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Simultaneous Maxima of Geomagnetic Pulsations and Riometer Absorption on the Afternoon Side of the Auroral Zone

Yu.P. Novikov[1], Yu.A. Kopytenko[2], O.M. Raspopov[3], T. Bösinger[4], J. Kangas[4], and H. Ranta[5]

[1] Department of Physics, State University, Leningrad, USSR
[2] Leningrad Branch Izmiran, Leningrad, USSR
[3] Polar Geophysical Institute, Kola Branch of Academy of Sciences, Apatity, USSR
[4] University of Oulu, Department of Physics, Oulu, Finland
[5] Geophysical Observatory, Sodankylä, Finland

Abstract. Bursts of irregular long-period magnetic pulsations have been observed in the afternoon sector of the auroral zone when a substorm was developing in the midnight sector. The maximum amplitude of these pulsations is coincident both in space and time with the maximum of riometer absorption. Short-period magnetic pulsations, usually an IPDP event, appear also at the same location at the same time. These observations are discussed for modelling the afternoon Pi2-like magnetic pulsations. Similarities with the midnight Pi2's are noted.

Key words: Pi2 magnetic pulsations – Substorm – Plasmapause.

Introduction

Irregular long-period magnetic pulsations called Pi2 pulsations occur typically at the onset of a substorm. Pi2's are believed to be an important manifestation of substorm processes (see, as general reviews, Saito 1969; Orr 1973). It has been confirmed by Raspopov et al. (1972), Stuart (1974), Fukunishi (1975), and Saito et al. (1976) that on the night side of the magnetosphere the amplitude of Pi2 waves has the main maximum (high latitude maximum) at the auroral oval and a secondary maximum (midlatitude maximum) inside the plasmapause. Phase reversals of about 180° are reported to occur at the high latitude maximum and at the minimum (subauroral minimum) between the two maxima (Björnsson et al. 1971; Saito et al. 1976).

Kopytenko et al. (1977) made an analysis of magnetic pulsations during the substorm in the local midnight sector using a dense network of magnetometers spaced by about 1° from $\phi=53°$ to $\phi=65°$ They reported an interesting result: an intermediate amplitude maximum of long-period magnetic pulsations appears between the high- and midlatitude maxima. It was concluded that this new maximum occurs at the plasmapause projection onto the ground. This was concluded earlier also for the subauroral minimum (Saito 1976), which, however, according Kopytenko et al. (1977) is located still 2–3° south of the plasmapause projection.

It is further known that Pi2 waves at the auroral oval are closely associated with the auroral electrojet (Olson and Rostoker 1975) and electron precipitation into the high atmosphere (Stuart et al. 1977). Also high-frequency pulsations are superimposed on Pi2 waves at high latitudes (Saito 1969).

In this paper bursts of large-amplitude irregular magnetic pulsations in the Pi2 period range on the afternoon side of the magnetosphere are studied. These bursts occur during the substorm in the longitude sector of the positive bay in the auroral zone. Such pulsations seem to be common according to Jacobs and Sinno (1960). A special interest here has been to give a detailed picture of the association of these long-period pulsations with the substorm development and with the electron precipitation events and high-frequency magnetic pulsations in the same local time sector using a dense network of riometers and magnetometers across the auroral zone and plasmapause region.

Observations

Long-period magnetic pulsations ($T \sim 10$–200 s) analysed here have been recorded by magnetostatic magnetometers of the same stations as those used by Kopytenko et al. (1977). The time resolution is about 4 s. The geomagnetic coordinates of the stations are given in Table 1 (Evans et al. 1969). A north-south chain of four 27.6 MHz riometers was operated by the Geophysical Observatory of Sodankylä. The time resolution is of the order of 2 min. A north-south chain of 3 induction coil magnetometers was operated by the University of Oulu. These detect short-period magnetic pulsations ($T \sim 1.0$–10 s) recorded on analog tapes and displayed by sonagrams with a time resolution of about 2 min. The geomagnetic coordinates of the Finnish stations are given in Table 2 (corrected geomagnetic coordinates calculated after Gustafsson 1970).

In this report, data from March 2 and 3, 1974 will be presented. The general magnetic activity during the events was characterized by the Kp value 4.

Table 1. Location of Russian magnetometer stations

Station	L	Geomagn. coord. (corrected)	
		Latitude	Longitude
Lovozero	5.1	63.8°	118°
Kniazhaya Guba	4.7	62.4°	116°
Angozero	4.5	61.4°	116°
Kem'	4.2	60.7°	116°
Muezerka	4.0	60.0°	113°
Suckozero	3.75	59.0°	111°
Suisaari	3.6	58.0°	114°

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Table 2. Locations of Finnish riometers and pulsation magnetometers

Station	L	Geomagn. coord. (corrected)	
		Latitude	Longitude
Kevo[a]	6.0	66.2°	111°
Ivalo[a]	5.5	65.0°	110°
Sodankylä	5.1	63.9°	109°
Oulu	4.3	61.8°	107°
Nurmijärvi	3.3	57.0°	103°

[a] Only riometer

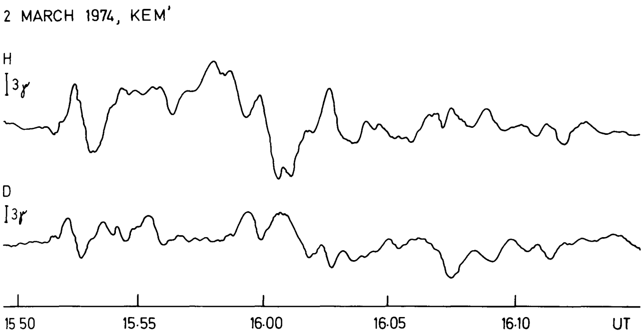

Fig. 1. Long-period magnetic pulsations registered in Kem' at T_2 = 15.52–16.10 UT on March 2, 1974

Events on March 2, 1974

Two trains of intense long-period magnetic pulsations appear at T_1=15.22–15.38 UT (~18.30 MLT) and at T_2=15.52–16.10 UT (~19.00 MLT). An example of the pulsations at T_2 is given in Fig. 1. Note that for the analysis we have always taken that part of the pulsation train that can be identified at each station as belonging to the same burst (a train usually consists of several bursts). The maximum amplitude of waves – derived from the H-component – occurs at $L \sim 4.7$ for the first event (T_1) and at or beyond $L \sim 4.2$ for the second event (T_2), as shown in the amplitude/time plots in the top half of Fig. 2a. It should be noted that data at $L > 4.2$ for T_2 are not available, and that 'amplitude' here is defined as the variation range between maximum and minimum in the records.

In the lower half of Fig. 2a the latitudinal variation of riometer absorption is presented. At the end of T_1 riometer absorption starts to increase at Sodankylä ($L \sim 5.1$), reaching its maximum shortly after T_1. Later at T_2 a strong absorption event has been recorded at Oulu ($L \sim 4.3$).

Dynamic spectra of high-frequency pulsations from two stations located at about the same meridian as the Russian magnetometers are illustrated in Fig. 2b. At the auroral zone station (Sodankylä) unstructured Pc1–2 waves (see Heacock 1971a) appear at T_1 which are most intense at the time of the strong absorption event at Sodankylä. Later, at T_2 typical Pil activity appears in the Sodankylä recordings. At a more southern station (Oulu) Pc1–2 pulsations have been observed at T_1 but at T_2 an IPDP pulsation event with a steep increase of the frequency is the prominent characteristic of short-period magnetic pulsations.

Figure 2c, d show the development of magnetic disturbances in the auroral zone and at low latitude, respectively. It is seen in Fig. 2c that negative magnetic bays start at Chelyuskin at 15.20 UT (~22.25 MLT) and at Dikson at 15.50 UT (~21.35 MLT). Both of these onsets at 15.20 and 15.50 UT can be related with the increase of the magnetic field at the stations in the afternoon sector, namely at Kiruna (~17.55, 18.25 MLT) and at Loparskaya (~18.20, ~18.50 MLT).

At low latitude stations at Guam and Lunping at T_1 and at Hyderabad and Alibag at T_2 an increase in the H-component has been measured as shown in Fig. 2d. This has occurred in the longitude sector of the negative bay in the auroral zone (cf. Fig. 2c). The local magnetic midnight of the various stations is denoted by a dot in Fig. 2c, d.

Events on March 3, 1974

A similar set of data as for the events of March 2 is shown for an event on March 3, 1974 in Fig. 3a–d. A burst of intense irregular long-period magnetic pulsations was observed at 13.47–14.05 UT (~16.50 MLT) with maximum at $L \sim 4.2$ as shown in the upper half of Fig. 3a. At the same time an intense absorption event appears in riometer recordings at the Oulu station (~16.20 MLT) at $L \sim 4.3$ as shown in the lower half of Fig. 3a. According to Fig. 3b strong IPDP pulsations have also been observed at Oulu.

A magnetic substorm starts at Dikson at 13.30 UT (~19.10 MLT) which is associated with a positive bay in the afternoon sector at Kiruna (~15.20 MLT) and Loparskaya as illustrated in Fig. 3c. At the same time an increase of magnetic field intensity is seen at low latitudes (Fig. 3c) at the meridian of the high latitude negative bay as shown in Fig. 3d.

Summary and Discussion

Meridional profiles of riometer absorption and occurrence of short-period magnetic pulsations have been analysed in the afternoon sector at the time when a burst of irregular longperiod magnetic pulsations has been observed during the positive bay at about the same meridian. Our observations can be summarized as follows:

1. The bursts of irregular long-period magnetic pulsations are associated with the substorm developing to the east from the meridian of pulsation magnetometers.

2. The maximum amplitude of pulsations occurs at about the same latitude and at about the same time as the riometer absorption maximum.

3. Short-period magnetic pulsations typed unstructured Pc1–2 or IPDP are also observed at the same latitude.

Note that the longitudinal difference of the Russian and Finnish meridians can be neglected as regards Pi2, IPDP and riometer absorption events, since each of them is reported to occur simultaneously over a large longitudinal extent (Sutcliffe 1979; Heacock 1971a, b; Berkey et al. 1974).

The comparison of the auroral zone and low latitude magnetograms with the observed Pi2-like pulsations shows that our afternoon Pi2's monitor the substorm development in the same way as Pi2's recorded in the midnight sector. We therefore propose that the afternoon Pi2's are due to night-time westward propagating Pi2 waves which succeed in penetrating into the afternoon side of the magnetosphere. This is consistent with Sutcliffe's (1979)

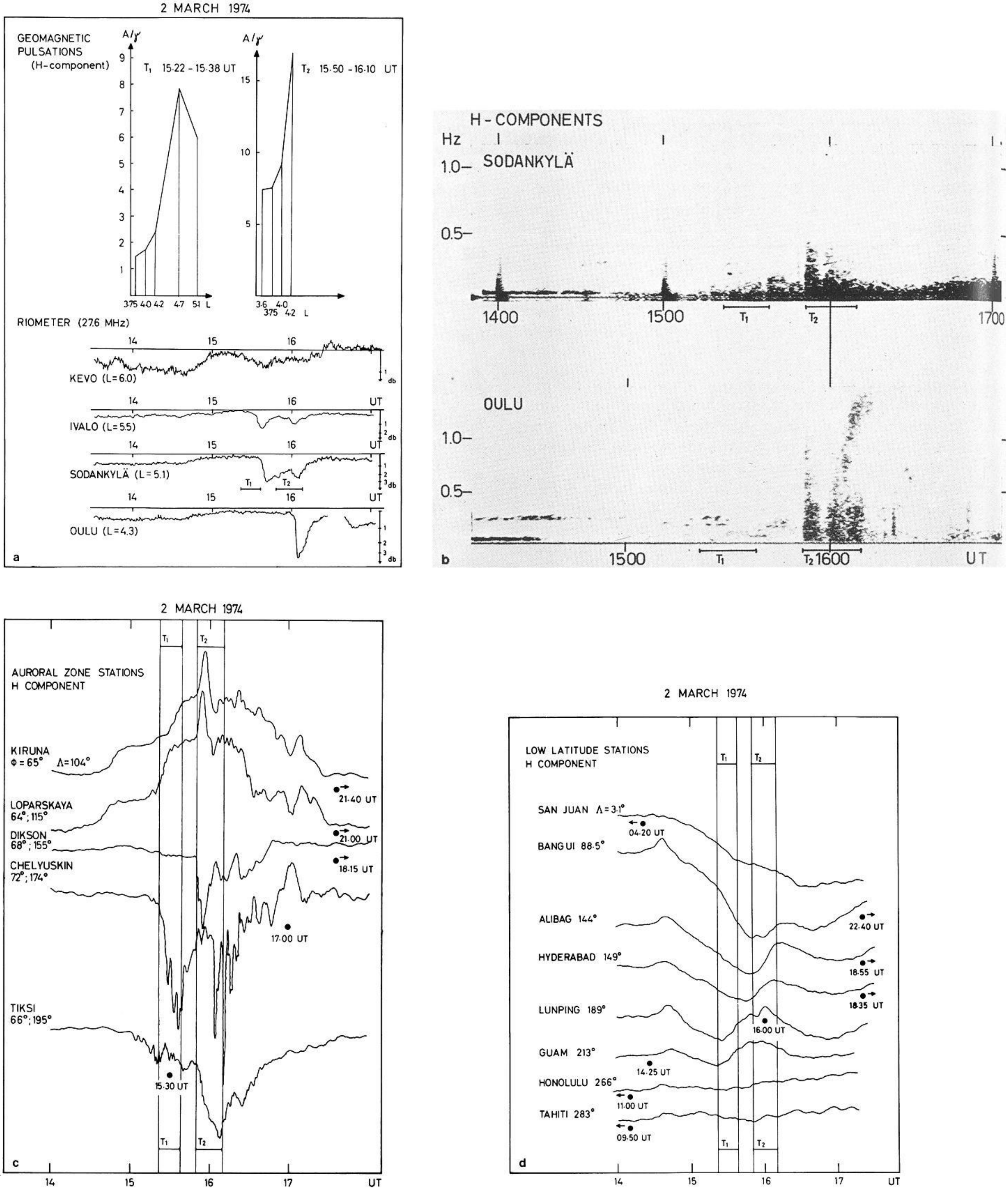

Fig. 2. a Latitude profiles of the maximum amplitude of long-period magnetic pulsations at $T_1 = 15.22$–15.38 UT and $T_2 = 15.52$–16.10 UT and riometer absorption in the local afternoon sector of the auroral zone on March 2, 1974. **b** Dynamic spectra of short-period magnetic pulsations recorded at Sodankylä and Oulu on March 2, 1974. **c** Magnetic recordings at some auroral zone stations on March 2, 1974. Local magnetic midnight is denoted by a *dot*. **d** Magnetic recordings at some low-latitude stations on March 2, 1974. Local magnetic midnight is denoted by a *dot*

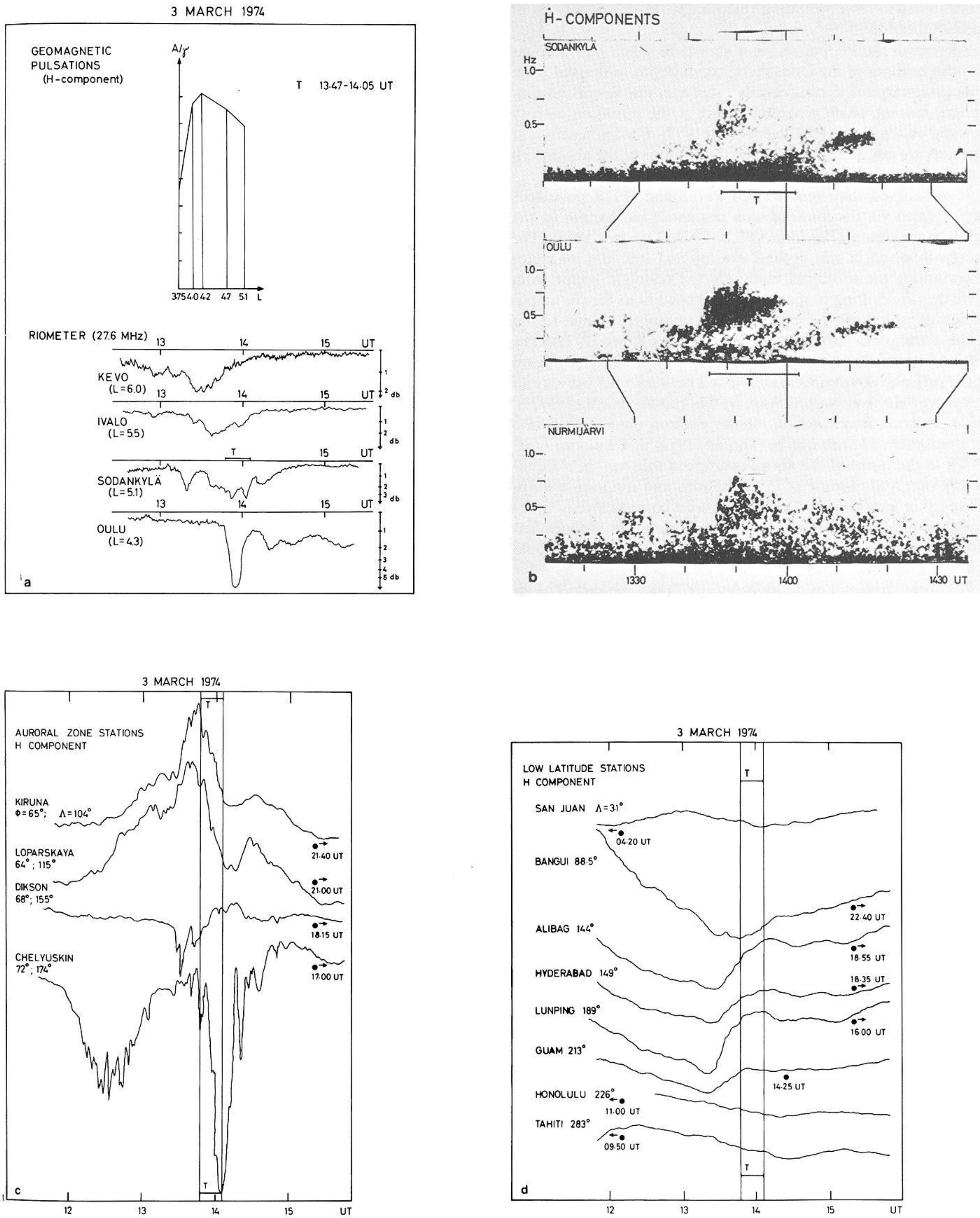

Fig. 3. a Latitude profiles of the maximum amplitude of long-period magnetic pulsations at $T = 13.47$–14.02 UT and riometer absorption in the local afternoon sector of the auroral zone on March 3, 1974. **b** Dynamic spectra of short-period magnetic pulsations at Sodankylä, Oulu and Normijärvi on March 3, 1974. **c** Same as in Fig. 2c but for March 3, 1974. **d** Same as in Fig. 2d but for March 3, 1974

result of westward propagating (before 23 LT) Pi2 pulsations at auroral latitudes.

As regards the Pi2 pulsations it should be taken into account that also changes of the ionospheric conductivity as derived from riometer absorption measurements cause modulation of the ionospheric current which generates a part of the pulsation activity observed on the ground (Wilhelm et al. 1977). Unfortunately, our riometers are not able to resolve the fluctuations of the absorption in the frequency range of the observed magnetic pulsations.

It is believed that unstructured Pc1–2 and IPDP pulsations are generated via the ion-cyclotron resonance mechanism in the plasmapause region (Heacock 1971b, 1973; Gendrin 1975). The protons involved in this process are injected into the magnetosphere during the substorm, mainly in the midnight sector from where they are drifting to the west. Good conditions for the amplification of waves can be met in the plasmaspheric bulge region on the evening side as shown by Perraut and Roux (1975). The same region in the magnetosphere is also a favourable region for the parasitic wave-particle interaction between ULF-waves and high-energy electrons as proposed by Thorne and Kennel (1971). This interaction may result in intense electron precipitation into the atmosphere as discussed by Thorne (1974) and Lukkari et al. (1977). In the frame of the above mentioned theories the simultaneously observed maxima of Pi2 pulsations and riometer absorption together with the IPDP pulsations are a consequence of interconnected processes in the plasmapause region. An independent measurement of the location of the plasmapause, therefore, would be highly desirable.

According to Novikov and Kiselev (1977) the increase of magnetic field intensity in the equatorial plane of the magnetosphere during substorms leads (among other agents like inward motion of a generation region and energy dispersion of westward drifting protons) to an increase of the wave frequency of IPDP events. Thus our display of low latitude magnetograms does not only allow to localize in time and space the substorms but also shows a possible connection between IPDP and equatorial magnetic field intensification.

Summarizing we can say that all three events presented here show a close connection between the pulsation amplitude and the riometer absorption maximum at the statistical position of the plasmapause projection onto the ground (Chappell 1972). Simultaneously observed IPDP events further support the idea of an interconnection of all three phenomena at the plasmapause where most favourable conditions for the development of ion and electron cyclotron instabilities exist.

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