"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 69- 72, 2007
© Kola Science Centre, Russian Academy of Science, 2007

Polar Geophysical Institute

CHANGES OF THE TOTAL ION PRESSURE IN THE NIGHTSIDE INNER MAGNETOSPHERE

T.V. Kozelova[1], L.L. Lazutin[2], B.V. Kozelov[1,3]

[1] *Polar Geophysical Institute, Apatity, 184209 Russia*
[2] *Russia Space Science Division, Scobeltsyn Institute for Nuclear Physics of Moscow State University, Russia*
[3] *Institute of Physics and Technology, University of Tromsø, Tromsø, Norway*

Abstract. The total ion pressure has been considered in the range of the magnetic shell parameter *L* from 2.3 to 6.7 in the nightside magnetosphere. The data of the LEPA (0.1-30 keV ions and electrons) and EPAS (21.5-285 keV electrons and 37-3200 keV ions) particle detectors and the magnetic field measurements onboard CRRES satellite have been used. The dynamics of the whole energy range of the electrons and ions have been considered to estimate the total plasma pressure during several events in disturbed periods before the substorm onsets. We consider here two events in more details. As the estimated electron contribution in the total pressure is small, we analyze the total ion pressure supposing that all ions are the protons. Besides, we consider also the pressure of the low-energy ions (LEPA) and high-energy ions (EPAS) separately. The estimated total ion pressure reaches a maximum at L ~ 3 and then a gradual decrease with increasing *L*. We found that an additional peak in the radial profile of the total ion pressure appears at *L* ~ 4.6 - 4.9. This peak coincides with an enhancement of LEPA portion of the ion pressure which disturbs the nearly monotonous drop of energetic ion pressure as a function of the parameter *L*. The penetration of the plasma sheet ions into the inner magnetosphere is discussed and compared with other observations.

1. Introduction

The radial distribution of the plasma pressure in the inner magnetosphere depends on the energy of the observed ions and the intensity of the geomagnetic activity. For the quiescent period, *Frank* (1971) observed a broad maximum of energy density of (80 eV to 46 keV) protons around *L* ~ 6.8. *De Michelis et al.* (1999) obtained that the radial profile of the total (~ 1 keV - 300 keV) ion pressure shown a peak at *L* ~ 4.2. *Lui and Hamilton* (1992) observed the radial profile of the total (~ 1 keV - 1 MeV) ion pressure with a peak at *L* =3. It is well known that the low-energy protons penetrating into the inner magnetosphere deeper than the plasmapause and having a nose-like structure [*Smith and Hoffman*, 1974] present the *innermost edge of the plasma sheet ion penetration*. However, the influence of this plasma advance to the plasma pressure was not clarified up to now. In this paper, we estimate the total ion pressure from the CRRES measurement at *L* ~ 2 – 6.6 and analyze the contribution of the ions with the energies W< 30 keV, which have a nose-like structure.

2. Observations

We considered two events of January 24, 1991 and February 9, 1991 in more details, using LEPA [*Hardy et al.*, 1993] and EPAS [*Korth et al.*, 1992] data and the magnetic field data from the CRRES satellite.

2.1. Event 1 on January 24, 1991. The measured perpendicular components of the total ion pressure and the LEPA and EPAS portions are shown in the panel 3 of Figure1. The radial profile of quiet-time proton pressure determined by *Lui and Hamilton* [1992] is shown by the dashed line with asterisks in the panel 4 for comparison. One can see that the measured ion pressure generally dominates the electron pressure during this event as well as for the event of February 9, 1991. The ion pressure decreases slowly from *L* ~ 4 to *L* ~ 6.6. The pressure enhancements around *L* ~ 5.5 and *L* ~ 6.3 can be associated with the substorm intensify-cations at T1 and T2. The total ion pressure exhibits an additional enhancement with a peak of ~ 10 nPa (denoted by 'b*') at *L* = 4.83. The LEPA ion pressure gives the main contribution to this peak.

From Figure 2 one can see that on 14:48 UT (*L* ~ =3.72), the *"nose"* structure of ions is observed with increase of 12.6-keV ion flux by two orders of magnitude. The flux increase spreads to higher (from 12.6 keV to 28.5 keV) and lower (from 12.6 keV to 0.28 keV) energies at *L*=4.55 and remains at the high intensity. The innermost edge of the ion nose structure appears within the plasmapause (indicated by PP in Figures 1-2). The LEPA ion pressure begin to increase near this edge.

The sharp maximum of LEPA pressure around b* coincides with a most significant increase of (16.5-21.7 keV) ion flux. Besides, one can see a small dynamical changes of the (0.831-12.6 keV) ion flux which also belong to the already pre-existing nose structure. These nose ions contribute to the partial ring current. Around b* the flux of the 28.5 keV ions increases slowly and gradually. These ions as the ions with the energy of 37-69 keV (from EPAS ion data, see the panel 2 of Figure 1) may be the 'old' trapped particles driftng around the Earth and creating a ring current.

After the PP, the cutoff energy of electrons (the Alfven layers) increases from 0.368 keV to 16.5 keV. This is "*the inner boundary of the earthward edge of the plasma sheet*" as noted by *Frank* [1971.

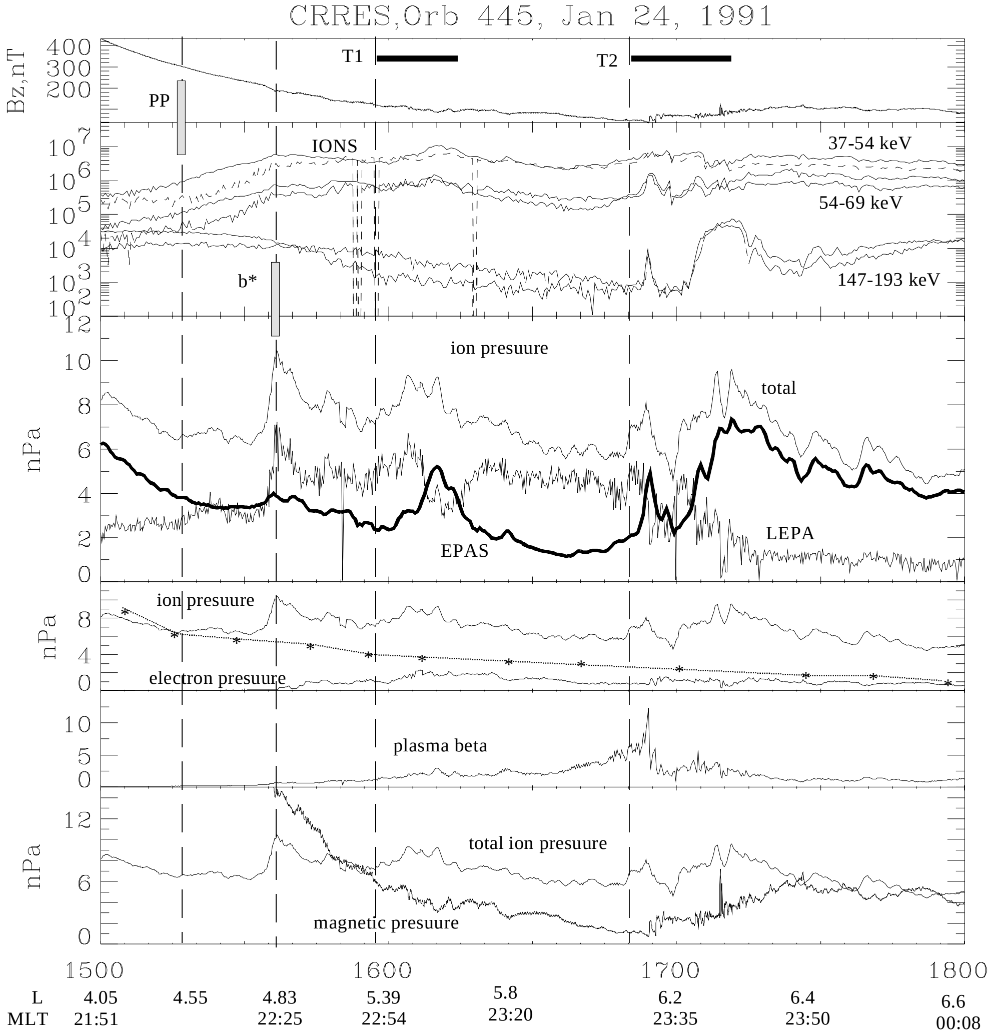

Fig. 1. Event 1 on January 24, 1991. From top to bottom: Z-component of the magnetic field, fluxes of EPAS ions in $cm^{-2}s^{-1}sr^{-1}keV^{-1}$ for three channels (the panel 2), the total ion pressure and two portions (LEPA and EPAS) ion pressure (the panel 3), the total ion pressure (thick line) and electron pressure (thin line) (the panel 4), the plasma beta (the panel 5), the total ion and magnetic field pressure (the bottom panel).

Thus, the pressure of the ions associated with nose structure results to sharp increase of the total ion pressure and to the appearance of the additional peak at L = 4.83.

2.2. Event 2 on February 9, 1991. Figure 3 illustrates this event in the same format as Figure 1. The total ion pressure deduced from CRRES data exhibits a peak at L ~ 3.1 similar to one fond by *Lui and Hamilton*, 1992. On L > 4.2 our pressure profile is higher as compared to the one obtained during low geomagnetic activity. The ion pressure enhancement at L = 6.3 – 6.5 is associated with the substorm onset at *T*o.

The additional peak of the total ion pressure appears at L = 4.6 from CRRES data. One may attribute this peak b* to the contribution from the LEPA portion. During this event, the *nose*-like structure of ion with the edge energy of 7.31 keV appears at L = 3.25. Small dynamical changes of the fluxes of ions with the (~ 1-22 keV) energies which belong to the pre-existing nose structure were observed around the b* moment.

Besides, the total ion pressure profile exhibits another particularity: a short plateau appears at L = 5 – 5.5. This plateau is formed by the drop of EPAS part of ion pressure associated with the outer edge of the radiation belt and the enhancement of LEPA part of ion pressure.

2.3. Appearance of the nose structure and substorm activity. In the event 1, the nose structure appears about 4-5 hours after previous substorm activation with the maximum *AE* value ~ 1000 nT. In the event 2, the nose structure is observed about 3.5 hours after substorm with the maximum *AE* value ~ 450 nT. The additional enhancements of the nose structure ion fluxes occur later. These enhancements lead to additional peak b* in the radial total plasma pressure profile. In the event 1, this peak is observed about 20 min before T1 substorm intensification onset. In the event 2, this peak is observed about 20 min after the local short peak of *AE*~200 nT.

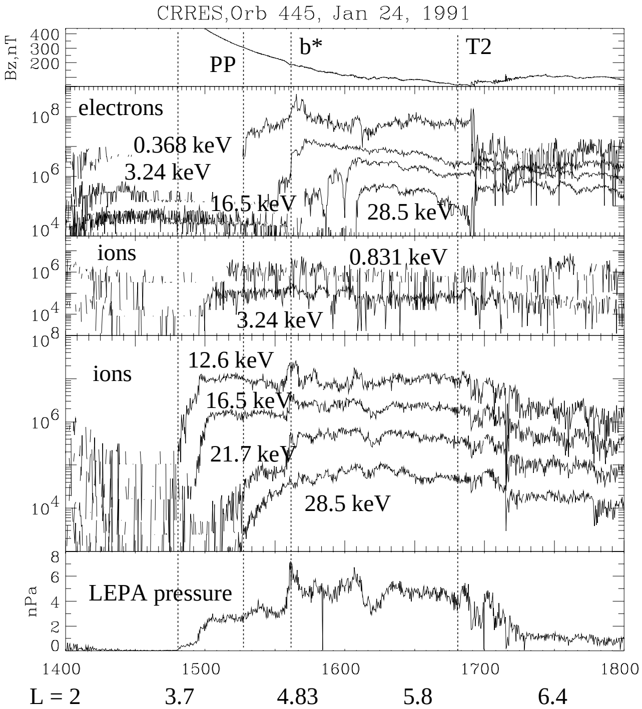

Fig. 2. Event 1 on January 24, 1991. From top to bottom: Z-component of the magnetic field, fluxes of LEPA electrons for four energy channels (the panel 2), fluxes of LEPA ions for six energy channels (the panels 3-4), the pressure of the LEPA ions is presented in the bottom panel. Particle flux in $cm^{-2}s^{-1}sr^{-1}keV^{-1}$.

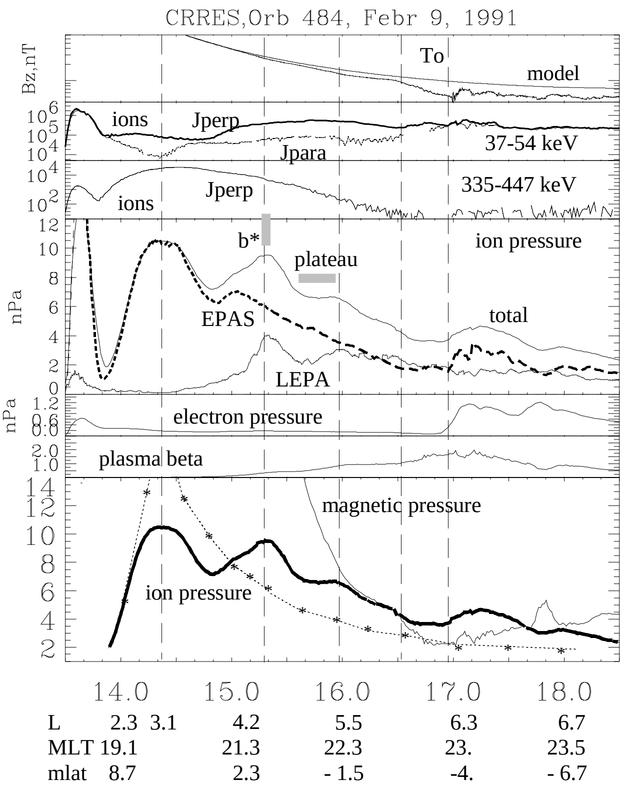

Fig. 3. Event 2 on February 9, 1991. Shown in the same format as Fig.1.

3. Discussion

It is known, that the spectrograms of the low energy protons penetrating into the inner magnetosphere have a nose structure [*Smith and Hoffman* , 1974; *Ejiri et al.*, 1980; *Sergeev et al.*, 1991; *Kerns et al.*, 1994; *Ganushkina et al.*, 2000]. A nose ion structure is a spatial phenomenon and presents the innermost boundary of the protons in the evening hours. Some characteristics of the nose ion structure are consistent with flow patterns resulting from combination of inward large-scale convection, gradient drift, and co-rotation [*Ejiri et al.*, 1980]. *Kerns et al.* (1994) observed the nose-like distributions of the (160 eV – 28 keV) ions on almost every orbit of the CRRES in the pre-midnight sector. They reported that 40 to 50 percent of the nose ion structures and the cutoffs in energy for electrons on the nightside of the Earth were consistent with those derived from the convection model.

In our events the nose structures are observed about 3-5 hours after last previous substorm activation. We suppose that both the innermost boundary of the protons and the plasmapause probably formed in the inner magnetosphere during significantly long period of a large-scale convection electric field preceding the nose structure observation as in [*Ejiri et al.*, 1980]. The calculated ion pressure reported here indicates that the pressure of ions associated with this innermost nose structure edge at L ~ 3.1 – 3.7 was small and, then, it was growing with the increase of radial distance. The additional total ion pressure maximum at L ~ 4.6 - 4.9 coincides with an enhancement of the pressure of the low-energy (0.831-21.7 keV) ions.

4. Summary

The main results of presented analysis are the following: The additional maximum of the total ion pressure appears at L ~ 4.6 - 4.9. This maximum coincides with the sharp maximum of the low energy (LEPA) portion of the ion pressure. The sharp maximum of LEPA ion pressure is associated with an most significant increase of the perpendicular flux of ions with energies of 16.5-21.7 keV and a small dynamical changes of the fluxes of ions with other (0.831-12.6 keV) energies. The ions with the (0.831-21.7 keV) energies belong to the already pre-existing nose structure of the ions which appears about 3-5 hours after previous substorm activation. We suppose that the innermost edge of the region with the pressure gradient $\delta P_{\perp}/\delta L > 0$ may be a signature of the inner portion of the active time partial ring current.

Acknowledgements. Authors grateful to N.P. Meredith and A. Korth for the CRRES particle data. The work was partly supported by the Russian Foundation for Basic Research (grants 06-05-64225 and 06-05-65044), by the Presidium of the Russian Academy of Sciences (RAS) through the basic research program "Solar activity and physical processes in the Sun-Earth system", and by the Division Physical Sciences of RAS through the program "Plasma processes in the solar system".

References

De Michelis P., Daglis I. A., Consolini G. A.:An average image of proton plasma pressure and of current systems in the equatorial plane derived from AMPTE/CCE-CHEM measurements. *J. Geophys. Res.*, 104, A12, 28,615-28,624, 1999.

Ejiri M., Hoffman R. A., and Smith P. H.: Energetic particle penetrations into the inner magnetosphere. *J. Geophys. Res.,* 85, A2, 653-663, 1980.

Frank, L. A.: Relationship of the plasma sheet, ring current, trapping boundary, and plasmapause near the magnetic equator and local midnight. *J. Geophys. Res*., 76, 10, 2265-2275, 1971.

Ganushkina N. Yu., Pulkkinen T. I., Sergeev V. A., Kubyshkina M. V., Baker D. N., Turner N. E., Grande M., Kellett B., Fennell J., Roeder J., Sauvaud J.-A., and Fritz T. A.: Entry of plasma sheet particles into the inner magnetosphere as observed by Polar/CAMMICE, *J. Geophys. Res.,* 105, A11, 25,205-25,219, 2000.

Hardy, D. A., Walton, D. M., Johnstone, A. D., Smith, M. F., Gough, M. P., Huber, A., Pantazis, J. and Burkhardt, R.: Low Energy Plasma Analyzer, *IEEE Trans. Nucl. Sci., 40*, 246, 1993.

Kerns, K. J., Hardy, D. A. and Gussenhoven, M. S.: Modeling of convection boundaries seen by CRRES in 120-eV to 28-keV particles, *J. Geophys. Res.,* 99, A2, 2403-2414, 1994.

Korth, A., Kremser, G., Wilken, B., Guttler, W., Ullaland, S. L. and Koga, R.: Electron and proton wide-angle spectrometer (EPAS) on the CRRES spacecraft, *J. Spacecraft Rockets*, 29, 609, 1992.

Lui, A. T. Y., Hamilton d. C.: Radial profiles of quiet time magnetospheric parameters, *J. Geophys. Res*., 97, A12, 19325-19332, 1992.

Sergeev V. A., Aparicio B., Perraut S., Malkov M. V., and R. J. Pellinen R. J.: Structore of the inner plasma sheet at midnight during steady convection. *Planet. Space Sci.,* 39, 8, 1083-1096, 1991.

Smith P. H. and Hoffman R. A.: Direct observations in the dusk hours of the characteristics of the storm time ring current particles during the beginning of magnetic storms. *J. Geophys. Res.,* 79, 7, 966-971, 1974.