The transmission of upstream waves to the magnetosphere: an analysis at widely separated ground stations.

by U. Villante, C. de Paulis, P. Francia

University of L'Aquila – Department of Physics – chiara.depaulis@aquila.infn.it

also at Area di ricerca in Astrogeofisica

On 18 February 2003 a long duration, almost monochromatic, wave event was detected by Cluster at radial distances from the bow shock smaller than ≈10 Re. We compared Cluster data with ground measurements at low and Antarctic latitudes.

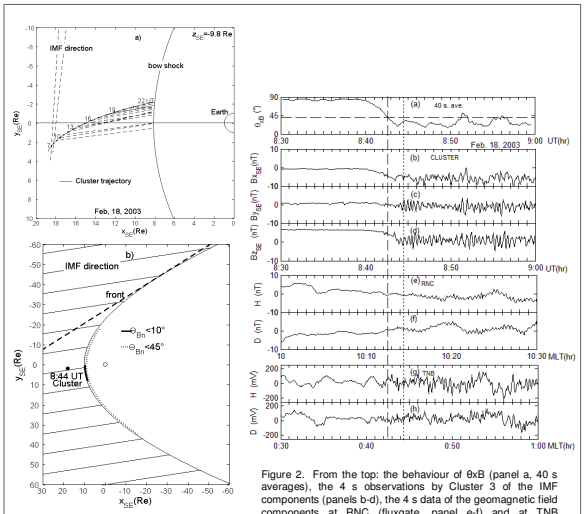

Figure 1. a) The projection onto the ecliptic plane of the hourly averages of the IMF direction along Cluster trajectory (6:30-7:30 UT; 07:30-08:30 UT; etc., dashed lines). b) The average IMF orientation provides conditions for a quasi-parallel bow shock from the dawn to the dusk/evening sector (dotted profile) and θbn (the angle between the interplanetary magnetic field and the shock normal) values <10° around the bow shock nose (solid profile). The approximate position of the first impact point of a front inclined at ≈30° with respect to the radial direction (solid dashed line).

Figure 2. From the top: the behaviour of θxB (panel a, 40 s averages), the 4 s observations by Cluster 3 of the IMF components (panels b-d), the 4 s data of the geomagnetic field components at RNC (fluxgate, panel e-f) and at TNB (induction coil, panels g-h) for the time period 08:30-09:00 UT. Ground measurements are organized in terms of the magnetic local time (MLT)

Figure 1a shows the change of interplanetary magnetic field (IMF) orientation after ≈ 8:30 UT. It led Cluster to be located on almost radial IMF lines, and determined a wide foreshock region around the bow shock nose providing high favorable conditions for a direct wave penetration into the magnetosphere. The delay time between Cluster and Ace observations (not shown) suggests that the IMF rotation occurred across a front tilted at ≈30° with respect to the radial direction. A similar front would impinge the dark side of the bow shock (≈08:36 UT) before reaching the morning sector (≈08:38 UT) and Cluster (≈08:44 UT, Figure 1b).

Figure 2 shows that the decrease of ΘxB (cone angle) was accompanied by the sudden onset of wave activity at Cluster as well as at RNC (Ranchio, λ=38°N, MLT (magnetic local time) = UT+1,5) and TNB (Terra Nova Bay, λ=80°S, MLT= UT-8). It suggests the upstream waves as common origin of ground pulsations simultaneously detected at widely separated sites. The onset of the wave activity at RNC was almost simultaneous to Cluster. TNB measurements revealed an earlier appearance of wave activity, suggesting a different origin/propagation path to the polar cap.

Assuming that the wave appearance at RNC is related to the impinging of highly favorable IMF orientations in the morning sector of the bow shock, we speculated a transit time of ≈5-6 min through the dayside magnetosheath and magnetosphere.

Figure 3 compares the dynamic spectra evaluated at Cluster (Y' and Z' components, in a coordinate system in which axes have been rotated to obtain X' along the direction of the average field), with those obtained at ground stations. At low latitudes the wave activity persisted through the entire dayside region, and it sharply decreased when the station rotated into the dusk sector. Between ≈15:00-17:30 MLT the power spectra revealed clear evidence of higher frequency activity, due to FLRs (field line resonance) processes at RNC (the white trace in panel c identifies the ratio, Rp, between the integrated power of the H and D component (f=50-70 mHz)). At TNB the wave activity appeared in the night sector and became much more significant in the morning hours; then it progressively intermingled to the wide band activity of the cusp region.

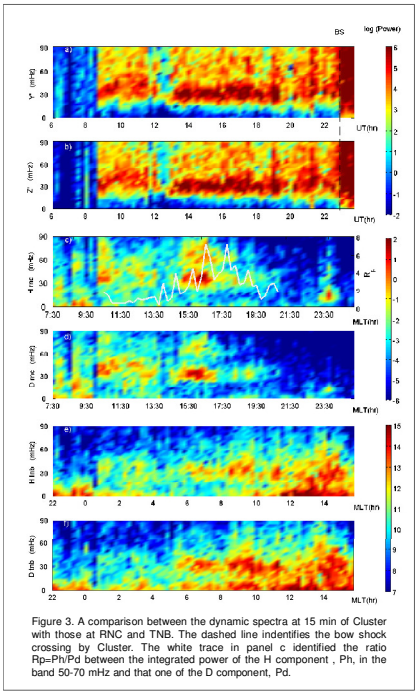

Figure 3. A comparison between the dynamic spectra at 15 min of Cluster with those at RNC and TNB. The dashed line indentifies the bow shock crossing by Cluster. The white trace in panel c identified the ratio Rp=Ph/Pd between the integrated power of the H component , Ph, in the band 50-70 mHz and that one of the D component, Pd.

Figure 4 shows the MLT dependence of the ratio R between the internal and the external power integrated in the frequency range of f=30-40 mHz. The level of the ground activity corresponds to ≈5-10% of the external power either in the daytime hours at low latitudes or in the nighttime in the polar cap. The sharp R decrease at RNC confirms the lack of wave transmission to the dark hemisphere at low latitude. The progressive R increase at TNB reflects the increasing morning activity and the influence of turbulence in the dayside cusp.

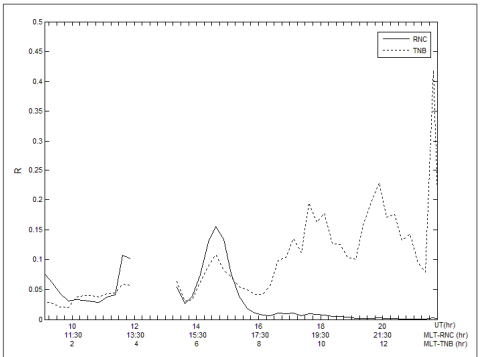

Figure 4. The MLT dependence of the ratio R between the internal (Ph+Pd) and the external power (Px+Py+Pz) integrated in the range f=30-45 mHz at RNC (solid line) and TNB (dotted line). The data gap corresponds to the interval of vanishing upstream activity.

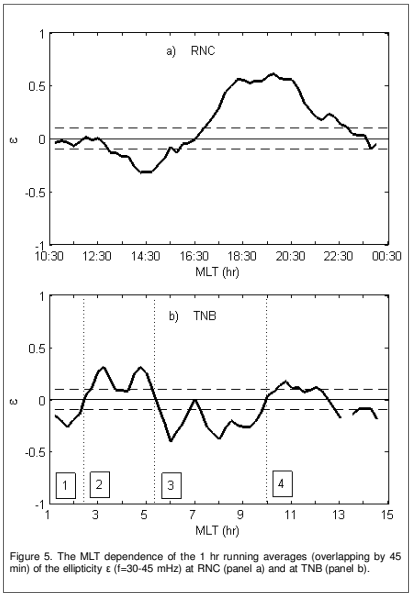

Figure 5. The MLT dependence of the 1 hr running averages (overlapping by 45 min) of the ellipticity ε (f=30-45 mHz) at RNC (panel a) and at TNB (panel b).

Figure 5 shows the polarization pattern at RNC and TNB (f=30-45mHz, positive/negative ε correspond to clockwise/counterclockwise polarization). In the afternoon, at RNC, the polarization was CW, consistent with the expected tailward propagation.

At TNB, in the postmidnight sector (1), the CCW polarization might be consistent with sunward propagating waves, penetrating through magnetotail lobes, possibly related to the first impinging of the IMF front on the predawn flank of the bow shock. The CW polarization detected between ≈3:00-5:00 MLT (sector 2) might be consistent with tailward propagating waves. In the sector 3 CCW polarization might be indicative of higher harmonics of fundamental FLRs occurring at lower latitudes, obscured by contribution of the cusp activity at later MLTs (sector 4).

Summary and discussion. The close correspondence between observations in the foreshock region and at ground stations makes clear that the external wave train is responsible for the onset of ground waves with similar characteristics from the dayside at northern low latitudes to the nightside in the southern polar cap. In the daytime, at low latitudes, the level of the ground activity was approximately the same as in the nighttime hours in the polar cap and might correspond to ≈5-10% of the external power. The polarization pattern at RNC, in the afternoon, appeared consistent with the expected tailward propagation. At TNB the complex pattern might be interpreted in terms of the relative contribution of several concurring elements.