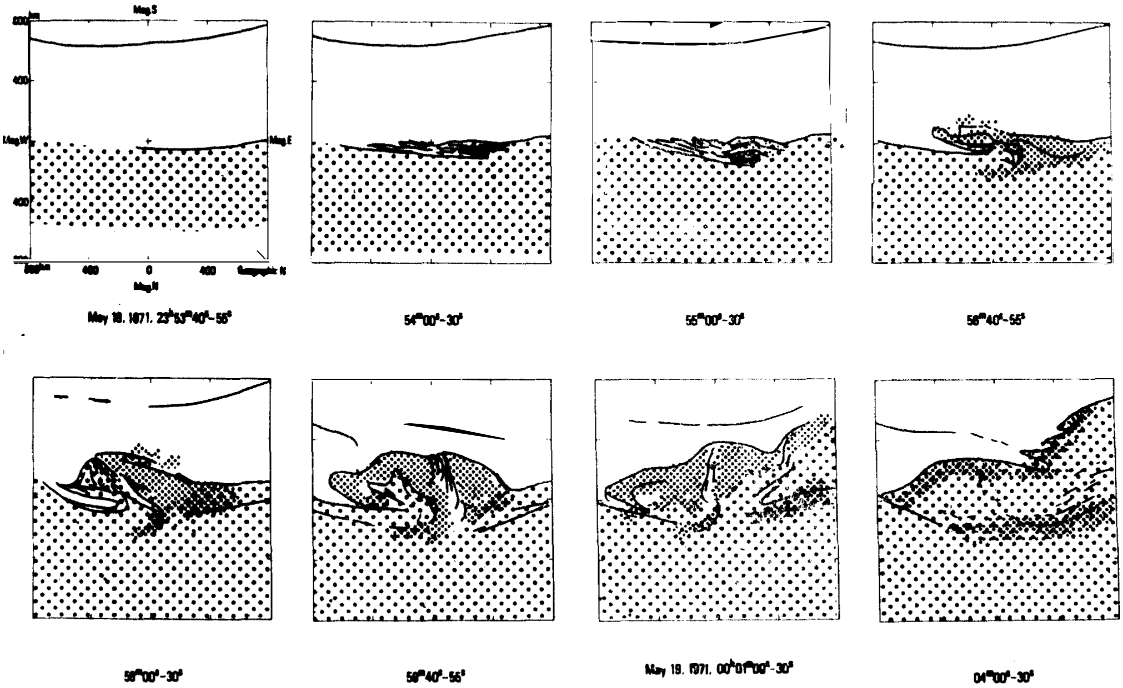


(*1a*) *All-sky camera photographs* (*in local geomagnetic coordinate; top–south, left–west*).

Fig. 1. Development of electron aurora and hydrogen emission



(*1b*) *Top: Meridian-time display of the electron aurora. Dense and sparse dots indicate active and diffuse auroras, respectively.*
Bottom: Meridian-time display of hydrogen (H_β) emission. The unit of the intensity contours is Rayleigh/Å.

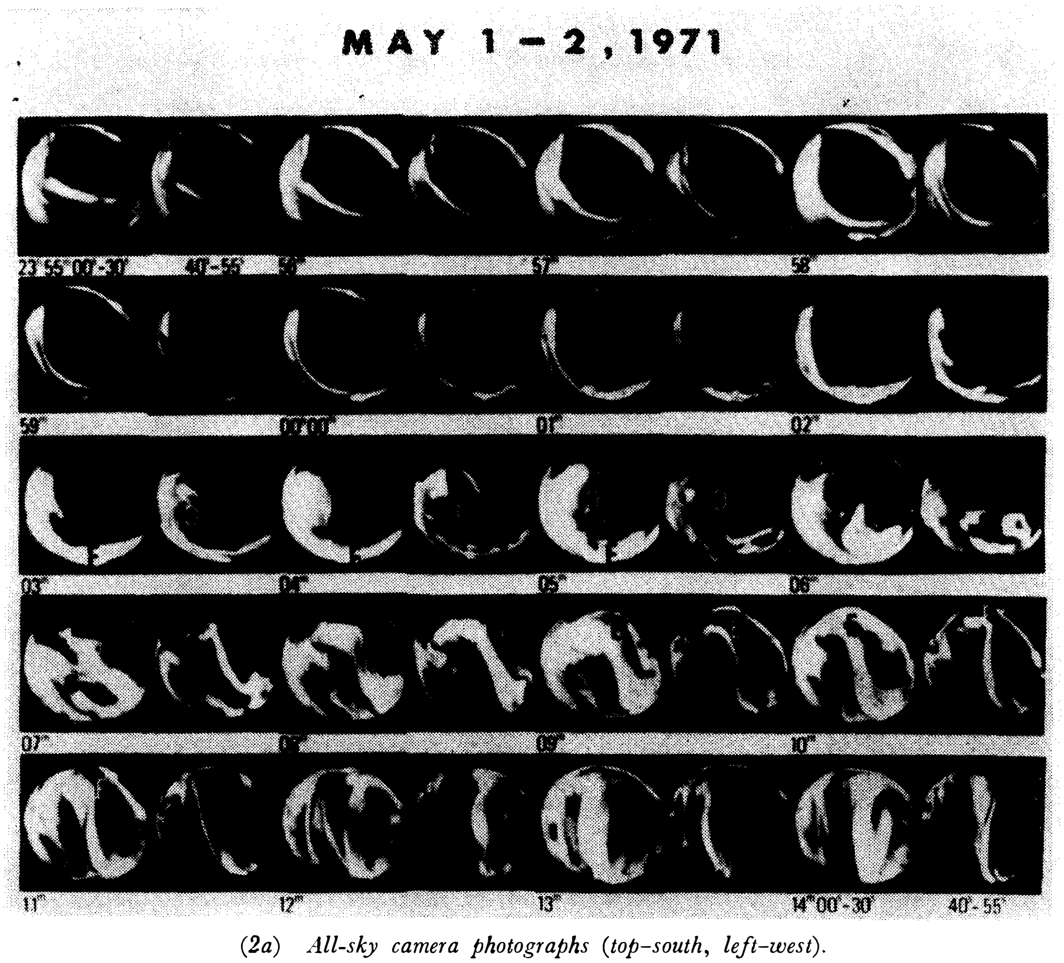


(*1c*) *Linear scale representation of the pattern and development of electron aurora and hydrogen emissions. Dense and sparse dots indicate the regions of strong and weak hydrogen emission, respectively. during the auroral breakup of May 18–19, 1971.*

shift precedes the onset of breakup. However, either the disappearance of aurora in high latitudes and the equatorward shift of aurora does not always lead to auroral breakup.

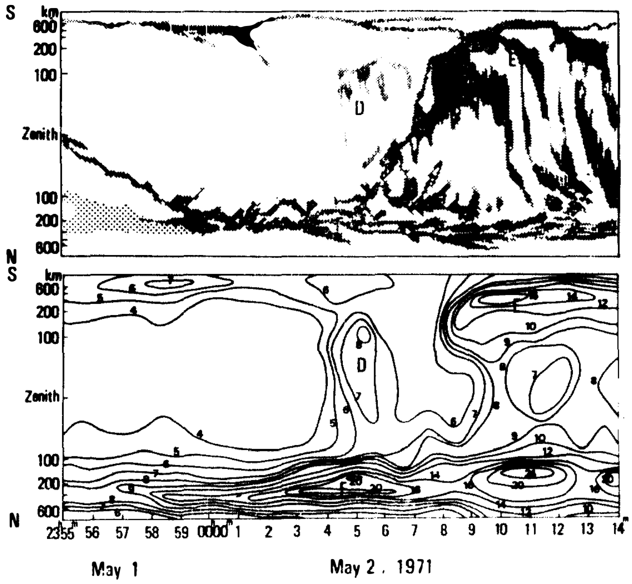
On the other hand, on many occasions breakup seems to start when the eastern end of the slant electron sheet aurora, which has split from the arc located in high latitudes and moved toward lower latitudes, comes into contact with the hydrogen arc. An example is shown in Fig. 2. A few minutes before 0000 May 2, 1971, an electron aurora splits from an arc at high latitude and moves equatorward. At 2358 to 0000 the electron aurora comes very close to the hydrogen arc and possibly comes into contact with it. Then, the breakup starts along the high latitude boundary of the hydrogen arc at the contact point or at the nearest point.

Several other cases of the contact breakup can be recognized in the auroral records in FUKUNISHI's report (1973a). The breakup without the "contact" such as the example 1 in this report may have the "contact" point out of sight.

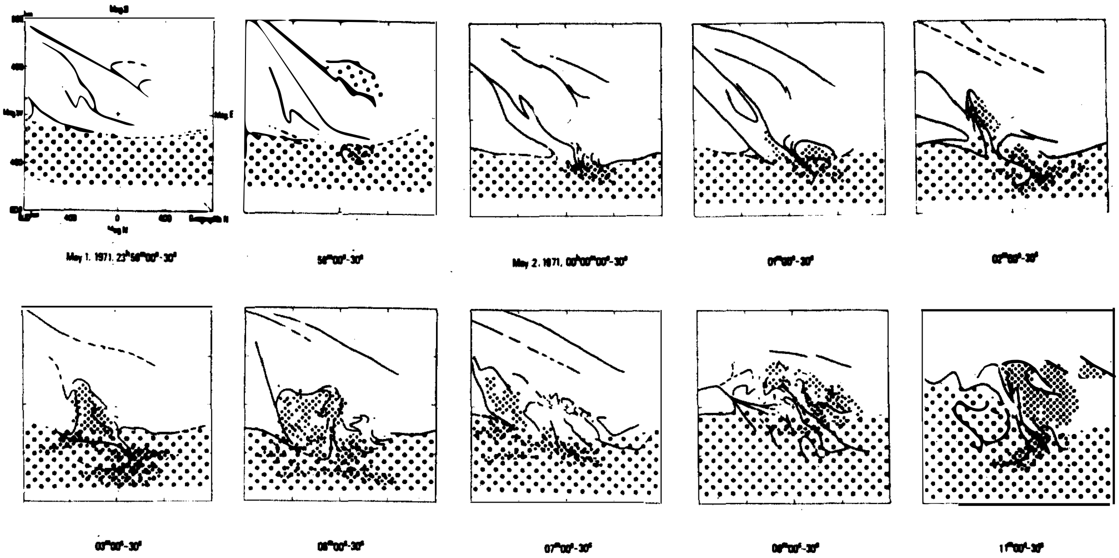


(2a) All-sky camera photographs (top–south, left–west).

Fig. 2. Development of electron aurora and hydrogen emission



(2b) Top: Meridian-time display of the electron aurora.
Bottom: Meridian-time display of hydrogen emission.



(2c) Linear scale representation of the pattern and the development of electron aurora and hydrogen emissions.

during the auroral breakup of May 1-2, 1971.

Nevertheless, we are not to claim, at present, that all breakups are initiated by the " contact ". The question remains as to whether all breakups are initiated by the contact or there is a distinction between contact and non-contact type auroral breakups.

The Distribution of Electron Aurora and the Region of Hydrogen Emission

After the activation of the electron sheet aurora, the overall level of the H_β emission is also augmented, as noted previously by MONTBRIAND (1971) and FUKUNISHI (1973a), but when viewed microscopically electron and hydrogen emissions do not act together. To illustrate this point, four regions of strong hydrogen emissions are indicated in Fig. 1 by A, A′, B and C (Fig. 1b, bottom). In the electron emission records (Fig. 1a, and 1b top) it is seen that all these four regions correspond to dark regions. Namely, in the region where the hydrogen emission is intensified the electron emission is weak. The same tendency is noted in the example of Fig. 3 where the regions of strong hydrogen emission designated as D, E and F are regions of weak electron emission. (Although AKASOFU *et al.* (1969) have recognized the absence of hydrogen emission in the surge, they have not mentioned the enhancement of hydrogen emission in the dark regions after the passage of the surge.)

The development of the May 1-2 aurora after the "contact" involves a series of rotations which are clockwise in the coordinate system of Fig. 2. At 0000 to 0002, the auroras in the contact region are intensified and split into multiple sheets. The western end of these sheets begins to rotate clockwise at 0002 and encloses region D of the hydrogen emission at 0005. This loop expands eastward and decays near the zenith. Another upturn of the electron aurora is seen to start at 0008 and a loop is formed at 0009 that accompanies the region E of the hydrogen emission near the southeastern horizon. Detailed pictures taken by the TV camera reveal that the eastward-expanding loop consists of small fragments of long-rayed thin sheets which are also rotating in the clockwise direction. As a result of the clockwise rotation the northwestern part of the loop becomes a N-S arc at 0009 to 0014.

Figure 3 is another example of distribution of electron aurora and proton emissions at the westward travelling surge on the occasion of breakup at 1830 of May 17. The west-poleward expanding front in this case is the electron aurora of a typical S-shape structure. It is worthy to note that the hydrogen emission is stronger on the east-equator side of the S-structure than the west-poleward side. Accordingly, strong hydrogen emission is seen on the loop which is open toward east, while the emission is relatively weak in the loop which is open toward west. In other words, the electron aurora appears at the west-poleward border of the westward-drifting front of the hydrogen region.

In the low latitudes of electron aurora, the sheet aurora splits from the poleward-expanding front, forming a loop at the eastern end of the S-shape, and drifts westward. Figure 4 indicates that the eastern end of the loop, which may be open toward west, regularly drifts westward, to be immediately followed by an

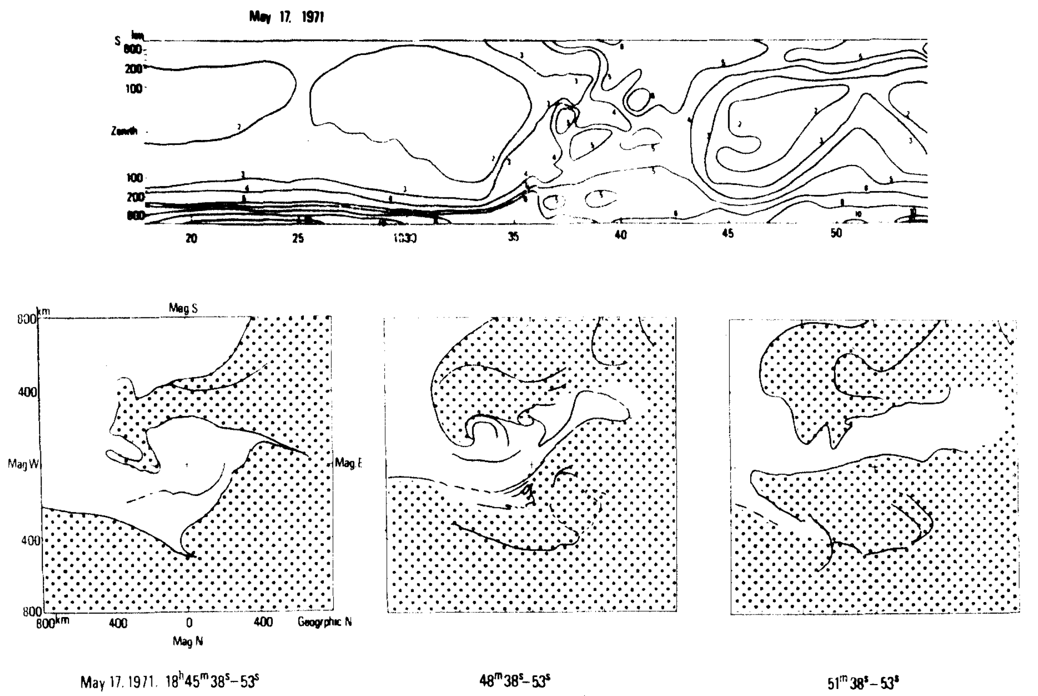


Fig. 3. *Development of electron aurora and hydrogen emission during the auroral breakup of May 17, 1971. The figure shows the part of the westward travelling surge of a global auroral activity. Dotted area schematically indicates the region of strong hydrogen emission.*

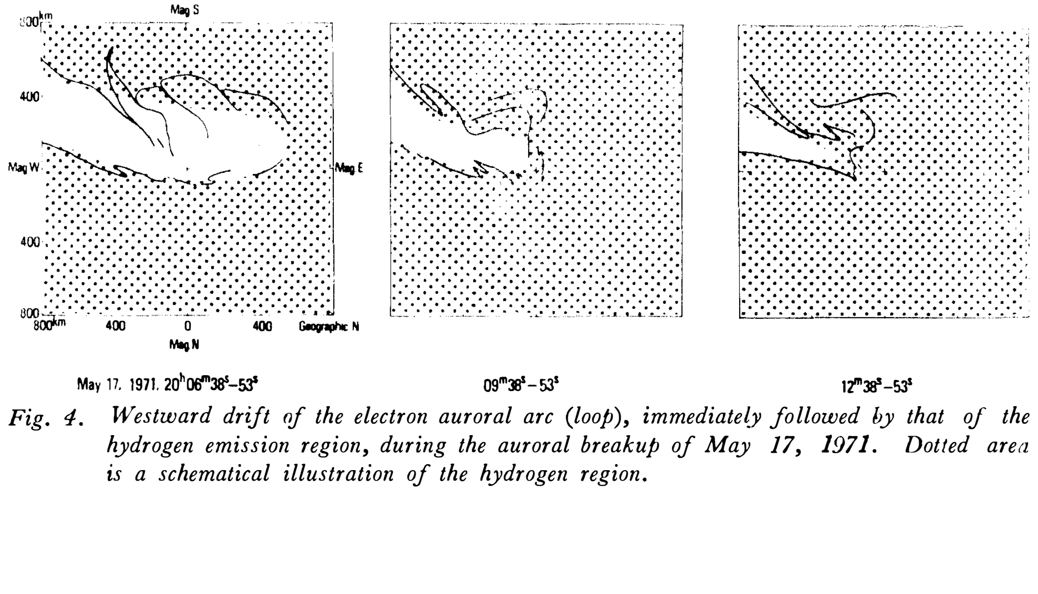


Fig. 4. *Westward drift of the electron auroral arc (loop), immediately followed by that of the hydrogen emission region, during the auroral breakup of May 17, 1971. Dotted area is a schematical illustration of the hydrogen region.*

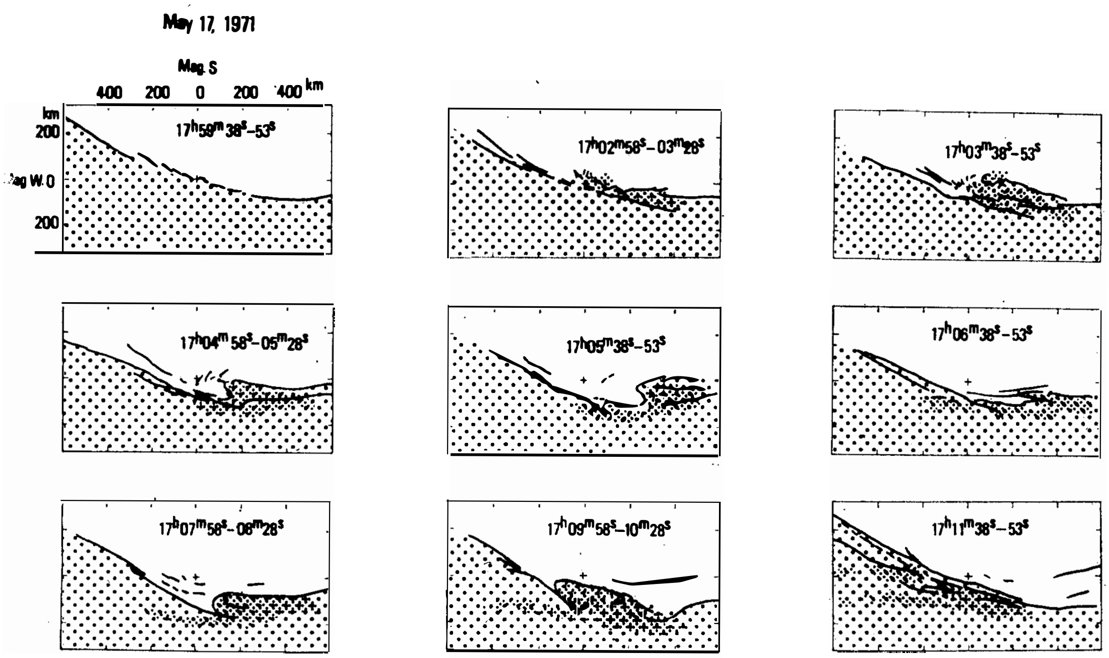


Fig. 5. Development of electron aurora and hydrogen emission during a local breakup which occurred in the evening of May 17, 1971. Though the pattern of the activity is much smaller than the previous examples, the general feature of development closely resembles the latter.

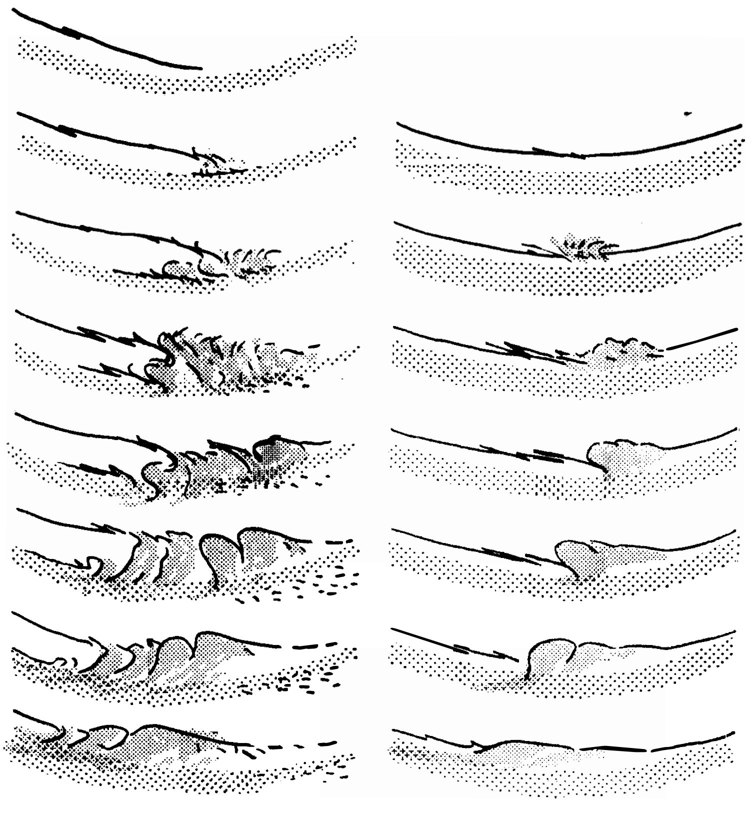


Fig. 6. A schematic illustration of a "contact breakup" (left) and a local breakup (right). The contact breakup starts when an electron sheet aurora, which has split from the high latitude arc, comes into contact with the hydrogen emission (indicated by sparse dots). Then a new electron aurora appears along the poleward boundary of the hydrogen emission, and the rotating expansion of the new aurora occurs in association with the enhancement of the hydrogen emission on its east-equatorward side. The local breakup is similar to the global contact breakup in the manner of development. The contact, however, is not clear.

enhancement of hydrogen emission. The electron aurora, in this case also, appears at the border of the hydrogen emission region. The speed of westward drift both in Figs. 5 and 6, is about 2 km/sec, which corresponds to the drift of protons in the magnetosphere in DEFOREST and MCILWAIN's result (1971), and to IPDP in FUKUNISHI's results (1973a, b).

Figures 3 and 4 are typical examples showing the utility of the meridian scanning photometer for obtaining the boundary and its movement in the hydrogen region by comparing with the pattern of electron aurora on all-sky photographs.

Thus we can conclude that there is a general tendency of spatial negative correlation between electron aurora and hydrogen emission. Hydrogen emission is enhanced in regions bounded by electron auroras, or in other words, electron aurora appears at the fringe of the region of strong hydrogen emission.

The enhancement of hydrogen emission depends on the local time as already pointed out by EATHER and JACKA (1966) and confirmed by FUKUNISHI (1973a). This corresponds to the general tendency of electron aurora which is stronger at dusk than at dawn.

A Possibility of Local Acceleration of Protons

The global distribution and development of electron aurora and hydrogen emission (*e. g.* FUKUNISHI, 1973a) suggest that acceleration of protons occurs mostly in the dawn sector and that of electrons in the dusk sector. However, we can see many examples of entirely local activation of electron aurora associated with a local enhancement of hydrogen emission.

An example of such a local activation (local breakup) is shown in Fig. 5, where the scope of the activation area is about several hundred km in area, and accordingly the whole activation can be recorded by the all-sky camera at Syowa Station. The splitting and the poleward expansion of electron sheet aurora occur at 1702, and the enhancement of hydrogen emission is found to fill up the split space. One or two minutes after the initial splitting, the hydrogen emission region shifts eastward first and in 4 minutes after the onset the drift changes its direction to westward, while it is confined to the low latitude side of electron aurora. Though the scale of the phenomenon is much smaller than the global breakup, the pattern and the mode of development are very similar to those of the global breakup.

This indicates that the pair acceleration of proton and electrons possibly occurs even in a limited area of several hundred km in horizontal scale as well as in global scale. The essential similarity between the local breakup and the global breakup suggests that the two phenomena are substantially equal.

Figure 6 schematically summarizes the global contact breakup and local breakup.

Discussion

The "contact" is not found generally on the occasion of a local breakup under the sensitivity threshold of the present all-sky camera.

There arises a question of whether the non-contact breakup is a local breakup and the contact breakup grows into a global one. However, we have not sufficient evidence to claim so at present, though many examples suggest that.

If we assume that electron and proton auroras occur at ionospheric projections of the plasma sheet and the proton trapping region, and that a global breakup occurs with contact whereas a local breakup begins without contact, the above observation indicates that the onset of the global auroral breakup is related to the close approach, or contact, of the inner boundary of the plasma sheet to the proton trapping region. Immediately after the onset of the breakup the region of electron precipitation spreads westward along the outer boundary of the proton trapping region, rather than along the inner boundary of the plasma sheet. It appears, therefore, that in the earliest stage of the breakup the steep outer boundary of the proton trapping region is the seat of the instability that causes the acceleration and/or scattering of the precipitating electrons.

During the poleward expansion of the aurora the electron precipitation tends to occur at the fringe of the proton precipitation region. This probably suggests the presence of the field-aligned electric field with a horizontal scale of $\sim$100 km. It may be that the electrons are accelerated at the front of the westward drifting proton clouds due to the electric field produced by excess positive charge.

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