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AZIMUTHAL ANISOTROPY OF THE PROTON FLUXES DURING THE SUBSTORM ONSET

T.V.Kozelova, L.L.Lazutin, B.V.Kozelov *(Polar Geophysical Institute, Apatity, Russia)*,
R.Rasinkangas *(University of Oulu, Oulu, Finland)*,
H Singer *(Space Environment Laboratory, NOAA, Boulder, USA)*,
A.Korth *(Max-Planck-Institute für Aeronomie, Katlenburg-Lindau, Germany)*

Abstract. The proton data obtained by EPAS spectrometer on board the CRRES satellite are used to examine the spatial evolution of the particle activation regions relative to the spacecraft located on L=6.3-6.7 at the midnight sector. It is found that the enhanced proton flux region differs from one injection to other. This difference may be associated with the specific stages of the reconfigurations of the magnetic field. Proton injections tailward of the CRRES occur during the local magnetic field dipolarization. The proton flux increases tend to occur inward of the CRRES orbit during the impulsive taillike stretching of magnetic field.

1. Introduction

This paper presents the CRRES data obtained during the three substorms. The particle detector MEB measured electrons with energies 21.5-285 keV in 14 differential channels and protons 37-3200 keV in 12 channels. Sometimes the proton fluxes exhibited strong azimuthal anisotropy during single spin period (30 s). This anisotropy can be interpreted in terms of spatial gradients of the particle fluxes and can be used to study motion of the trapped particles outer boundary and for location of the substorm (or intensification) onset [*Walker et al.*, 1976; *Lui*, 1988].

2. Particle anisotropies and proton injection locations

On Febr 9, 1991 between 1630 and 1800 UT the CRRES was near L=5.9-6.7 at magnetic latitudes between -3^{0} and -6.7^{0} and at 22.6-22.9 MLT. Figure 1 presents the variations of intensity J_{+}(J_{-}) for the proton (PA=90^{0}) with gyrocenters inward (outward) of the CRRES orbit from 3 channels P1, P3-P4. $J_{+}>J_{-}$ implies a higher flux inside (earthward and/or equatorward) of the CRRES orbit. Figure 2 presents the total magnetic field B_T, inclination angle relative to the XY plane, and magnetic pulsations, defined by dB=B-<B>, on the CRRES. Azimuthal anisotropy of integral (>37 keV) proton fluxes computed as J_{+}/J_{-} is also shown.

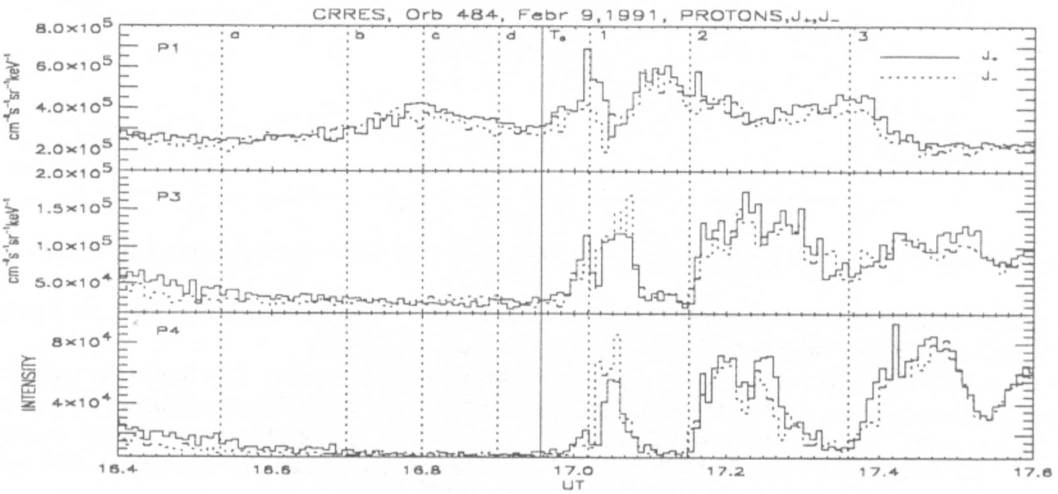

Fig.1. Anisotropy of proton intensity for PA=90° from three channels P1, P3-P4 on Feb 9, 1991. I+ (I-) denotes intensity for particles with gyrocenters inward (outward) of the CRRES orbit.

At the moment "a", the first weak auroral arc appeared poleward of Kilpisjarvi. Small auroral intensifications or pseudobreakups were observed during the substorm growth phase at the moments "b", "c" and "d". At T_0=165730 UT the substorm 1 begins near the Norilsk meridian which was close to the CRRES longitude. Three strong intensifications, denoted as 1, 2, 3, occured near or eastward of this longitudinal sector. From Figures 1-2 one can see the following.

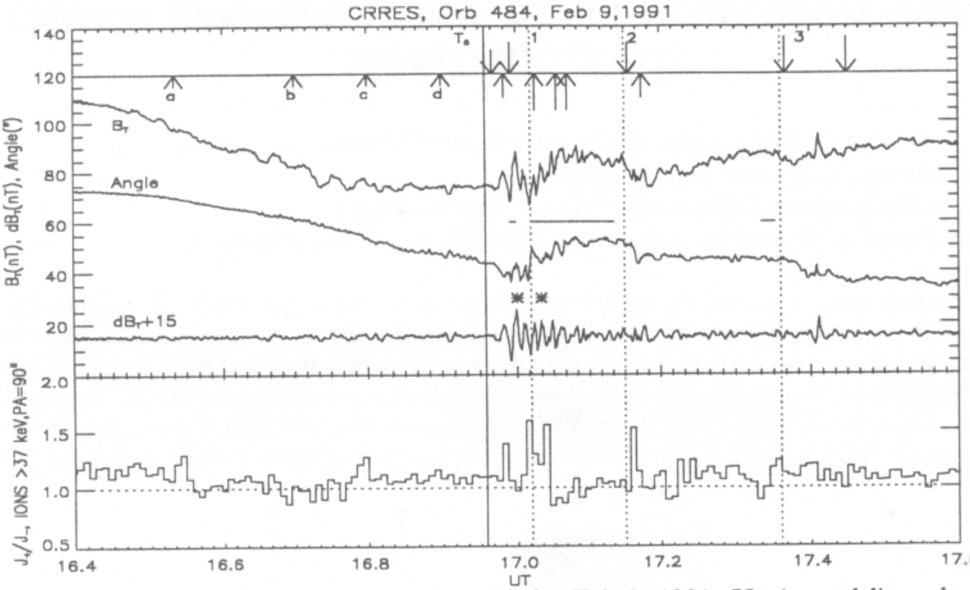

Fig.2. Magnetic field variations on the CRRES for Feb 9, 1991. Horizontal lines denote the intervals of enhanced (21.5-80 keV) electron fluxes. Anisotropy of integral ion fluxes is also shown.

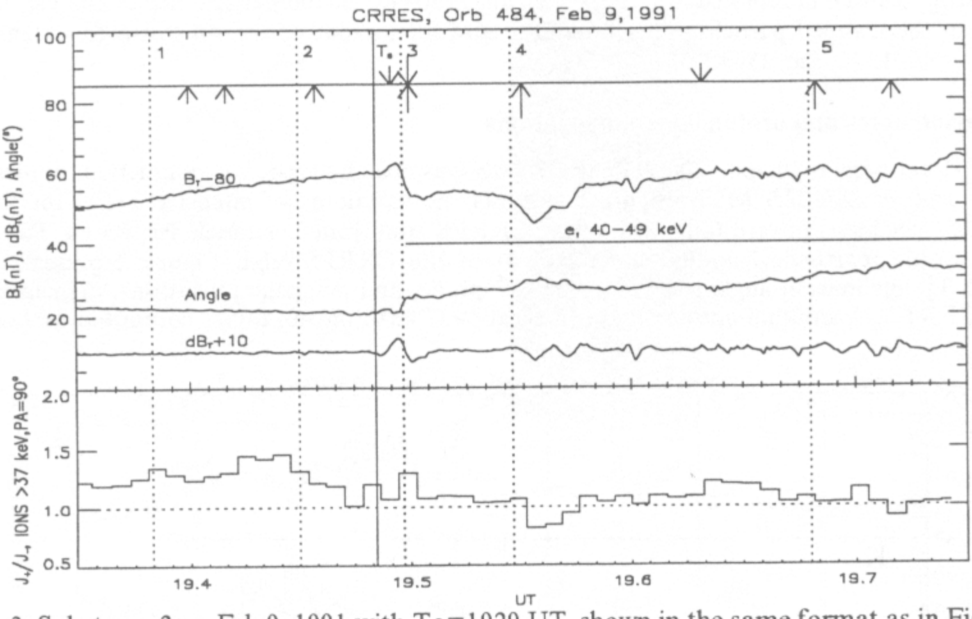

Fig.3. Substorm 2 on Feb 9, 1991 with To=1929 UT, shown in the same format as in Fig.2.

1. During the substorm growth phase the small low energy proton injection (in the channels P1-P3) come from outside of the CRRES orbit with the speed about 20 km/s.

2. Near the substorm onset region (in the interval lasted about 4 min after T_0) the lower energy proton flux increase (in the channels P1-P4) strarts in flux tube inward of the CRRES orbit. During this interval, the smooth <B> magnetic field changed insignificantly, except small stretching of magnetic field. Magnetic field pulsations have the period of about 50 s. The field-aligned electron fluxes increase at energies up to about 20 keV simultaneously (private communication, *A.Johnstone*, 1994).

3. During the proton injection 1 the following can be observed:

* The local magnetic field dipolarization occurs at this time.
* Small increase in electron fluxes (in channels E1-E6) is observed in general, however a fine structure of particle flux variations is more complex [*Lazutin et al.*, 1996].
* Proton fluxes decrease at lower energies (in the channels P1-P3), however spatial earthward gradient of proton fluxes increases.

* Energetic proton injection pulses arrive from the outside of the CRRES orbit. Spatial boundary that separates the newly injected population from the preexisting one propagates earthward with the speed of about 40 km/s for the energy channel 5.
* Nearly dispersionless proton injection in the channels P3-P6 occur in about 30 s after sharp local dipolarization onset, and lower energy proton injection (in the channels P1-P2) is delayed for about 60 s with respect to the dipolarization onset.

4. Proton injections 2-3 are accompanied by the following:
* Impulsive stretching of magnetic field occur at this time.
* No electron flux increase was registered.
* At the leading temporal edges of this injections, the increase in particle intensity occurs for particles with gyrocenters earthward of the CRRES.

3. Magnetic field reconfiguration and proton anisotropy

As we have shown above, the location of enhanced proton flux region shifted repeatedly from earthward to tailward (and vica versa) of the CRRES location during the substorm. In this section we will investigate the relationship of azimuthal anisotropy with the magnetic field reconfiguration. Proton anisotropy from particle data at three substorms were examined, and a list of 35 (small and large) flux increase events that have distinctly noticeable anisotropy was compiled. These injections were recorded at least in two differential channels. Injections without clear pattern of anisotropy were excluded. Moments of proton flux enhancements are marked by the arrows in Figures 2-4. Upward (downward) arrows denote the particle activation location tailward (earthward) of the CRRES orbit. From Figure 2 one can see that the source of enhaced proton fluxes locates inward of the CRRES orbit during the substorm onset and impulsive tailward stretching of magnetic field. However the source of large proton injection tailward of the CRRES arises during the local magnetic field dipolarization.

Figure 3 shows the second substorm of Febr 9,1991 with magnetic field data in the same format as in Figure 2. At this time the CRRES was near L=6.6-6.2 at magnetic latitudes between -8.9^{o} and -11.2^{o} and at 00.0-00.5 MLT. The small substorm onset at T_0=1929 UT took place eastward of Loparskaya and remained eastward as it expanded. Before T_0, three weak auroral arcs were observed from Loparskaya. In the moments "1-2" weak auroral brightenings occured on the poleward arc. During this pseudobreakups the proton flux starts to increase outward of the CRRES orbit. In the moments "T_0" and "3", the small auroral intensifications occured in the most equatorward arc. At the moments "4-5" the auroral poleward expansion arises. Near the substorm onset, the proton intensity increase occurs inward of the CRRES orbit. During the expansion phase the local dipolarization (stretching) of magnetic field were accompanied by the intensity increase outward (inward) of the CRRES orbit.

Figure 4 shows the substorm 3 on Febr 28, 1991. At this substorm between 2300 an 2400 UT the CRRES was near L=6.2-6.7 at magnetic latitude between 8.8^{o} and 6.7^{o} and at 21.8-22.3 MLT. As in the previous events, during the local dipolarization (impulsive stretching) of magnetic field the proton fluxes increase

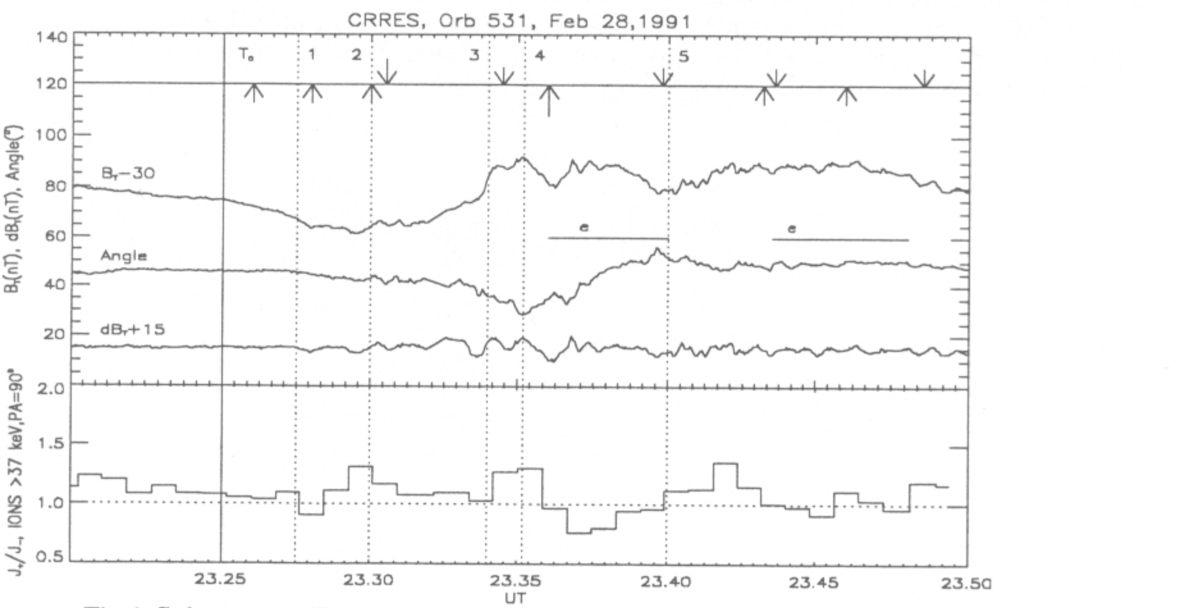

Fig.4. Substorm on Feb 28, 1991. Shown in the same format as in Fig.2.

tailward (earthward) of the CRRES. Slow stretching before the local dipolarization was accompanied by the proton injection outward of the CRRES orbit similarly to the growth phase situation of previous substorms 1 and 2. From Figures 2-4 one can see that the anisotropy pattern of differential proton fluxes may differ from the anisotropy of integral fluxes.

Although we examined only the small number of injection events, we believe the analyzed events reveal general tendency in relation of particle injection and magnetic field reconfiguration.

4. Conclusion

The analysis of azimuthal anisotropy of the proton fluxes near L=6.3-6.7 has showed the following:

1. Anisotropy of different energy proton fluxes may be different. Sometimes the flux variations are incoherent within a small spatial region (2 gyroradii).

2. During the local magnetic field dipolarization, the proton injection comes from outside of the CRRES orbit accompanied by small electron flux enhancements. This injection of energetic protons may have the form of earthward propagating spatial structure. Pseudobreakups during the substorm growth phase are accompanied by small proton injections outward of the CRRES orbit also.

3. Proton flux increase inward of the CRRES orbit are observed during the impulsive tailward stretching of geomagnetic field without the local electron flux enhancements.

4. During the first initial minutes after the substorm onset the proton flux increase starts inward of the CRRES orbit while the orientation of smooth magnetic field <B> is nearly invariable (or is stretching weakly) and the magnetic field pulsations dB have maximum amplitude in the Pi2 range. This has similarity with the plasma ejections from the Earth rather than the injection from the tail during the substorm onset. Potential candidates for the substorm onset mechanism may be the current disruption model [*Chao et al.*, 1977], ballooning instability [*Liu*, 1970] and MHD instability with formation of protoplasmoid configuration [*Erickson, Heinemann*, 1992].

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