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OBSERVATIONS OF AURORAL FADING BEFORE BREAKUP

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ABSTRACT

We have obtained detailed observations of the onset of auroral breakup using a variety of instruments with time resolution of some tens of seconds. Rapid sequences of all-sky photographs, and fast meridian scans by photometers, show that breakup is usually preceded by moderate brightening, followed by fading of the auroral brightness lasting one or two minutes, before the actual breakup itself. At the time of the fading there is a brief darkening of the poleward sky. Often the breakup is preceded by one or more rapid intensifications, each one preceded by local fading. Pseudo-breakups may also occur without the development of a major event. A bonafide breakup may begin on the fading arc, on an adjacent arc, or in an entirely new region nearby. This optical activity is closely correlated with the development of auroral radar echoes, suggesting that variations in the ionospheric and magnetospheric electric and magnetic fields are responsible for the observed auroral variations. Data from the IMS magnetometer network provide some indication of a correlated response by the local auroral and ionospheric currents, although this could be partly due to changes in conductivity. Riometer recordings show a slow decrease in ionspheric radio wave absorption over a period of about ten minutes prior to breakup, with the largest decrease essentially to quiet-time values in the region of auroral fading and subsequent breakup. The implications of these observations regarding the trigger mechanism for the expansion phase of a magnetospheric substorm are discussed.

OBSERVATIONS OF AURORAL FADING BEFORE BREAKUP

Risto J. Pellinen and Walter J. Heikkila

1. INTRODUCTION

Recognition of the magnetospheric substorm as a distinct entity has been a great advance in the history of auroral and magnetospheric physics. To some extent Birkeland (1908) discovered the concept, when he observed that during the course of a geomagnetic storm that generally lasts for a few days there can be several short lived, but intense events which he called "polar elementary storms". However, we owe to Akasofu (1968) the clear and explicit description of the magnetospheric substorm, with its many manifestations. His conclusions were based on an analysis of the large amount of coordinated data that became available during the International Geophysical Year, 1957-8; all-sky auroral photographs were an important part of the data set.

A singular event in the development of the substorm is the sudden brightening of one of the auroral arcs, followed immediately by an auroral breakup and poleward expansion (Akasofu, 1964). This brightening is well localized in space and in time, and so it can be used to designate T_o, the beginning of the auroral breakup and the expansion phase of the substorm.

In spite of numerous studies there is still no clear understanding of the processes that are responsible for the new activity. We do know that the expansion phase is essentially an explosive release of stored energy, whereby the magnetosphere adjusts itself from a state of high to a state of lower total energy. This energy is apparently stored during the growth phase of the substorm, partly as increased plasma energy, and partly in the associated magnetic field as it becomes distended into a more tail-like configuration. It is possible that the sudden release can be triggered from the outside, for example by changes in the solar wind or interplanetary magnetic field. However, it is also possible that it is triggered by some mechanism that operates entirely within the magnetotail, independently of any changes in the external conditions.

We have undertaken an observational study of the short period of time just before the auroral breakup, hoping to discover some new clues as to the nature of the physical processes that are involved. In situ observations within the magnetotail are, in practice, not especially suitable for this purpose; satellites in the magnetotail would not be likely to intercept the region involved, since it is presumably small, and even if one did it would provide only a single point observation. However, the processes operating deep within the magnetotail may be mapped down to low altitudes along the magnetic field lines (although there may of course be some distortion in the process), and development of activity may therefore be studied with ground based instruments. These instruments can be of several kinds, distributed over an area large enough to permit mapping of the spatial distribution and extent of the various features. The best network of ground based instruments in operation today is in northern

Scandinavia, particularly now that it has been augmented for coordinated studies with the GEOS satellite during the International Magnetospheric Study (IMS), 1976-9. For this initial phase of our study we have used data collected primarily in Finland, since this was readily available to us, and especially because some of the instruments, such as the network of all-sky cameras, were operated at several frames per minute to give good time resolution.

Examination of sequences of all-sky auroral photographs has revealed a fairly common feature of the onset of breakup that has not been reported previously: there is a distinct fade in the intensity of the auroral arc or arcs for about one or two minutes just prior to the brightening that is commonly used to define T_o. This fading was first suggested by data obtained by the auroral scanning photometer on the ISIS-2 satellite, with the satellite in the cartwheel mode with spin axis normal to the orbit plane (data obtained by Dr. C. Anger, University of Calgary). It was then clearly identified in a sequence of all-sky photographs, shown in Figure 1, taken on a flight of the Airborne Ionospheric Laboratory (courtesy of Dr. J. Whalen of the U.S. Air Force Geophysics Laboratory). The photographs, taken at one minute intervals, show a single bright auroral arc near the northern horizon,as well as a wide band of diffuse glow south of it. The quiet arc had existed without noticeable change for over 30 minutes before the set shown here. Suddenly the arc began to fade in intensity, having disappeared completely by the time the middle photograph was taken at 21.34 UT. One minute later the arc had reappeared in its former location, but at the same time a new arc began to form south of it: this new arc then developed into a major breakup event lasting for nearly one hour. The last photograph shown here would represent the classical onset time T_o defined by the first brightening of the aurora.

This observation prompted us to examine all sky photographs taken during a three week interval in January, 1975 in northern Finland. The cameras were operated at a rate of three frames per minute, thus providing better time resolution. It quickly became apparent that practically every major auroral intensification or breakup was indeed preceded by a brief fade, and a preliminary report of the findings was made (Heikkila and Pellinen, 1975). However, comments made by a number of persons indicated that more detailed and quantitative observations were needed before the fading phenomenon could be reasonably well demonstrated. Accordingly, we set up a meridian scanning photometer; it was operated during the N-MAC observing intervals centered on new moon dates during the winter of 1975-6 (see the Geophysical Calendar), and the first Porcupine Campaign March 17 - April 4, 1976 (IMS-Newsletter, 2, 1977, page 3). A number of new events suitable for study were thus recorded (IMS-Newsletter, 7, 1976, page 5). In addition, the large network of instruments set up for the International Magnetospheric Study (IMS) had come into full use (Stoffregen, 1976), providing a new dimension to the study, including in particular a fine grid of new magnetometers. Very recently, the breakup phenomenon has also been studied by means of the new Scandinavian Twin Auroral Radar Experiment (STARE, private communication by Dr. R. Greenwald, Max Planck Institute, Lindau); however, those observations are not yet analysed in sufficient detail to ' ` included in this paper.

We believe that clues regarding the nature of the trigger mechanism that sets off the expansion phase of a magnetospheric substorm are most likely to be found in detailed ground based observations of the kind now being made during the IMS. The phenomenon of auroral fading is one such clue. Correlated variations in other types of observations obtained during the IMS should go a long way toward revealing the nature of the substorm phenomenon.

2. INSTRUMENTATION

Observation of visible auroras provides probably the best resolution of the spatia. development of substorm activity. Furthermore, the definition of T_0 is based on auroral observations. Consequently, we regard the all-sky camera as the primary instrument for our study. Five of these were operated in a north-south chain, at the locations listed in Table 1 and shown on the map in Figure 2. These instruments are of a new design (Hyppönen et al., 1974), with digital time display accurate to the nearest second. With special processing the 16 mm color film can be used with an ASA rating of 1000, permitting good sensitivity with an exposure time of about two seconds. Radioactive sources were used to activate calibration surfaces, visible on each photograph, for calibrations in both the red and green parts of the spectrum. For most of our observing periods the cameras were operated at a rate of one frame per twenty seconds, but some data were obtained at a rate of one frame per eight seconds. Thus these all-sky photographs provided our best data in terms of resolution, in both time and space.

For a more quantitative instrument for these studies we used at Kevo two meridian scanning (360°per minute) photometers operating alternately on N_2^+ 4278 nm and HI 4861 nm(Hβ) wave-lengths. These photometers were synchronized with the all-sky camera clock to permit comparison of the all-sky pictures with the photometric recordings. A second photometer was routinely operated at Sodankylä at a lower speed. No correction was made to the Hβ recordings for possible electron produced effects.

Two standard geomagnetic observatories are operated in Finland, at Sodankylä and Nurmijärvi. Two German universities have provided a network of 38 magnetometers in Scandinavia for the IMS-period (IMS-Newsletter, 1977-1, page 4). A part of this network was operating already in January 1975, but the whole network was completed in the fall of 1976. The line through Kevo operated by the Technical University of Braunschweig produces digital data directly on magnetic tape; the rest of the network, operated by the University of Münster, stores data in analog form on 35 mm film. The time resolution is between 10 seconds to one minute in the both types of magnetometers. The data on the 35 mm film is digitized for selected periods. We have studied some examples of these data to see how magnetic phenomena associated with the auroral fading are observed throughout the network. More detailed studies of variations in the current systems will be published in joint publications with the other groups.

Two auroral back-scatter radars provided additional supporting data. The 97.0 MHz transmitter for one radar used an omnidirectional antenna at Pihtipudas, while the receiver at Sodankylä used a directional antenna with 30° beam-width pointing north as shown on the map. This system is sensitive to auroral backscatter in a very limited region north of the line of all-sky camera stations, as shown in Figure 2. The center of this region is near 72°N, 29°E, being at an invariant latitude of 68°; auroras in this region are within sight of Kevo and Ivalo. Analog recordings were made with a chart speed of 80 mm/h.

The 144.96 MHz transmitter for the second backscatter radar was situated at Borlänge, Sweden, while the receiver used in this study was situated at Nurmijärvi. The effective backscatter region was situated between 65°N and 66°N geographic and near 63° invariant latitude. The closest all-sky camera stations to this location were Oulu, Muonio and Sodankylä. Recordings were made with a chart speed of 120 mm/h.

A chain of seven riometers for measurement of ionospheric absorption of cosmic radiowaves, also listed in Table 1, was operated on a routine basis through all the studies. The operating frequency was 27.6 MHz, and the region sampled at 100 km altitude was about 200 km in east-west, and about 90 km in north-south extent, as shown by the shaded areas in Figure 2. The data were recorded with a chart speed of 60 mm/h, allowing one minute time resolution.

Some additional supporting photometric, radar and all-sky data were obtained from the other Scandinavian countries and the Soviet Union. More details on the instruments and networks used in this study are given by W. Stoffregen (1976) in the CCOG - Handbook for the IMS-GEOS (Period 1976-79).

3. OBSERVATIONS

(a) January 8, 1975

Five breakup events were chosen in our earlier work (Heikkila and Pellinen, 1975); as an example of these we show event number 4, exhibited in Figure 3; it was observed at Sodankylä in the evening sector. The arc that faded was formed by 18:07 UT, and ten minutes later it was bright and quiet, situated slightly to the south of Sodankylä, near Rovaniemi. The northern sky had cleared for a while, but then a new arc started to form there. Fading of auroral intensity was registered over a two minute period, with minimum intensity at

18:19 UT, on both the southern and northern arcs. At the same time, the northern sky became quite dark, as may be seen on the original film. The brightness then increased slowly at first, but by 18:21 UT bright arcs were registered both to the north and to the south. At 18:24:43 a westward travelling surge (WTS) started to move, leading quickly to breakup.

This fade was well located for observation by the 144.96 MHz radar at Nurmijärvi. Figure 3 shows a steady decrease in echo amplitude from 3.2 db down to 0.5 db at the moment of fade. The subsequent increase in intensity was slow at first, and then rapid as the aurora also brightened. The 97.0 MHz radar record looks rather different but this is probably due to the fact that its backscatter region is well north of the auroral breakup. In fact a slightly earlier breakup, beginning at 18:18:30, was registered at Kevo 400 km to the north, as may be seen at the very top of these photographs. Thus the 97.0 MHz radar return reflects a combination of these two breakups. In any case, it too shows fading of the echo just before breakup at 18:25 UT.

The riometers at Rovaniemi and Oulu show a similar pattern, with some absorption before 18:18 UT and a reduction in absorption at the time of the auroral fade. This absorption is essentially down to quiet time values. The Kevo riometer shows a faster breakup at 18:20 UT.

(b) October 30, 1975

Our next example is from the first night of observations with the faster meridian scanning photometer; we both witnessed the events by eye. There was weak to moderate aurora during most of the evening, with a rather complex pattern of magnetic and radio activity. The all-sky photographs show an auroral breakup of moderate intensity beginning in the north-west part of the sky at Kevo at 20.39 UT.

Before the main breakup there were two weak auroral intensifications and fades during the previous hour. Then, with weak to moderate emission from most of the sky, an arc developed in the north again, brightening steadily as it moved southward after 20:31 UT (Figure 4). It faded appreciably at 20.38 UT, as can be seen by the photometer record; it also shows a darkening of the poleward sky. After 20.39 UT a new feature shows up toward the north-west, leading to auroral breakup.

The development in the hydrogen emission is interesting. As the emission in the zenith faded, a distinct hydrogen arc appeared in the southern part of the sky, just above the horizon. This remained in place as the new activity began in the north. The hydrogen emission in the north was slightly fading at 20:38 UT, but it increased thereafter in the same part of the sky as the electron excited breakup began.

(c) April 2, 1976

The third event on 2 April, 1976, is from an active period, following an x-ray flare at 18:40 UT on 28 March, and a sudden commencement at 02.55 UT on 1 April. The radar echoes show the onset of breakup just before 21:00 UT (Figure 5), or more precisely between 20.56 and 20.57 UT as shown by the all-sky photographs in Figure 6. The short spike in the radar record at 20.54 is probably real (although the earlier one may not be), since it occurred at the same time as the auroral arc developed a ray structure (see the first photograph). On other occasions we have seen the echoes enhanced when rays appeared. Thus again the radar return faded at 20.56 UT.

A deep fade at 20.56 UT was recorded by the photometer at 427.8 nm (Figure 6). All-sky photographs show that this fading was quite localized, being most pronounced just to the west. The continuous bright arc at 20.55:23, west of the bright spot, shows a short bite-out in the next two photographs at 20 second intervals. In addition, there was a distinct but brief diminution of the sky brightness toward the north of the arc at 20.55:43 UT; this was made obvious by the fact that the northern horizon did not stand out against the moonless sky on that one photograph. This brief minimum was missed by the photometer, which was viewing in H_β at the time. By 20.56:23 UT the spot to the east began to grow in size and intensity without appreciable motion, and it soon filled most of the field of view.

Again there seemed to be weak proton activity to the south, but there was a burst of protons in the zenith at the time of auroral breakup.

The storm magnetometer record from Sodankylä is shown in Figure 7. The onset of breakup at 20.56 is seen most clearly in the D-component, suggesting that a strong field-aligned Birkeland current began at that time. The actual breakup was preceded by several distinct peaks in the D-component, and it appears that these are closely correlated with the variations in auroral brightness, which showed several distinct increases clearly identifiable in the all-sky photographs (not included). Inspection of the set of regional IMS magnetometer records supports the view that the brief increases in auroral brightness might be accompanied by spurts of field aligned current. It seems as if the magnetotail were trying to achieve breakup, but in each of these three or four preliminary attempts it did not quite make it. Qualitatively, there seems to be little difference between these preliminary pulses and the final one that did lead to breakup.

(d) April 6, 1975

The auroral radar backscatter echoes on April 6, 1975, obtained on the Pihtipudas-Sodankylä bistatic system (Figure 8), shows the sudden onset of an auroral breakup at 21.22 UT. The activity on this night is being reported by Pellinen et al. (1977) in great detail, so we report only the salient facts.

Auroral forms existing before 21.17:03, seen in the all-sky photographs taken at Kevo and Ivalo (not included) produced little or no radar returns. They were generally of a quiet nature, although a number of alternate minor brightenings and fades took place. Some simultaneous small changes in the magnetic field occurred; for example the H and D components at Kiruna showed small increases during each brightening, and a return toward undisturbed values during each fade. A brightening at 21.17 (shown in more detail in a rapid series of photographs from Ivalo at 8 frames per minute, data not included) was the first one to produce a definite, but temporary, enhancement in the radar return. Although the subsequent auroral activity is rather complex, the occurrence of large scale fading of activity is shown clearly by the loss of the echo between 21.19:25 and 21.21:30 UT. During this time the main auroral feature was a short bright segment that travelled rapidly from west to east.

From the continued all-sky pictures taken at Ivalo (Figure 9) we can state that the first indication of the new activity that led quickly to breakup was the formation of fine rays distributed in a loop around the zenith at 21.21:34. At the same time the bright segment of arc shown at 21.21:03 in Figure 9 began to twist itself suggesting the beginning of an upward electric current. This suggestion is supported by the magnetic horizontal component recordings around Kiruna (Pellinen et al., 1977). The subsequent radar and optical data both show the rapid development of a major breakup directly overhead at Ivalo.

The riometer record in Figure 10 shows the complete absence of precipitation of energetic electrons at Kevo at the moment of the fade; overhead at Ivalo it shows a slight reduction before breakup.

Irregular magnetic pulsations appear in the recordings of all stations before the main phase of the substorm. There are three (possibly four) separate bursts before the onset of the main burst at 21.22 UT (J. Kangas, private communication). Between 21.19 and 21.22 UT there is a distinct minimum in the pulsation activity at Kevo (Figure 11) which is located nearest to the breakup area.

4. CONCLUSIONS

Transient fading of quiet auroral forms prior to breakup appears to be a rather common phenomenon. We have described only a few events, but we can distinguish many others in the data obtained during our observing periods. There are, of course, always random variations of auroral intensity, some of which may not be significant. However, the pattern of development that we have described above is observed with such regularity in the few minutes preceding the breakup that it does appear to be a characteristic of substorm development. The main features seem to be as follows.

(1) Quiet auroral forms fade briefly in intensity, for about one or two minutes, just before breakup initiates the expansion phase of a substorm; at the same time there is a darkening of the poleward sky (Snyder and Akasofu, 1972). The fading is usually preceded by a short intensification of the auroral brightness. In some cases "multiple onsets" can be recognized, with a sequence of fadings and intensifications of short duration prior to the final breakup.

(2) There is a simultaneous weakening in the strength of back-scatter radar echoes. Usually the behaviour of the radar echo and optical aurora are similar during the multiple onset events.

(3) The fading can be best recognized in the electron aurora. The proton aurora shows similar behaviour, but somewhat weaker.

(4) The fading can be seen in the magnetic H and D components, most clearly close to the breakup region.

(5) There is a weakening of the magnetic pulsation activity just before the breakup.

(6) Ionospheric absorption of radio waves also decreases, nearly reaching quiet time levels in the vicinity of the auroral fade. There are typically two different types of decrease often acting simultaneously: (a) slow variation starting about 15 minutes before the breakup, and (b) rapid decrease correlated well with back-scatter and other observations just prior to the final onset (Pytte et al., 1976).

(7) The fading occurs under a variety of conditions: before and after midnight, during quiet and active periods, on poleward and equatorward auroral arcs.

(8) The subsequent increase in activity that initiates the expansion phase can take place on the same arc that show the deepest fade, or it can occur on another arc, often a new arc, either poleward or equatorward of the fading arc.

(9) On many occasions it is clear that the aurora fades in place, while at other times there is a suggestion that the fade travels ahead of a surge, either eastward or westward.

(10) The geographical area where fading occurs simultaneously, or nearly so, can have dimensions of as small as a few hundred kilometers.

5. DISCUSSION

It is rather surprising that this fading has not been reported earlier, since it appears to be a very common feature of auroral breakup. Perhaps this is due to inadequate time resolution, since most all-sky cameras operate at a rate of only one photograph per minute. Meridian scanning photometers are often even slower. Another reason may be that the fading may seem insignificant, in comparison with the spectacular developments that follow during the auroral breakup. However, it is possible to identify similar fades in published data. For example, Fukinishi (1975) shows data for several breakup events where fading is evident, as at 21.31 on September 27, 1970 (Figures 10a and 10b of his paper), and at 22.03 on September 6, 1970 (his Figure 13).

One practical lesson to be learned from these observations is that it is necessary to have good time resolution, often to within a few seconds, in order to resolve the rapid development of auroral breakup. Although this fact is surely obvious and well known, nevertheless practical considerations (such as a desire to limit the volume of data that is collected) are often allowed to compromise an adequate observing program. Our fast sampling rate was inspired by the appeal for good time resolution in the project for Noon-Midnight Auroral Correlations (N-MAC), proposed by Heikkila and Hultquist in the first Newsletter of the Joint IAGA-URSI Working Group on the Auroral Oval and its Extension into Space, September, 1974. These N-MAC periods have been included in the Geophysical Calendar for 1976, 1977, and 1978.

We think that the fading phenomenon is an indication of the behaviour of the magnetospheric electric field. This is borne out by the fact that auroral radar returns are due to an instability in the E region of the ionosphere that depends on the electric field. Thus, at the time of the fade, the magnetospheric electric field is diminished locally in the vicinity of the fade. The transverse electric field causes the lowering of mirror points for particles undergoing adiabatic energization (Heikkila, 1974), due to conservation of the first adiabatic invariant. Removal of this field will hold the mirror points constant, removing the precipitation. This is true at all energies, such as the kilovolt electrons causing the aurora, and the 100 kilovolt electrons causing the riometer absorption. Also, it is true of both signs of particles, thus explaining how the protons can behave in the same manner as the electrons.

There can be two distinct mechanisms for the electric field, namely charge polarization causing an irrotational field, and induction producing a rotational field. Induced electric fields must be involved in the expansion phase, at least if it is assumed that the magnetic field supplies the energy. Polarization of the plasma has serious difficulties in neutralizing the induced electric field (<u>Heikkila and Pellinen</u>, 1977). We think the fading phenomenon is an expression of those difficulties.

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We appreciate the opportunity of studying data collected by Cliff Anger using the ISIS-2 auroral scanning photometer, and all-sky photographs taken by Jim Whalen on the Airborne Ionospheric Laboratory, operated by the Air Force Geophysics Laboratory. The first recognition of auroral fading came from these studies in January, 197[illegible]. We also wish to express our gratitude to Mrs. Hilkka Ranta at Sodankylä Geophysical Observatory and Prof. Jurgen Untiedt at the University of Munster for providing the data for this study, and to Drs. Ray Greenwald and Jorma Kangas for valuable discussions. We thank Dr. B. Maehlum of the Norwegian Defence Research Establishment for providing the photometer, and Dr. K. Maseide of the University of Oslo for doing the calibration.

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FIGURE CAPTIONS

Figure 1. A sequence of all-sky photographs illustrating the optical auroral fading prior to activation. This is the series of figures where we first time identified this phenomena. (The photographs were taken on the Airborne Ionospheric Observatory; courtesy of Dr. J. Whalen of the U.S. Air Force Geophysics Laboratory).

Figure 2. Map of northern Scandinavia showing the locations of various instruments; see Table 1 for coordinates. The large circles give the field of view of the cameras at 100 km for 15° elevation angle. Shaded areas indicate the riometer coverage. The dotted areas show the most effective back-scatter curves of the two radar systems, and the arrows indicate the direction of maximum antenna gain.

Figure 3. An example of the fading diagrams of our preliminary study in 1974-75. Observe the similarities in the riometer recordings at Rovaniemi, 144.96 MHz backscatter recording, and the variation of the auroral brightness. The all-sky pictures are from Sodankylä, and the fading arc is located in the southern sky near Rovaniemi.

Figure 4. Meridian scanning photometric recordings (427.8 and 486.1 nm), and all-sky photographs at Kevo on October 30, 1975. Fading is observed at 20.39 UT, and the breakup starts at 20.40 UT.

Figure 5. Auroral backscatter recording on April 2, 1976. Fading of the intensity was observed at 20.56 UT.

Figure 6. Meridian scanning photometric recordings (427.8 and 486.1 nm), and all-sky camera observations at Kevo on April 2, 1976. The scan is from south to north. Optical fading from 3.7 % to 0.8 % observed at 20.56 UT.

Figure 7. Storm magnetogram from Sodankylä on April 2, 1976. The fading moment at 20.56 UT is clearly seen in the H and D components. There was some precursor activity in the D component, suggesting field aligned currents.

Figure 8. Auroral backscatter recording from the Pihtipudas-Sodankylä radar. The amplitude is given in arbitrary units. Loss of the echo was observed between 21.19:25 and 21.21:30 UT. The 144:96 MHz radar, located in south, did not record any echo during 21 to 23 UT.

Figure 9. Sequence of rapid all-sky photographs taken at Ivalo on April 6, 1975; the breakup started at 21.22 UT.

Figure 10. Cosmic noise absorption recordings from Kevo and Ivalo for April 6, 1975. An auroral fade occurred from 21.19 to 21.22 UT. Quiet time levels are shown by the solid line.

Figure 11. Pulsation recordings show a decreased intensity at the moment of the fade.

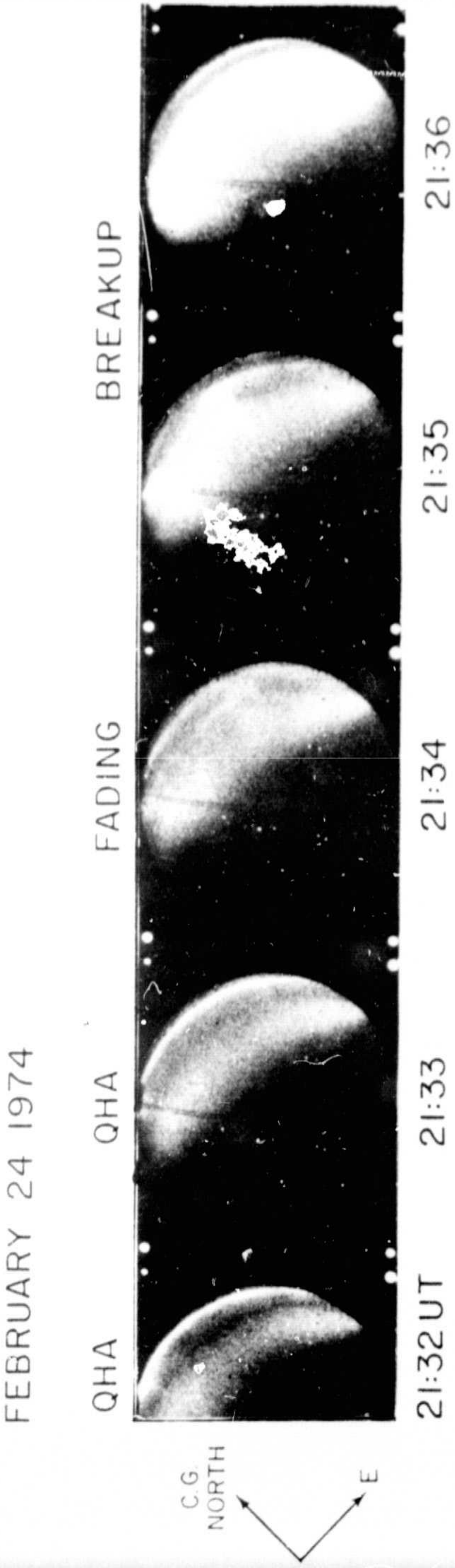
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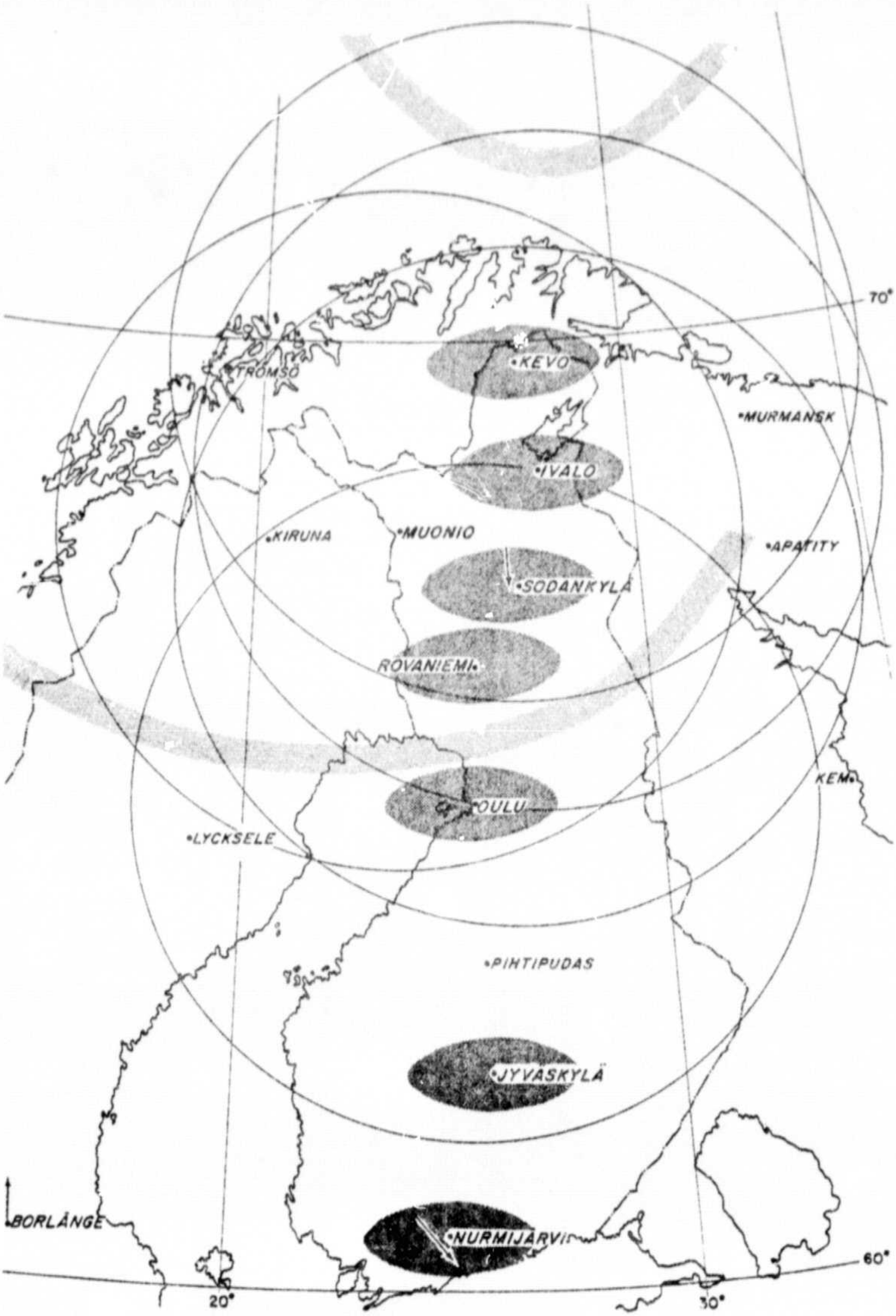
Figure 1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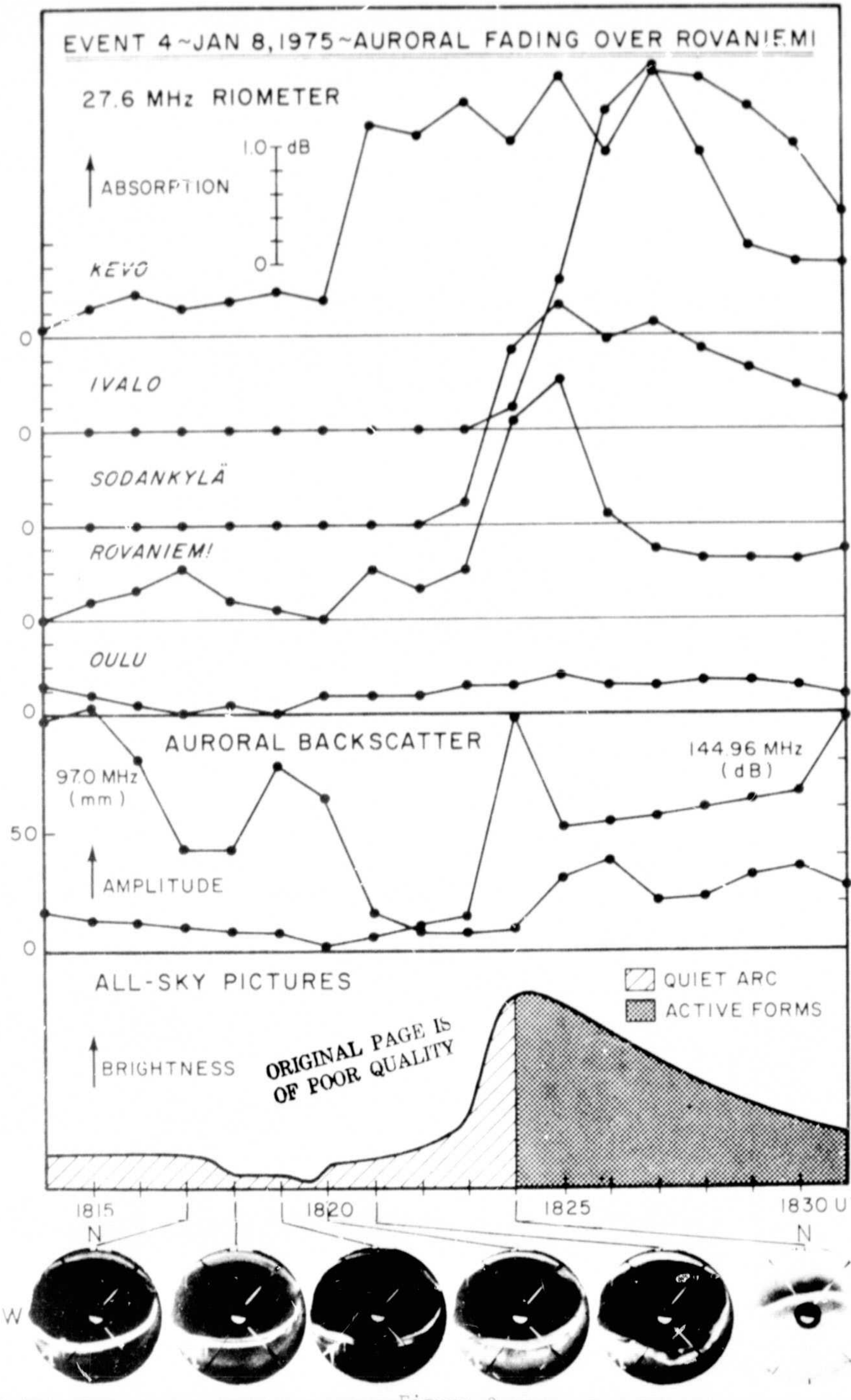
•PIHTIPUDAS
•JYVÄSKYLÄ
BORLÄNGE
•NURMIJÄRVI
60°
20°
30°

Figure 2



EVENT 4~JAN 8,1975~AURORAL FADING OVER ROVANIEMI
27.6 MHz RIOMETER
1.0 dB
0
ABSORPTION
KEVO
IVALO
SODANKYLÄ
ROVANIEMI
OULU
0
0
0
0
0
AURORAL BACKSCATTER
97.0 MHz (mm)
144.96 MHz (dB)
dB
16
12
8
4
0
50
0
AMPLITUDE
ALL-SKY PICTURES
QUIET ARC
ACTIVE FORMS
BRIGHTNESS
ORIGINAL PAGE IS OF POOR QUALITY
1815
1820
1825
1830 UT
N
N
W
E

Figure 3

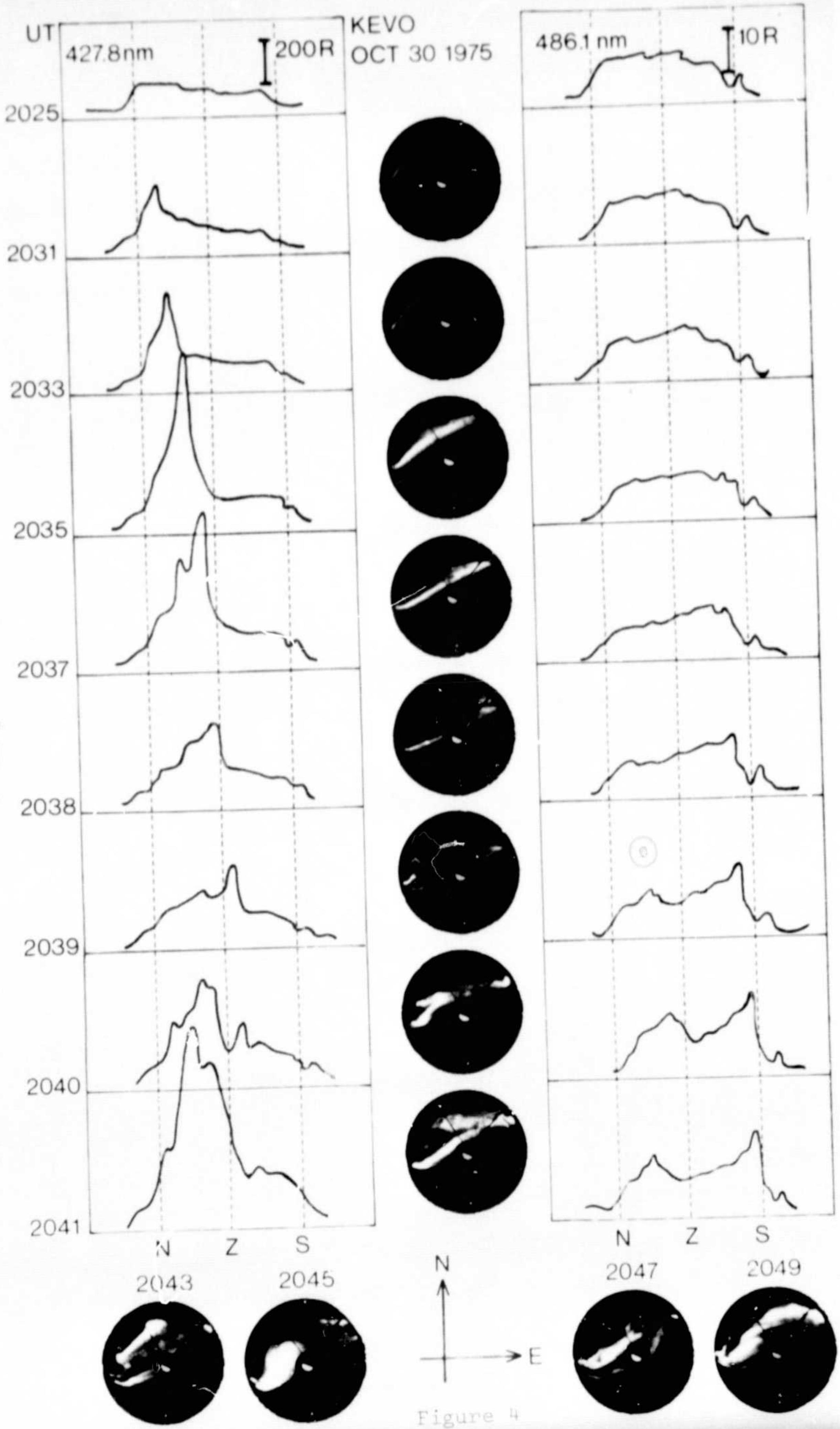

UT
427.8nm
200R
KEVO
OCT 30 1975
486.1 nm
10R
2025
2031
2033
2035
2037
2038
2039
2040
2041
N
Z
S
2043
2045
2047
2049
E

Figure 4

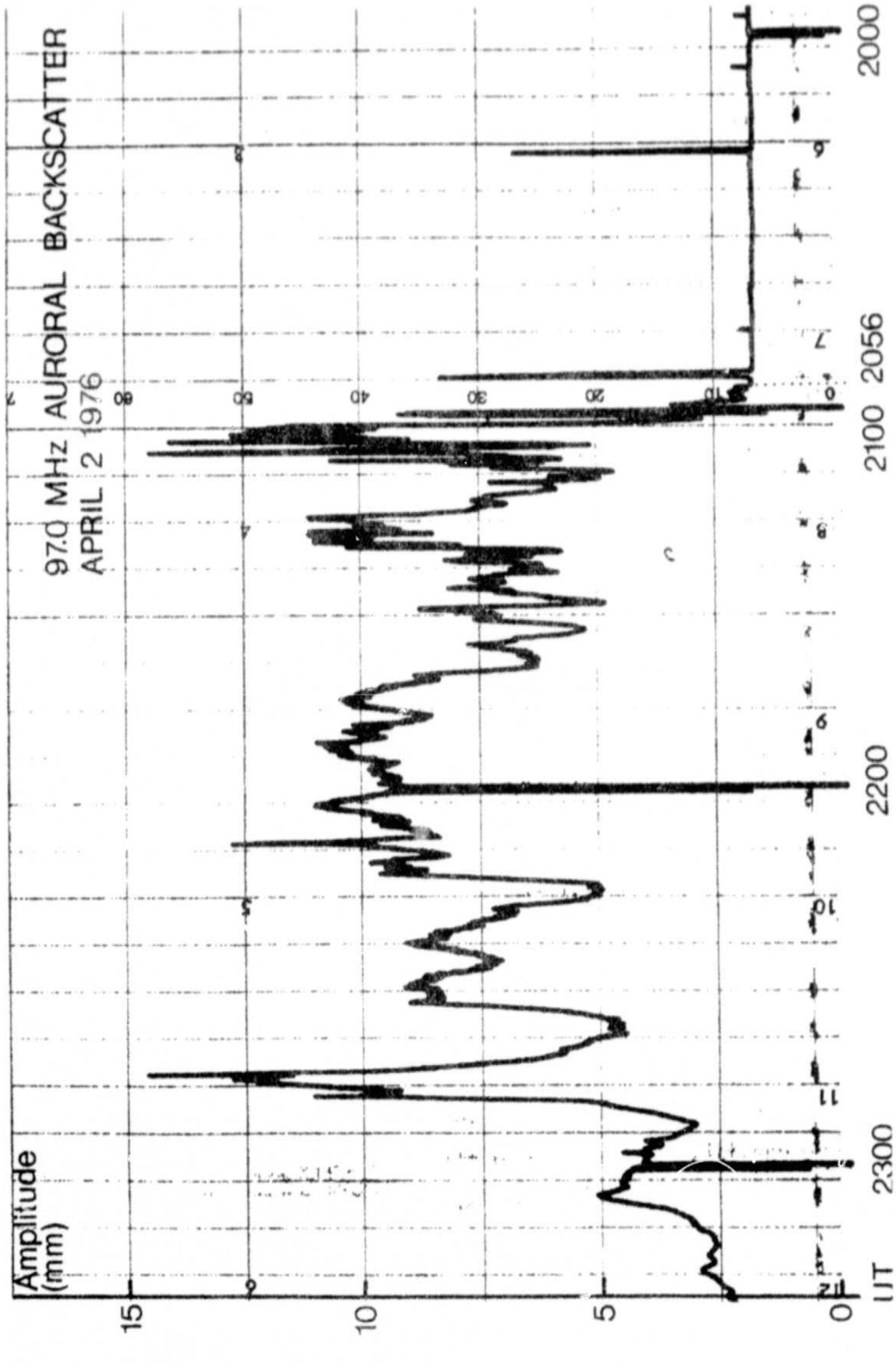
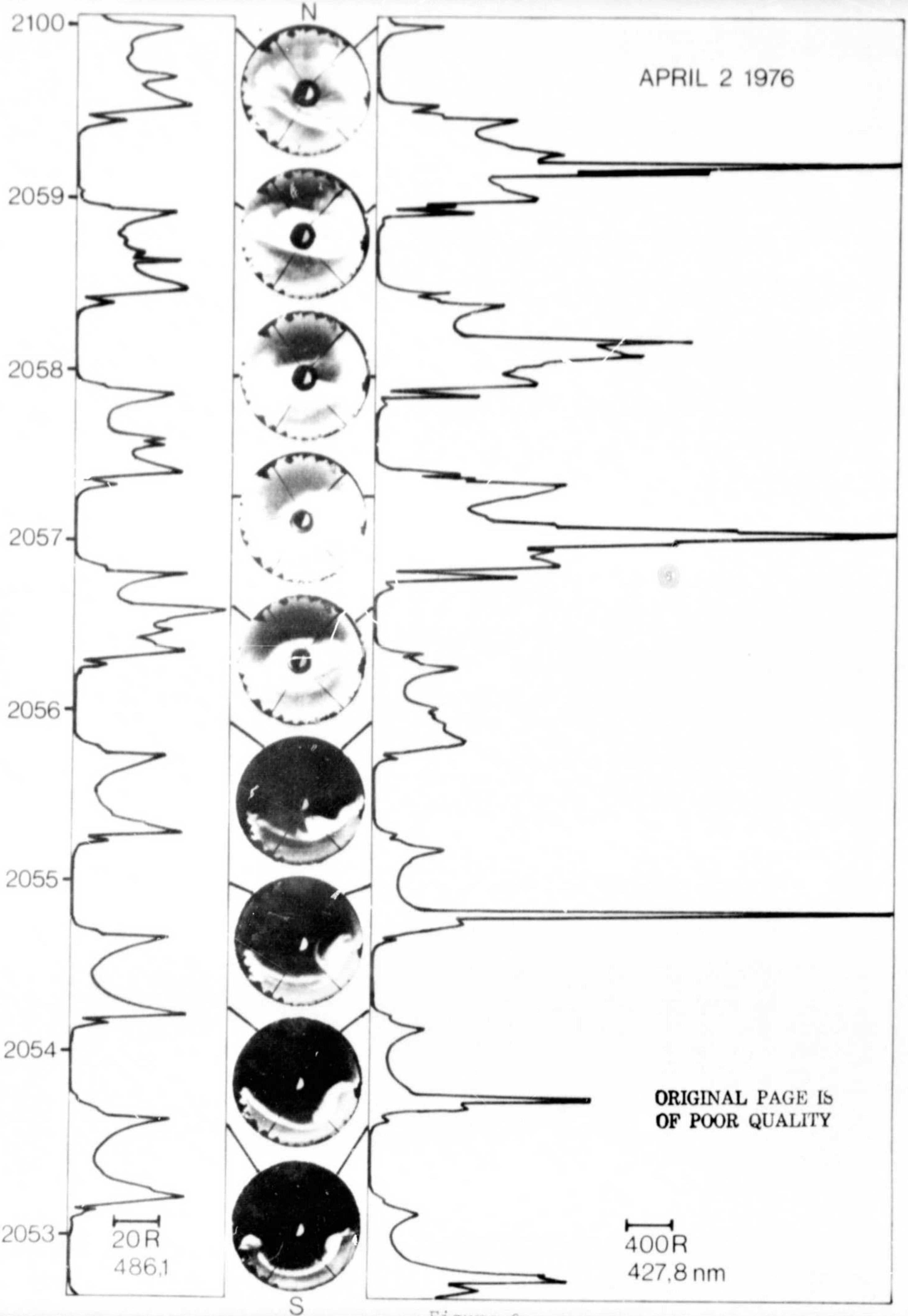

97.0 MHz AURORAL BACKSCATTER
APRIL 2 1976
Amplitude (mm)
15
10
5
0
UT
2300
2200
2100
2056
2000

Figure 5



N
S
APRIL 2 1976
2100
2059
2058
2057
2056
2055
2054
2053
20 R
486,1
400 R
427,8 nm

Figure 6

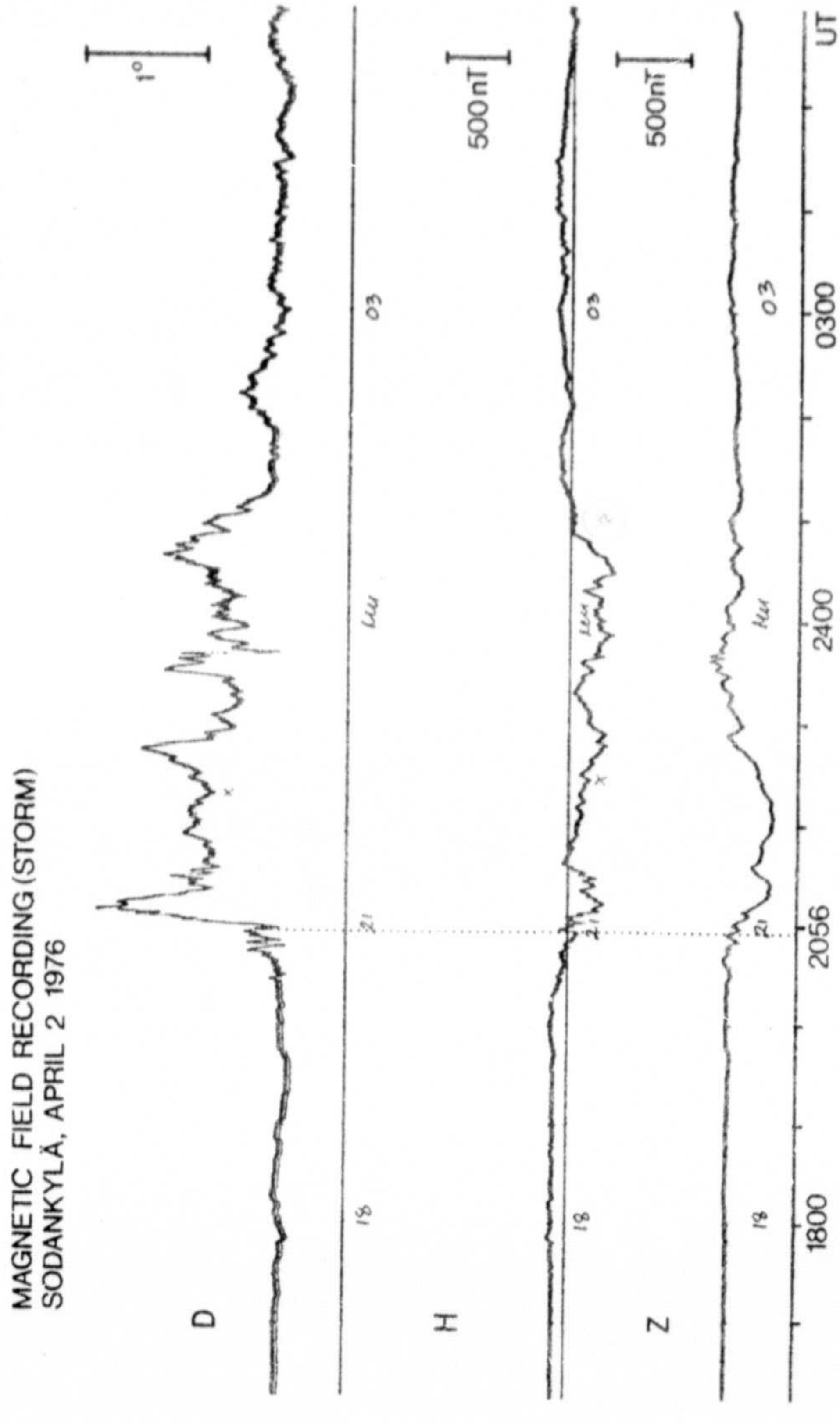

MAGNETIC FIELD RECORDING (STORM)
SODANKYLÄ, APRIL 2 1976
D
H
Z
1°
500nT
500nT
1800
2056
2400
0300
UT

Figure 7

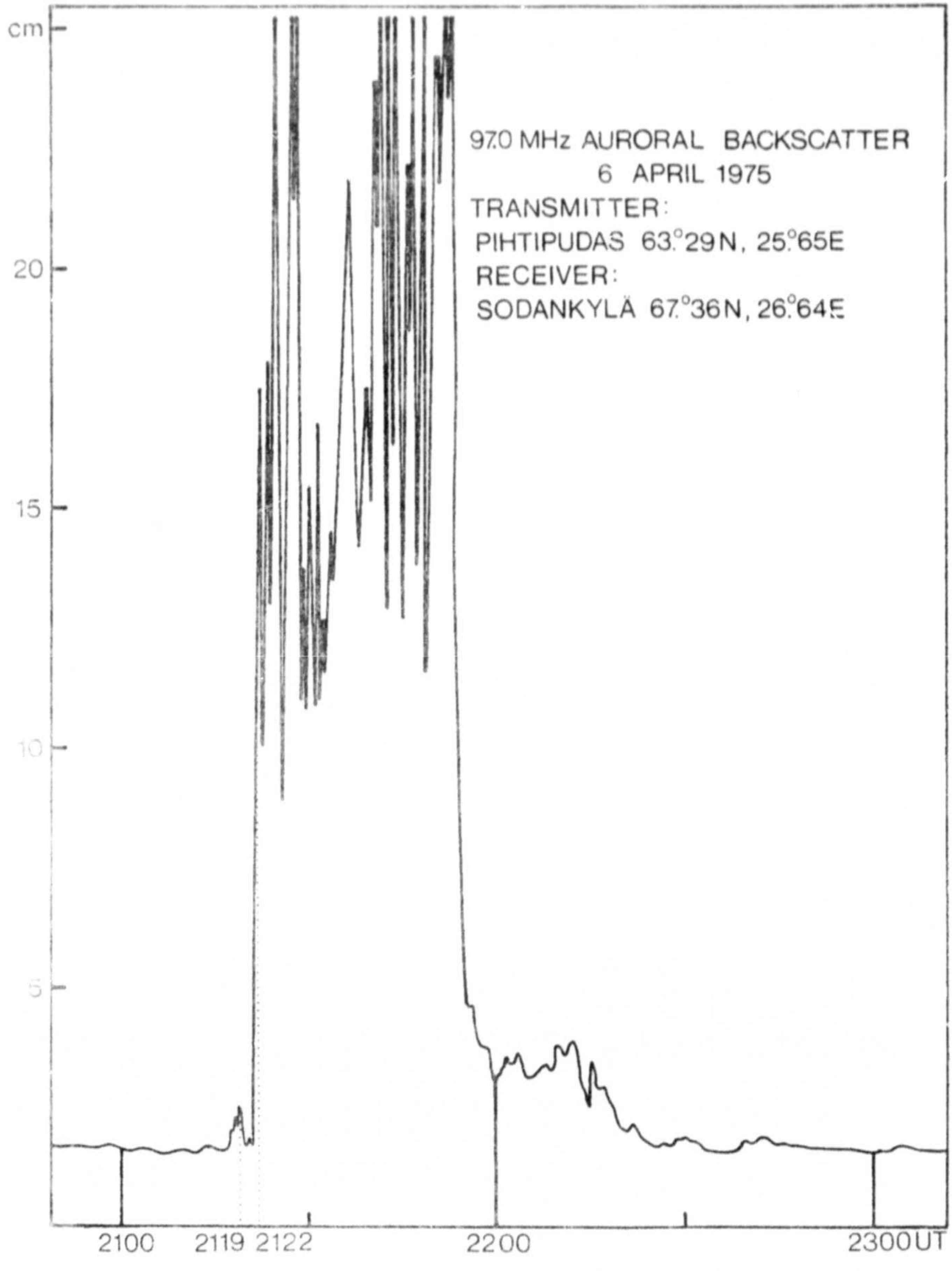


Figure 8

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APR 6 1975
IVALO
ALL-SKY PHOGRAPHS
1 FRAME/8 SECONDS

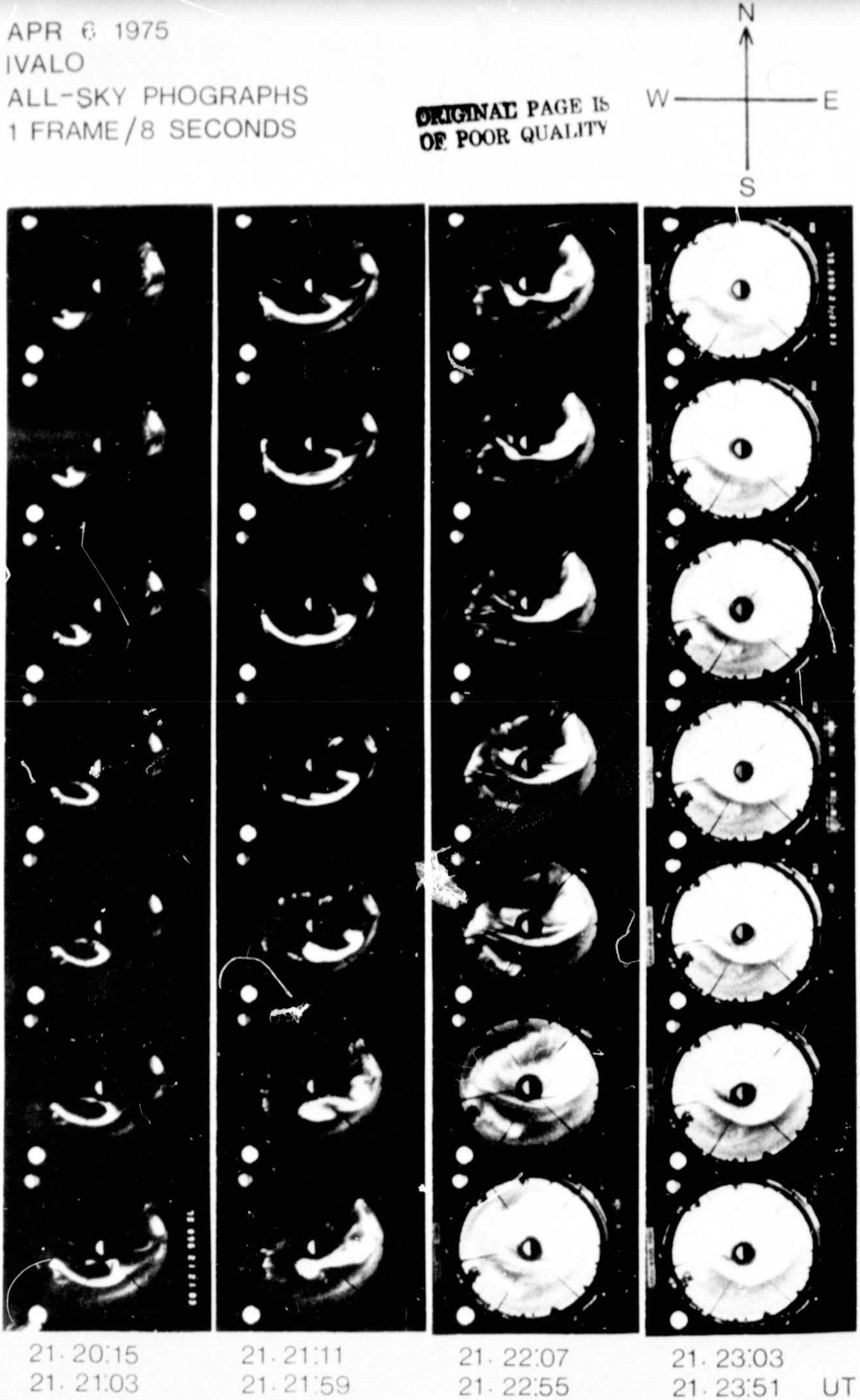

Figure 3 (continued)

Figure 9

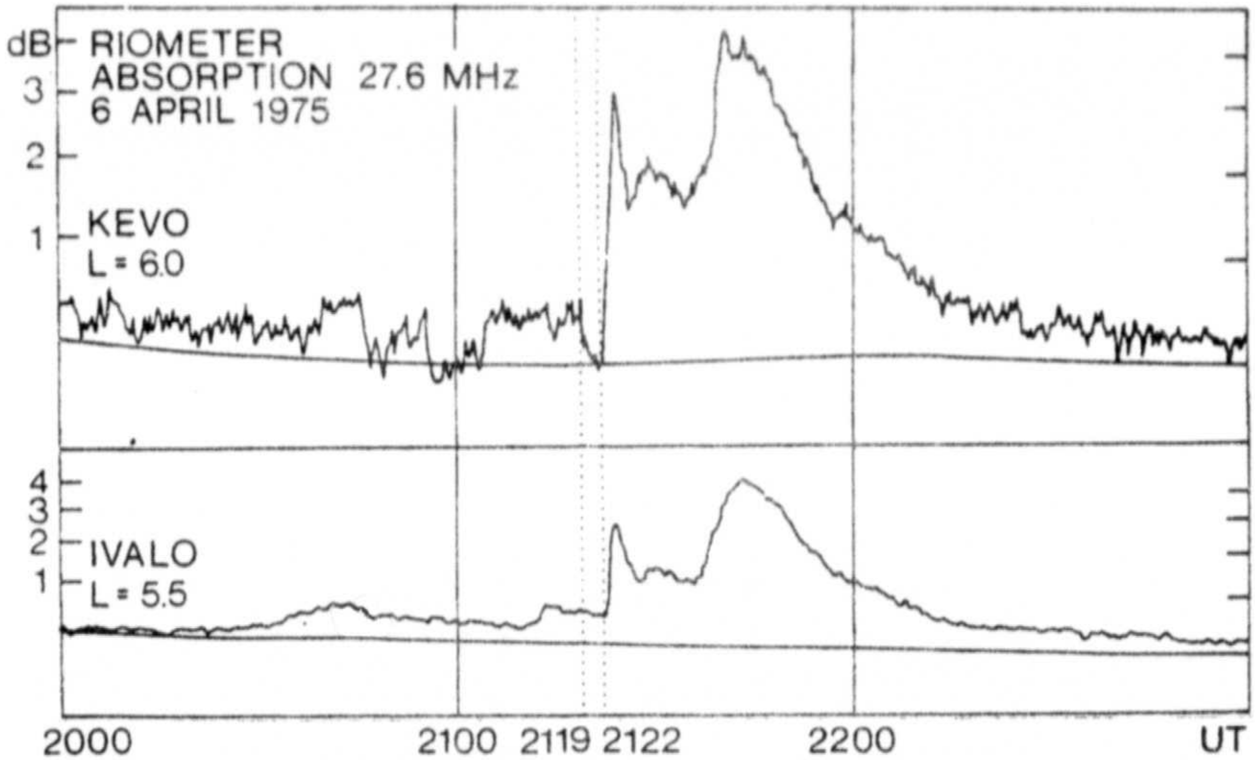

Figure 10

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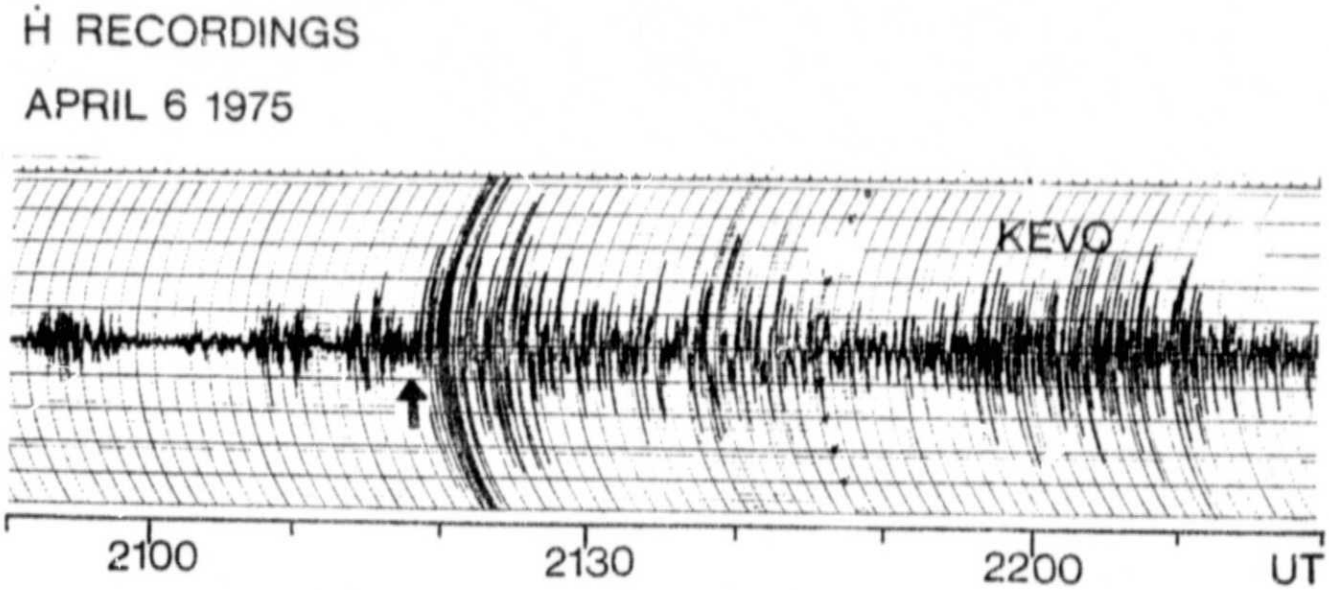

Figure 11

Table 1.

Auroral and cosmic noise absorption recording stations.

Name of Station	Geogr. Lat N	Coords Lon E	Geomagn Lat N[1]	t_{dp}-UT[2]	All-Sky Camera	Backsc. Receiver	Rio-meter
Kevo	69.75	27.02	65.62	3h38m	x		x
Ivalo	68.60	27.47	64.52	3 34	x		x
Muonio	68.03	23.56	64.68	3 21	x		
Sodankylä	67.36	26.64	63.55	3 27	x	x[3]	x
Rovaniemi	66.56	25.83	63.68	3 22			x
Oulu	65.11	25.49	61.70	3 15	x		x
Jyväskylä	62.41	25.67	59.19	3 07			x
Nurmijärvi	60.51	24.66	57.62	2 58		x[4]	x

[1] From IMS Bulletin No. 2;

[2] The difference between magnetic dipole time and universal time given for April 6 at 21.00 UT;

[3] 97.0 MHz transmitter at Pihtipudas, Finland 63°.29 N, 25°.65 E;

[4] 144.96 MHz transmitter at Borlange, Sweden, 60°.38 N, 15°.14 E;

TRITA-EPP-78-05

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OBSERVATIONS OF AURORAL FADING BEFORE BREAKUP

R. J. Pellinen and W. J. Heikkila

February, 1978, 35 p. incl. ill., in English

We have obtained detailed observations of the onset of auroral breakup using a variety of instruments with time resolution of some tens of seconds. Rapid sequences of all-sky photographs, and fast meridian scans by photometers, show that breakup is usually preceded by moderate brightening, followed by fading of the auroral brightness lasting one or two minutes, before the actual breakup itself. At the time of the fading there is a brief darkening of the poleward sky. Often the breakup is preceded by one or more rapid intensifications, each one preceded by local fading. Pseudo-breakups may also occur without the development of a major event. A bonafide breakup may begin on the fading arc, on an adjacent arc, or in an entirely new region nearby. This optical activity is closely correlated with the development of auroral radar echoes, suggesting that variations in the ionospheric and magnetospheric electric and magnetic fields are responsible for the observed auroral variations. Data from the IMS magnetometer network provide some indication of a correlated response by the local auroral and ionospheric currents, although this could be partly due to changes in conductivity. Riometer recordings show a slow decrease in ionospheric radio wave absorption over a period of about ten minutes prior to breakup, with the largest decrease essentially to quiet-time values in the region of auroral fading and subsequent breakup. The implications of these observations regarding the trigger mechanism for the expansion phase of a magnetospheric substorm are discussed.

Key Words: Auroral brightness, auroral intensity, magnetosphere, auroral radar, riometer, pulsations, electric field