Sodankylä Geophysical Observatory Publications (2001) 92:29–32

Cosmic Radio Noise Absorption Associated with North-South Aurora

M. Danielides[1], **S. Shalimov**[2], **and J. Kangas**[3]

[1]Department of Physical Sciences, P.O. Box 3000, FIN-90014 University of Oulu, Finland
[2]Institute of Physics of the Earth, Moscow, Russia
[3]Sodankylä Geophysical Observatory, FIN-99600 Sodankylä, Finland

Received: 15.10.2001 – Accepted: 24.9.2002

Abstract. We report first observations of cosmic radio noise absorption signature of the north-south (N-S) aurora. The N-S auroral structures are auroral forms, which originate in the wake of the westward travelling surge (WTS). We used Imaging Riometer for Ionospheric Studies (IRIS) and All-Sky Camera (ASC) data from Kilpisjärvi, Finland in order to analyse the development of both absorption and auroral distribution on October 25, 1999. We found that the development of the N-S aligned auroral structures are associated with specific N-S aligned localized absorption events (only with a duration of few minutes) that resemble their ASC counterparts accompanying by Hall current jets and PiB pulsation activity.

1 Introduction

Ionospheric attenuation of high frequency cosmic radio waves depends on the product of electron density and electron collision frequency, integrated along the path of propagation. Among several causes of absorption the most common at auroral latitudes is the arrival of energetic auroral electrons, which can penetrate down to about 95 km and even below resulting in strong increase of electron density. New observations by imaging riometers (Hargreaves et al., 1997; Ranta et al., 1997) tend to improve the picture of a substorm development in terms of cosmic radio noise absorption (CNA) in which the substorm-related energetic electron precipitations produce a slowly southward moving absorption bay, which may precede the intense precipitation at substorm onset, and is identified as an arc-like feature extending east-west across the entire field of view (Ranta et al., 1983). It appears now that the onset is due to the intensification within this arc giving rise to "spike events" elliptical in shape with major axis generally along the L-shells and the duration of only a few minutes (Hargreaves et al., 1997). In the course of the substorm development the precipitation region may expand with a sharp onset at the front towards the west in spatially confined regions at high ($L > 6$) and low ($L < 4$) L-values separately with about equal velocity (Ranta et al., 1983). At high latitudes PiB pulsations, and at low latitudes IPDP pulsations were seen simultaneously with the absorption events (Lukkari et al., 1977; Ranta et al., 1997). They related the absorption at high latitudes to direct magnetospheric injection and that at lower latitudes to substorm-injected protons near the plasmapause region. Recent studies of the relationship between bursty bulk flows (BBFs) in the magnetotail and narrow (in MLT) energetic particle injections in the nightside part of geosynchronous orbit on one hand and auroral activity on the other hand (Henderson et al., 1998; Sergeev et al., 1999; Sergeev, et al., 2000) revealed that these transient phenomena correspond to narrow N-S aligned optical auroral forms also referred to as "auroral streamers" (Elphinstone et al., 1996). These auroral streamers are localized auroral activations that expand equatorwards from the poleward aurora to form N-S structures, often during expansion phase of a substorm (Elphinstone et al., 1996). They are therefore quite similar with the N-S aurora described by Nakamura et al. (1993). Based on TV observations Nakamura et al. (1993) showed that at the early stage of the bulge growth the N-S structures typically develop in the equatorward direction eastward of the westward travelling surge. According to Nakamura et al. (1993), the westernmost N-S aurora forms showed a hook-like tilt to the west, whereas the easternmost ones show such a tilt towards the east. These results are consistent with VIKING satellite observations by Rostoker et al. (1987) and with Freja satellite observations by Marklund et al. (1998). In later substorm phases, the N-S aurora develops to diffuse or pulsating aurora (Nakamura et al., 1993). In its turn the bulk of energy flux of pulsating aurora is carried by precipitating electrons having energies between 5 and 40 keV (Sandahl et al., 1980), which is higher than that of the discrete aurora. From all these reports it may be expected that spatially-structured increases in absorption, which is normally caused by relatively high energy particles

Correspondence to: Michael Danielides
(e-mail: michael.danielides@oulu.fi)

will be observed in the ionosphere by imaging riometer simultaneously with optical N-S aurora development. The aim of this report is to compare spatial and temporal variations in ionospheric absorption with the characteristics of the N-S aurora.

2 Observations

In our case study, we present IRIS and ASC auroral image data obtained in northern Finland at Kilpisjärvi (69.05 N, 20.79 E, L=5.9) on October 25, 1999 in time interval from 1630 to 1730 UT, which clearly illustrate correspondence between riometer absorption and N-S aurora development. The selected time period is characterized by disturbed geomagnetic conditions (Kp (15-18 UT) = 3+). The interplanetary magnetic field (IMF) and the solar wind parameters were measured by the WIND space probe, which was operating between Earth and Sun at about 60 Re from Earth at that time. The IMF Bz-component has been southward orientated after 1525 UT. The solar wind velocity was about 400 km/s, so these disturbances reached the magnetopause with about 16 minute delay. Figure 1 shows relevant magnetograms for this time interval. From IMAGE magnetometer data it can be seen that there are several isolated activations observed at Kilpisjǎrvi in the time interval from 1630 to 1730 UT (at 1641, 1649, 1709, and 1719 UT). Among these only the activation at 1709 UT marks the onset of expansive phase, and only this event will be considered here. Short-lived positive excursions in the X component at 1711 UT at stations south of MAS are signatures of the passage of a westward travelling surge (WTS) over the chain of stations. After to the WTS the X component becomes negative, first at MAS then at SOR and it continues to be progressively delayed at stations further north.

The development of both absorption and auroral phenomena can be seen with the ASC data for the time interval 17 10:50-1712:40 UT (Figure 2, where 1 min 50 sec must be added to ASC time mark due to GPS clock offset) and the IRIS images during 1709-1713 UT (Figure 3) with 10 sec resolution for the both type of data. The N-S aurora has broke off from the developing WTS near 1711:20 UT just after the WTS passing (by 1711:10 UT) and remains attached to the WTS wake while slowly drifting in the west-south direction and showing clockwise rotation at later local times. Two minutes after its appearance the N-S aurora fades out and develops to diffuse patches. The remarkable feature of the IRIS images in the period of the onset and later is both spatial and temporal similarity with the visible aurora. While the average energy of the visible aurora is usually associated with a few keV electrons, the average energy of precipitating electrons associated with the N-S auroral absorption can be roughly estimated from the IRIS (f=38.2 MHz) data. The colour scale is saturated at 1.8 dB during the event. Taking into account the empirical relations of the Hall $\sum_H$ and Pedersen $\sum_P$ conductance with absorption intensity (Walker et al., 1989) and calculating the ratio $\sum_H / \sum_P$ we use the

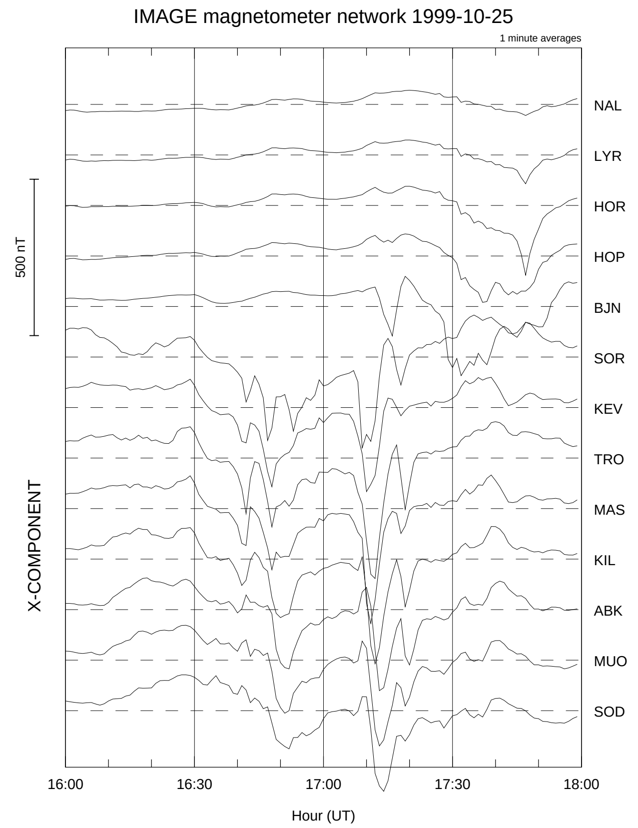

Fig. 1. Selected X-component magnetograms from IMAGE network of station. Of special interest for this study is the event around 1711 UT.

relation (Robinson et al., 1987) $\sum_H / \sum_P = 0.45 \cdot E^{0.85}$, where E is the average energy of the precipitating electrons. The calculation gives the result E = 11.4 keV. We thus conclude that, at least in this case, the morphology of ∼few keV electrons manifested in optical observations also applies for the electrons of higher energies (∼few tens keV) that produce cosmic noise absorption. The IRIS image taken at 1712 UT is shown again in Figure 4 (the absorption is not normalized this time) projected on a geographical grid. The ASC N-S aurora mapped on the IRIS image and added by equivalent current pattern was sketched on the same frame (the circle shows the ASC reliable field of view). From the equivalent current pattern we can see that the westward electrojet region is widely distributed in the evening auroral zone during this event. A contraclockwise current pattern can be seen at the western and southern side of the N-S aurora, and a clockwise area spreads at the poleward side of it, whereas the N-S aurora is associated with a northwest equivalent current. The occurrence of PiB pulsation activity at Kilpisjärvi has also been detected in association with N-S pattern (Figure 4a in Danielides et al. (2001)). Thus the development of the N-S aligned aurora in the wake of WTS appears to be coincident with precipitation of high- energy particles (hence with the corresponding structure in absorption), the equivalent current jet and with generation of PiB pulsations.

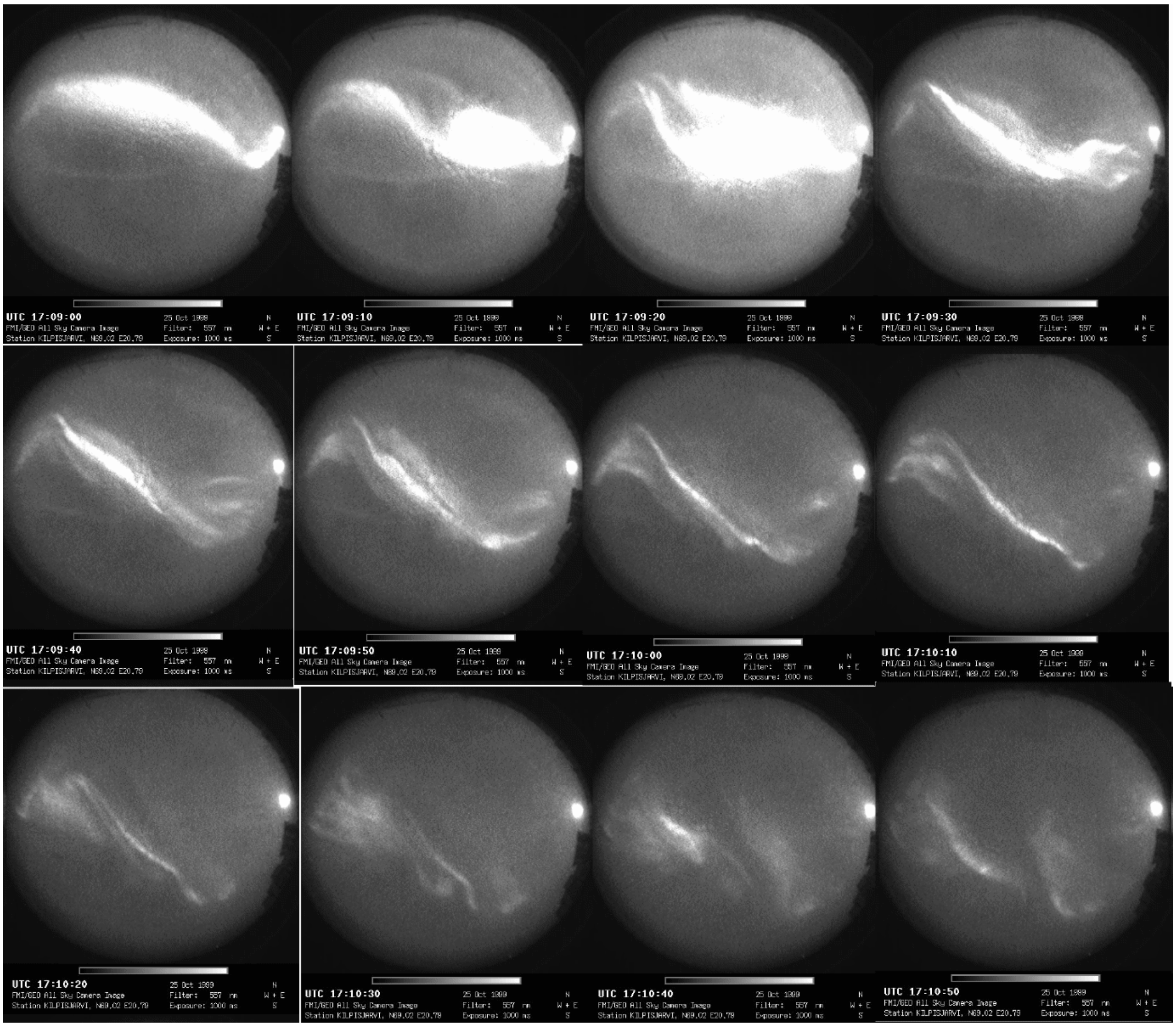

Fig. 2. Collection of all-sky frames on October 25, 1999; notice that 1 min 50 s must be added to the time mark due to GPS clock offset.

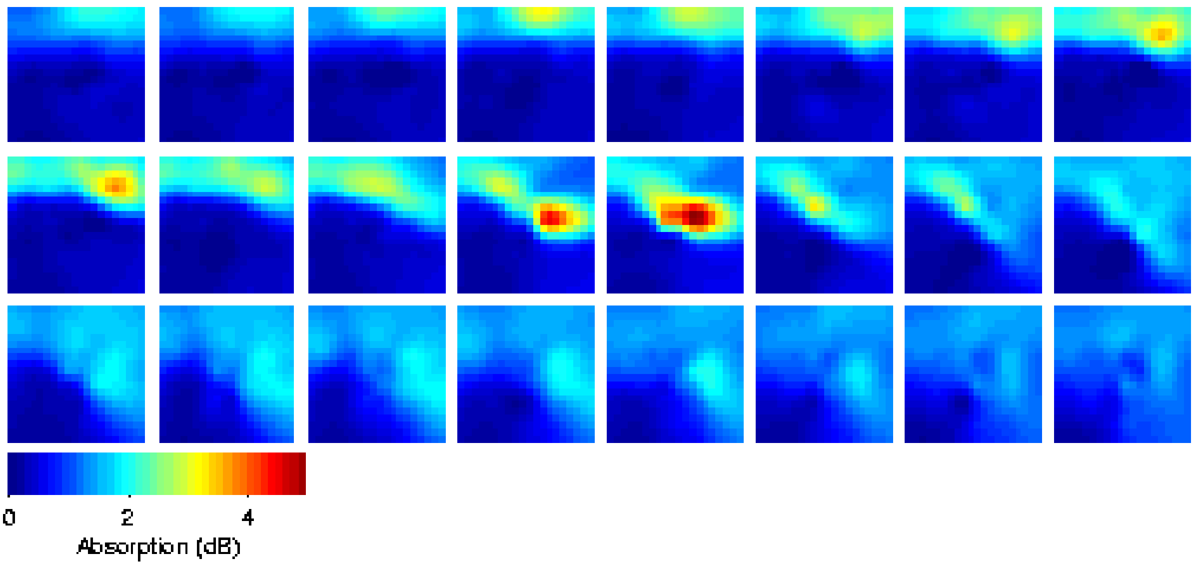

Fig. 3. Horizontal distribution of radio absorption derived from the Kilpisjärvi IRIS observations for the same event.

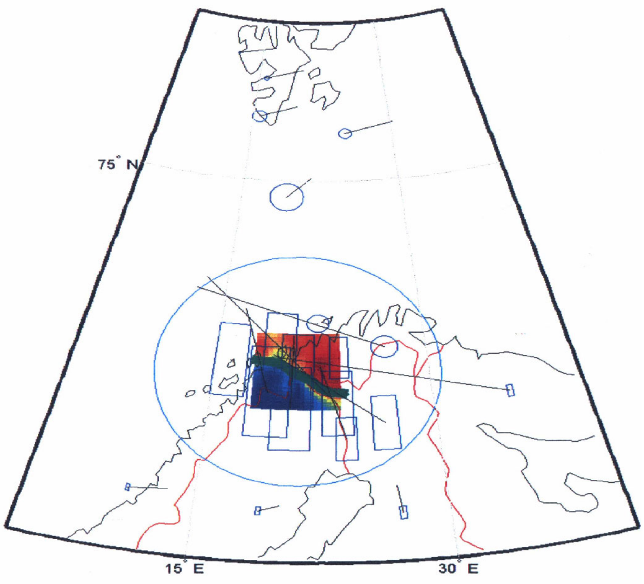

Fig. 4. ASC N-S aurora mapped on the IRIS image and added by equivalent current plot sketched on a geographic grid (the circle shows the ASC reliable field of view).

3 Concluding Comments

Simultaneous observations by ground-based IRIS system and ASC at Kilpisjärvi, Finland are used to investigate the distribution of riometer absorption and visual auroras associated with N-S aligned auroral structures. N-S auroral structures relate to the global expansion of the auroral substorm bulge as described by Nakamura et al. (1993). Typically, the substorm expansion phase is a series of pulses, which produce the bulge (e.g. Sergeev et al. (1979)). These pulses are associated with the creation of new arcs at the poleward edge of the bulge together with the appearance of N-S orientated auroral forms at the equatorward edge, which evolve into diffuse pulsating auroral forms. In the present study we found an association between an isolated N-S aligned aurora with the occurrence of corresponding N-S aligned structure in riometer absorption and the northward equivalent component of the Hall current. This situation is in agreement with Nakamura et al. (1993) suggestion about the ionospheric current signature for the N-S auroral structures localized between the negative potential peak concentrated at the western part of the bulge and the positive potential region spread poleward, so that N-S aurora elongated at the line between the two current systems. Finally, it should be noted that while there is a similarity between the N-S aurora structures and auroral streamers in associated ionospheric effects it is not clear are these structures generated by the same or different mechanisms in the tail? Further discussion of the N-S structure formation is beyond the scope of our paper.

Acknowledgements. Numerous discussions with T. Bösinger are greatly acknoledged. Without the IMAGE and ASC data provided by the Finnish Meteological Institute and the IRIS riometer data provided by Lancaster University this study would have been not possible.

The editor thanks X. Y. Furore and another referee for assisting in evaluating this paper.

References

Amm, O., A. Pajunpaa, and U. Brandstrom, Spatial distribution of conductances and currents associated with a nourth-south from during a multiple-substorm period, *Ann. Geophys.*, *17*, 1385, 1999.

Danielides, M.A., S. Shalimov, and J. Kangas, Estimates of the field-aligned current density in current-carrying filaments using auroral zone ground–based observations, *Ann. Geophys.*, *19*, 699, 2001.

Elphinstone, R.D., J.S. Murphree, and L.L. Cogger, What is a global auroral substorm ?, *Rev. Geophys.*, *34*, 169, 1996.

Hargreaves, J.K., S. Browne, H. Ranta, et al., A study of substorm- associated nightside spike events in auroral absorption using imaging riometers at South Pole and Kilpisjärvi, *J. Atm. Sol.-Terr. Physics*, *59*, 853, 1997.

Henderson, M.G., G.D. Reeves, and J.S. Murphree, Are north-south aligned auroral structures an ionospheric manifestation of bursty bulk flows ?, *Geophys. Res. Lett.*, *25*, 3737, 1998.

Kennel, C.F., The Kiruna conjecture: the strong version, Proceedings of the First ICS-1, *Eur. Space Agency Spec. Publ.*, *335*, 599, 1992.

Lukkari, L., J. Kangas, and H. Ranta, Correlated electron precipitation and magnetic Ipdp events near the plasmapause, *J. Geophys. Res.*, *82*, 4750, 1977.

Marklund, G.T., T. Karlsson, L.G. Blomberg, et al., Observations of the electric field fine structure associated with the westward travelling surge and large-scale auroral spirals, *J. Geophys. Res.*, *103*, 4125, 1998.

Nakamura, R., T. Oguti, T. Yamamoto, and S. Kokubun, Equatorward and poleward expansion of the auroras during auroral substorms, *J. Geophys. Res.*, *98*, 5743, 1993.

Ranta, A., H. Ranta, T.J. Rosenberg, et al., Development of an absorption substorm: studies of substorm related absorption events in the afternoon-early evening sector, *Planet. Space Sci.*, *31*, 1415, 1983.

Ranta, H., A. Ranta, J.K. Hargreaves, and S. Browne, Localized absorption events in the afternoon sector, *J. Atm. Sol.-Terr. Phys.*, *59*, 891, 1997.

Robinson, R.M., R.R. Vondrak, K. Miller, et al., On calculating ionospheric conductances from the flux and energy of precipitating electrons, *J. Geophys. Res.*, *92*, 2565, 1987.

Rostoker, G., A.T.Y. Lui, C.D. Anger, and J.S. Murphree, North-south structure in the midnight sector auroras as viewed by the Viking imager, *Geophys, Res. Lett.*, *14*, 613, 1987.

Sandahl, I., L. Eliasson, and R. Lundin, Rocket observations of precipitating electrons over a pulsating aurora, *Geophys. Res. Lett.*, *7*, 309, 1980.

Sergeev, V.A., and A.G. Yahnin, The features of auroral bulge expansion,, *Planet. Space Sci.*, *27*, 1429, 1979.

Sergeev, V.A., K. Liou, C.I. Meng, et al., Development of auroral streamers in association with localized impulsive injections to the inner magnetotail, *Geophys. Res. Lett.*, *26*, 417, 1999.

Sergeev, V.A., J.A. Sauvaud, D. Popescu, et al., Multiple-spacecraft observation of a narrow transient plasma jet in the Earth's plasma sheet, *Geophys. Res. Lett.*, *27*, 851, 2000.

Walker, J.K., and V.P. Bhatnagar, Ionospheric absorption, typical ionisation, conductivity, and possible synoptic heating parameters in the upper atmosphere, *J. Geophys. Res.*, *94*, 3713, 1989.