

CASE STUDY OF THE Pi3 GEOMAGNETIC PULSATIONS ASSOCIATED WITH AURORAL BREAKUP (07.10.1994)

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Abstract

Two wave packets of Pi3 geomagnetic pulsation occurred on October 07, 1994 in association with two different events of the auroral breakup have been analyzed by using the IMAGE magnetometers, IRIS riometer and IMP-8 satellite magnetic measurements in the magnetotail at (- 32.5, 6.4, 18.4) Re. The spectral and wavelet analysis of the ground geomagnetic pulsations and the oscillations in the tail magnetic field were compared. Contrary to the ground observations, where the amplitude of the first Pi3 burst was smaller than the second one, the IMP-8 data showed the stronger Bx (compression component) amplitude in the first Pi3 wave packet. Both pulsation bursts were associated with auroral breakups: the poleward expansion velocity during the first breakup was two times smaller than that of the second one. It was found that the first breakup was associated with a compression type of magnetic wave in the magnetotail, and the second breakup – with a transverse type of wave.

Introduction

The mechanism for the initiation of magnetospheric substorm is very active topic in space plasma physics. The low frequency magnetic

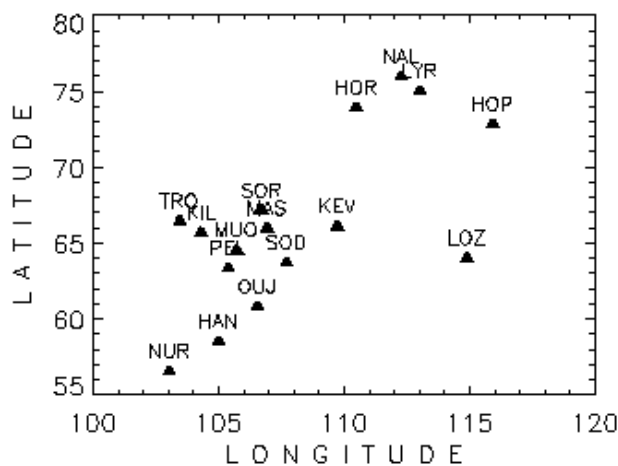


Fig.1. The map of IMAGE magnetometer network in corrected geomagnetic coordinates.

oscillations at and after substorm onset are the important facts for understanding the onset nature. The question is - do the oscillation trigger the breakup or are they a consequence of it? It is very complicated

problem because of different reasons. The aim of this paper is doing a small step into its solution and to study the Pi3 range (1-6 mHz) geomagnetic pulsations on the ground and in the magnetotail by IMP-8 satellite at (X= - 32.5 Re, Y=6.4 Re, Z=18.4 Re) during two events of auroral breakup.

Observations

The optical and TV aurora records (October 7, 1994) from Kalkkoavi station (KAL, $\Phi' = 65.5^\circ$, Λ'

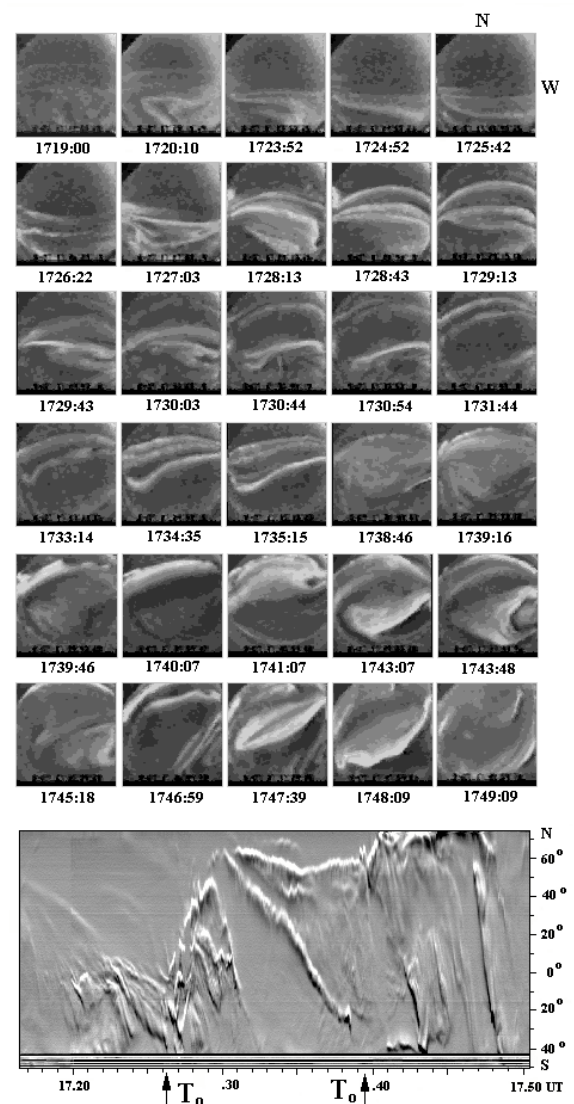


Fig.2. Optical aurora data and filtered keogram.

= 105.4°) located near Kilpisjärvi have been compared with geomagnetic Pi3 pulsations from IMAGE magnetometer chain (Fig.1). Fig.2a shows the optical aurora data and Fig.2b - the gradient filtered keogram, allowing to enter into details of auroral arc dynamics. Two strong aurora activations were observed: the first

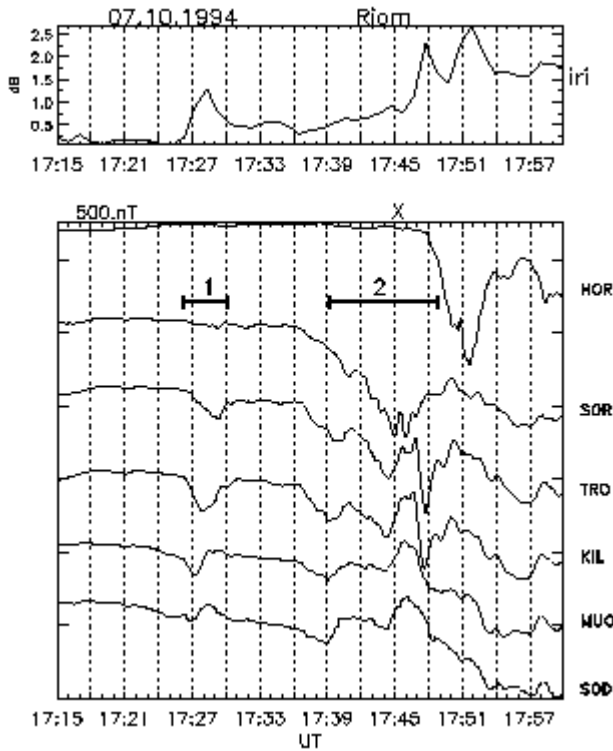


Fig.3. The magnetic data from several IMAGE stations and KIL (IRIS) riometer data.

at ~17.25–17.30 UT and the second – at ~17.39–17.48 UT. The different space-temporal structure of these events is seen in Fig.2. Both activations started to the East from KAL. The first propagated to the North - West and to the South, the second one - to the North - West as well as to the South – West. Velocity of the aurora poleward propagation during the second activation was twice as large as during the first one.

IRIS riometer data and geomagnetic data from several IMAGE stations are shown in Fig.3. Both activations were accompanied by geomagnetic disturbances, drifted the same manner as the aurora activation. In the first case it was localized negative magnetic impulse and in the second case - the negative magnetic bay with the strongest amplitude at SOR. The amplitude spectra of Pi3 geomagnetic pulsations (2-10 mHz) from 4 stations in both intervals are shown in Fig.4 (top panel). In the second case the Pi3 pulsation spectrum was broader and the amplitudes were three times as large as ones in the first interval. The strongest signals were observed at KIL. At polar latitudes (LYR) the wave intensity was insignificant.

The IMP-8 spacecraft, located during the time interval under consideration in the magnetotail (X = -33, Y = 17, Z = 7 Re), also recorded two burst of Pi3 range magnetic pulsations with different spectral

structure (Fig.4, bottom panel). Contrary to the ground data the wave intensity in the tail during the first interval was stronger than in the second one. In the first case the pulsations were observed mostly in the X-component, but in the second case the amplitudes of all components were comparable with the minor X values. The spectral distribution on the ground and in the magnetotail differed in details, while the overall wave enhancement was observed in the common frequency range (~3-7 mHz). The 3-7 mHz filtered pulsations on the ground are shown in Fig.5 (top panel). At 17.25-17.35 UT the waves in the tail were mostly compressional (strong X-component), thereafter suddenly the wave structure changed and became mostly transverse. The associated geomagnetic pulsations on the ground were less intense in the case of the first (compressional) wave burst than in the second case (transverse wave).

Fig. 5 (bottom panel) demonstrated also the Pi2 range (8-20 mHz) pulsations at given IMAGE stations. It is seen that in the second interval the Pi2 as well as a magnetic substorm started at SOR, i.e. poleward from KIL.

The considered Pi3 pulsations are essentially non-steady-state in time and frequency, so for their more correct study we used the wavelet spectral analysis

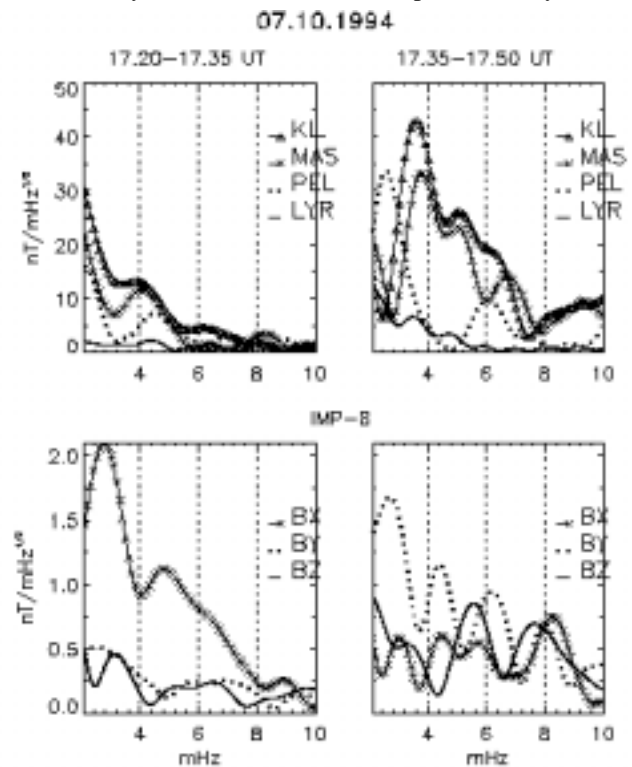


Fig.4. Spectra of Pi3 pulsations during two time intervals considered, for selected IMAGE stations (top panel) and IMP-8 located in the magnetotail (bottom panel).

method. Fig. 6 demonstrates the results of the wavelet analysis of the pulsations (the periods higher than 15 min) in the magnetic X, Y, and Z components on IMP-8, in the riometer absorption at KIL and in the

geomagnetic field (X-component) at the ground stations. Two bursts of pulsations were observed simultaneously in geomagnetic and riometer ground data with a similar frequency-temporal structure in the period range of about 2-8 min ($f \sim 2-7$ mHz). The signature of these bursts is seen in the magnetic field fluctuations at IMP-8.

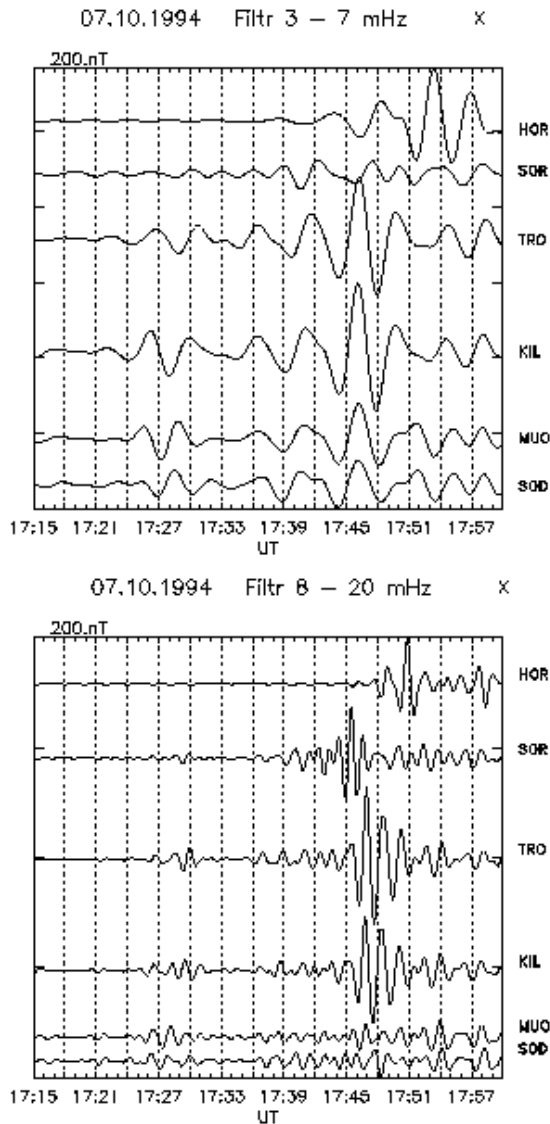


Fig.5. The 3-7 mHz (top panel) and 8-20 mHz (bottom panel) filtered magnetic pulsations.

Discussion

Poleward aurora expansion and breakup dynamics have been widely discussed in the literature [e.g., Sergeev and Yahnin, 1979; Kornilova et al., 1990; Nakamura et al., 1993]. The localized character of the breakup processes was well established. Kleimenova et al. (2002) showed that the auroral breakup is accompanied by the space-temporal localized burst of Pi3 pulsations in the geomagnetic field and riometer absorption. The maximum of the Pi3 amplitudes was observed near the footprint of the ionosphere

projection of the upward field aligned currents (FAC). It was suggested that the source of Pi3 pulsations is related to quasi-periodic variations in the ionospheric conductivity caused by modulated precipitation of the FAC associated electrons.

It is well known that magnetospheric compressional wave when arriving at the ionosphere does not bring in a field-aligned current. In the first case of the aurora brightening at ~17.25 UT, accompanied by the compressional wave burst in the magnetotail, only a localized negative impulse was observed near KIL. We may attribute this activation to the first breakup. The second auroral breakup was observed near 17.39 UT, it was accompanied by mostly transverse structured waves in the magnetotail. The breakup led to a magnetic bay at SOR (Fig.3). It suggests the stronger FAC in the second of the above events. We assume the possible source of Pi2-3 pulsations, observed on the ground, as well as optical breakup, is associated with the processes in the ionosphere footprint of enhanced FAC caused by plasma instabilities, related to substorm development.

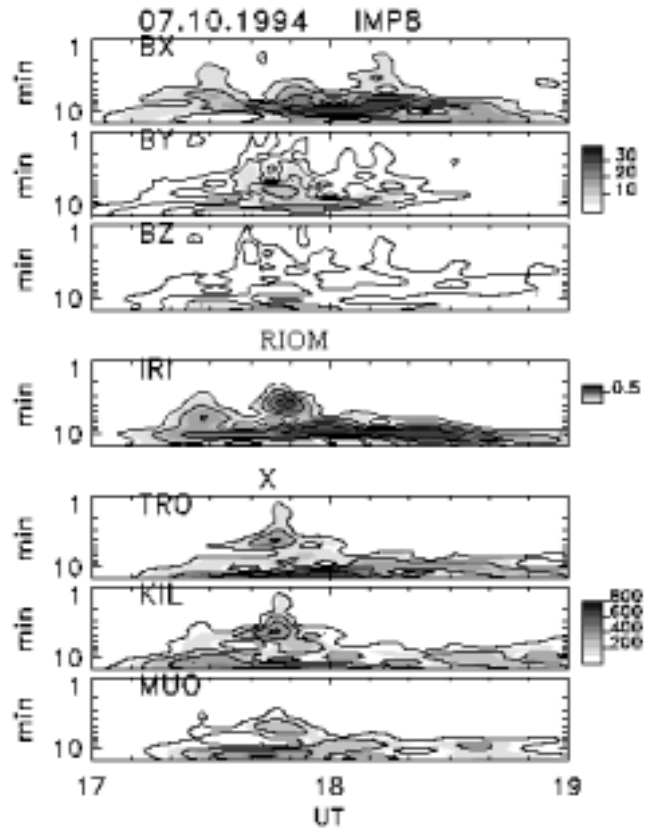


Fig.6. The results of wavelet analysis of the pulsations at periods shorter than 15 minutes.

According to Lui (2001) substorms involve a number of physical processes covering a wide range of spatial and temporal scales including different types of plasma instabilities, such as shear ballooning instability, tearing instability, magnetic reconnection and others. Which particular process dominates in a

given substorm depends on the present and previous states of the magnetosphere.

In the case under consideration we suppose that both aurora activations were related to each other. The first one, started with brightening of a pre-existing equatorward located auroral arc, has been related to dipolarization of the magnetic field, presumably due to current diversion (CD), which caused injection of energetic particles, observed as a burst of riometer absorption. A dipolarization could have a quasi-periodical character, with oscillations propagating both earthward and tailward. These waves could be observed on the ground as Pi3 geomagnetic pulsations and by IMP-8 in the magnetotail (Unfortunately, we have no information about the direction of the wave propagation). Some evidence of our suggestion could be the existence of strong magnetic field fluctuations, observed in the magnetosphere in the vicinity of the dipolarization region, e.g., by Fairfield et al. (1999). These waves could be a stimulator of the quasi-periodic variations in the energetic electron precipitation caused pulsations in the riometer data. Because the bursts of Pi3 range pulsations were observed almost simultaneously, we assume that their source was located in the plasma sheet at about 10-15 Re and the waves propagated from the source both earthward and tailward.

Tailward propagation of CD causes thinning of the mid-tail plasma sheet and a new X-type magnetic neutral line development. The formation of a magnetic neutral line in the plasma sheet at radial distances in the range of 15-20 Re is an important candidate for the onset mechanism [e.g., Hones et al., 1984]. The second aurora brightening, observed near 17.38 UT poleward of the first one (Fig.2) could be attributed to this process.

Conclusion

The analysis of the Pi3 geomagnetic pulsations, associated with two events of auroral breakup, showed that in both cases considered the pulsations just accompanied the auroral breakups, not being their cause. We assume the geomagnetic and riometer pulsation source to be collocated with the region of plasma instability development (dipolarization region), responsible for a substorm. The pulsation occurrence demonstrates a quasi-periodical character of dipolarization.

We found that the first breakup was related to the compressional type of magnetic wave in the magnetotail, while the second one – to the transverse type of wave.

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