

ELECTROSTATIC AND ELECTROMAGNETIC EMISSIONS NEAR THE PLASMASPHERE. A CASE EVENT: 27 MAY 2003

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ABSTRACT

We present in this paper a review of electric emissions in the high frequency range (2-80 kHz) by the CLUSTER constellation crossing the outer plasmasphere at its perigee. During the considered event, dated 27th May 2003, the constellation separation was large (5000 km) and the geomagnetic activity high ($K_p \sim 4 - 5$). A large panel of natural emissions are observed, in particular non thermal continuum emissions (NTC) and electrostatic emissions related to f_{ce} , where f_{ce} is the local electron gyrofrequency. Intense NTC emissions visible in the northern hemisphere can be related with simultaneous observations from the IMAGE satellite, informing about large scale beaming properties. We present details about equatorial emissions at $(n + \frac{1}{2}) f_{ce}$ and emissions at $(n+1.1) f_{ce}$ observed at higher latitude. Lastly, intense emissions near the local plasma frequency f_p are observed within large scale density irregularities.

1. INTRODUCTION.

Plasmasphere is a large toroidal region of the inner magnetosphere, composed by dense ($10-1000$ particles/cm³) ion and electron populations of ionospheric origin trapped along magnetic field lines [1]. Several kinds of natural emissions have been observed in the plasmasphere region by previous satellites [2], [3], such as non thermal continuum emission (NTC), bandwidth emissions at $(n + \frac{1}{2}) f_{ce}$, where f_{ce} is the local electron gyrofrequency, plasmaspheric hiss, or chorus.

In this work we are using data of Whisper (Wave of High frequency and Sounder for Probing of Electron density by Relaxation) instrument [4] on the CLUSTER mission [5]. WHISPER instrument records the natural waves and yields a diagnostic of the electron density n_e using the sounding technique in the band 2-83 kHz. The electron density is related to the plasma frequency by

$$f_p \text{ (kHz)} = 9\sqrt{n_e \text{ (cm}^{-3}\text{)}}.$$

The four identical satellites (named C1, C2, C3, C4, hereafter) are placed in a tetrahedron layout with a polar orbit (perigee at $4 R_E$, apogee at $19.6 R_E$). The perigee passes provide excellent opportunities to study plasmopause equatorial regions

During the 2003, 27th May, plasmasphere crossing, some of these natural emissions can be observed particularly NTC, Auroral Kilometric Radiation and electrostatic emission at $(n + \frac{1}{2}) f_{ce}$. In this paper a detailed examination of the equatorial emissions is presented. NTC emission is also studied using CLUSTER and conjunction with IMAGE satellite.

2. CASE PRESENTATION

During the 27th may 2003, the four CLUSTER spacecraft cross the plasmasphere between 19 UT and 23 UT. These satellites orbit at 19 hours MLT with a separation of 5000 km. Their orbit configuration is plotted in Fig. 1 in SM coordinates. The magnetic equator is crossed between 20:10 and 21:30 UT

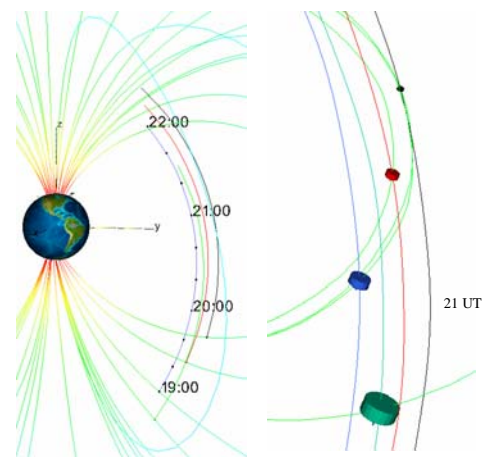


Fig.1 Orbit configuration of the plasmasphere crossing between 19 UT and 23 UT in SM coordinates.

In the spectrograms shown in Fig. 2, we can observe waves recorded by Whisper instrument on the four CLUSTER satellites between 19:00 and 22:10 UT. The orbit parameters are given for C4 in SM coordinates. The plasma frequency is recognized as the narrow banded thermal noise (greenish feature) which rises and falls in frequency position with time, reaching 80 kHz around 20:00 UT for C1. The four time intervals

at highest frequency values correspond to the four plasmasphere crossings. The plasma frequency variations, hence density variations, along the orbits are not smooth, however. Irregularities and large scale features are showing up. The large scale features seen on both sides of the equator, i.e. at $\sim 21:15$ UT and $21:45$ UT for C3 are plumes, or plasmaspheric tails. Attached to the plasmasphere body, each one is encountered twice, as each satellite crosses the corresponding range of L shells first in the southern hemisphere, then in the northern hemisphere. In this particular case, the main plume is placed closer to the plasmasphere body at smaller longitudes (C3 close-by crossings at ~ 18.8 MLT, compared to larger apart C1 crossings at ~ 19.15 MLT), in contrast with typical plume configuration [6].

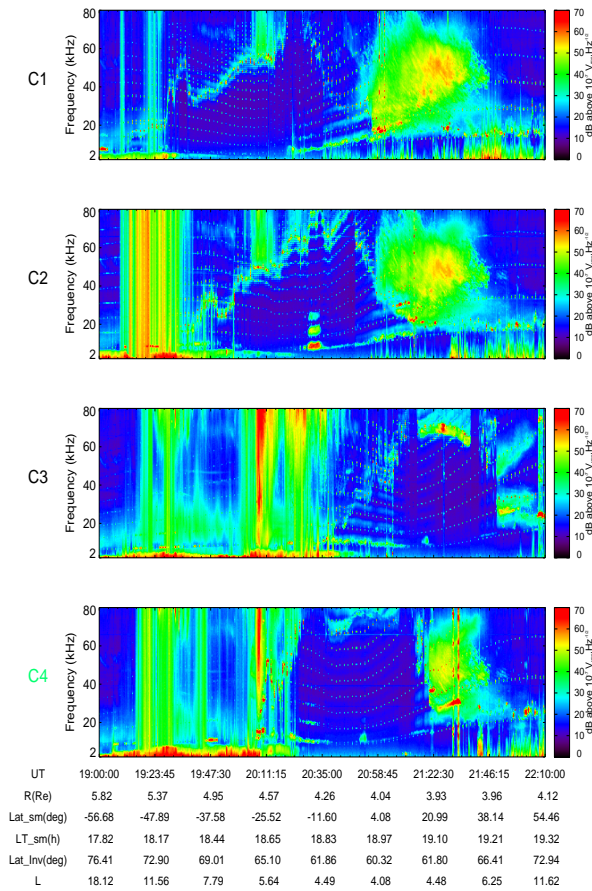


Fig. 2 Dynamic spectrograms of HF electric field produced by WHISPER

Most emissions appear differently according to the observing satellite, which is not a surprise considering their large separation. Indeed, even electromagnetic emissions propagating mainly in free space (Auroral Kilometric Radiation, AKR, and NTC), which reach thus all SC almost simultaneously, will have encountered different plasma regions along the ray paths, eventually blocking part of the spectrum. This is

the case for instance with the intense AKR radiation appearing shortly after 20 UT. AKR emission will not be further described in this study.

The first emissions we can examine are emissions related to f_{ce} . Equatorial ones, positioned in frequency at $(n+1/2)f_{ce}$, appear near the magnetic equator on C2 ($\sim 20:30$ UT), C3 ($21:20$ UT) and C4 ($20:50$ UT). Other emissions related to f_{ce} appear for latitudes up to 30 degrees, both in the southern and the northern hemisphere and below the local plasma frequency. Besides, intense emissions are observed near the local plasma frequency (intensity about $10^{-5} V_{rms} m^{-1} Hz^{-1/2}$) for C3 at about $21:22$ UT, i.e. within the density notch placed between the plume and the plasmasphere body. Another type of emission, is observed by C3 in the same region of space: faint, “narrow band” features at frequency positions along nf_{ce} (see blow up in Fig. 8). Furthermore, we can clearly survey electromagnetic emissions in an energetic and large form between $20:30$ and $21:46$ UT for C1. Similar emissions appear on C2 and C4 whereas they are blocked on C3, which is travelling inside the outer plasmasphere at this time. We interpret those intense emissions as NTC, owing to the latitude of observation, despite rather unusual spectral characteristics, i.e. narrow band elements, rapidly decreasing with frequency. Satellite C3 crosses an NTC beam shortly after $21:45$ UT, with spectral characteristics more frequently observed on CLUSTER, i.e. two large frequency bands, here at central frequencies increasing with latitude. Those bands are not visible from the three other viewpoints at that time. Details about both types of NTC are presented below.

3. ELECTROSTATIC EMISSIONS RELATED TO f_{ce}

Intense emissions related to the electron gyrofrequency are observed during the plasmasphere crossing. These emissions appear at different magnetic latitude and with different forms. Large emissions near $(n+1/2)f_{ce}$ take place near magnetic equator and narrow bands at $(n+1.1)f_{ce}$ come into view at higher magnetic latitude.

3.1 Equatorial emissions at $(n+1/2)f_{ce}$

The equatorial region of the plasmasphere is a favoured area where wave-particle interaction and wave generation can occur. Near magnetic equator intense emissions at $(n+1/2)f_{ce}$ can take place. These emissions have been observed for the first time by the mission OGO5 [7].

In the 27th may 2003 CLUSTER perigee pass, the $(n+1/2)f_{ce}$ appear on C2, C3, C4 respectively while no emission appears in C1. In fig. 3 we can clearly observe different number of harmonics for the three satellites

with various intensities levels and various time durations.

Three harmonics are observed by C2 between 20:25 and 20:37 UT respectively at $1/2 f_{ce}$, $3/2 f_{ce}$ and $5/2 f_{ce}$, where $f_{ce}=6\text{kHz}$.

One harmonic is observed by C3 between 21:16 and 21:23 UT at $1/2 f_{ce}$, where $f_{ce}=7\text{kHz}$.

One harmonic is observed by C4 between 20:49 and 20:55 UT at $1/2 f_{ce}$, where $f_{ce}=8\text{kHz}$

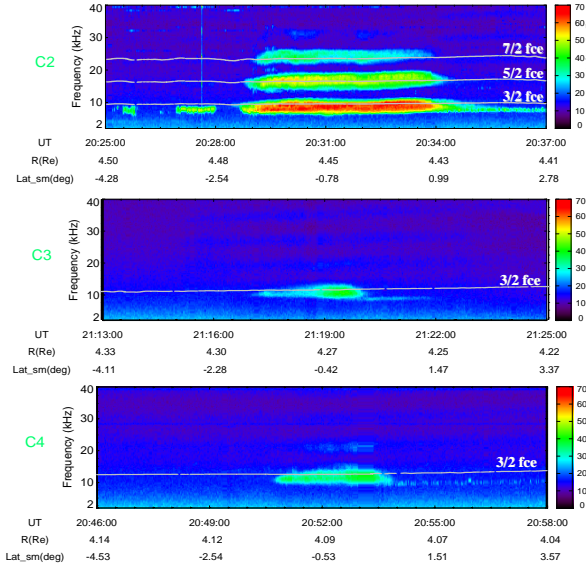


Fig. 3 Equatorial emissions at $(n+1/2)f_{ce}$.

The good sensitivity of the WHISPER instrument allows a precise determination of the maximum frequency of the harmonic. Intensity variation of the waves shows a maximum about $10^{-4} V_{\text{rms}} \text{ m}^{-1} \text{ Hz}^{-1/2}$ at the magnetic equator corresponding to a maximum value of the bandwidth about 3kHz.

3.2 Higher latitude emissions at $(n+1.1)f_{ce}$

Another kind of electrostatic emissions related to f_{ce} can be observed at higher magnetic latitude, both in the northern and in the southern hemisphere. Fig. 4 underlines in white colour one of these “ $1.1 f_{ce}$ ” emissions. It is observed by C1 between 20:20 and 20:55 UT for the northern hemisphere.

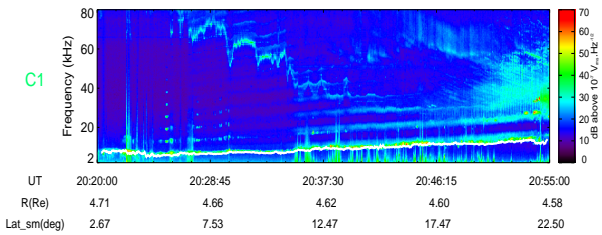


Fig. 4 Emission at $1.1 f_{ce}$ recorded by C1

We can observe that these emissions appears below the plasma frequency and at $(n+1.1)f_{ce}$. They show up on the four CLUSTER satellites with various numbers of harmonics in each hemisphere.

We have represented the frequency time variation of these emissions in Fig. 5, for each spacecraft. In this figure, the plasma frequency is plotted in black colour, the experimental $(n+1.1)f_{ce}$ in green and the local corresponding value of $(n+1.1)f_{ce}$ is red.

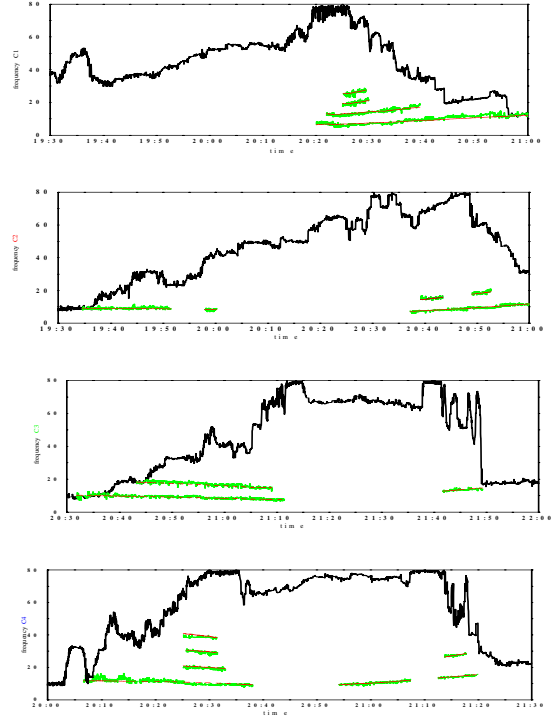


Fig. 5 Evolution with time of $(n+1.1)f_{ce}$ frequencies.

We can observe that these emissions appear in an harmonic form respectively at $1.1 f_{ce}$, $2.1 f_{ce}$, $3.1 f_{ce}$ and $4.1 f_{ce}$ for the four satellites. No emission appear in the southern hemisphere for C1, whereas one emission appear on C2 (discontinue in time) between 19:00 and 20:00 UT, two emissions for C3 between 20:40 and 21:10 UT, and four emissions for C4 around 20:30 UT. In the northern hemisphere, we can notice four emissions on C1, two emissions on C2, one emission on C3 and two emissions on C4.

4. NON THERMAL CONTINUUM EMISSION

NTC radiation is an electromagnetic wave of weak intensity, observed usually during long time intervals. steady in time It has first been observed in the Earth environment at frequencies above 500 Hz [8] and propagating in the L-O mode [9].

In this case event, NTC emissions are observed by three of the four CLUSTER satellites at a particularly intense level, as stated above, in this particular case up to $10^{-5} V_{\text{rms}} \text{ m}^{-1} \text{ Hz}^{-1/2}$. Electromagnetic emissions

observed by the IMAGE satellite during the time span of the studied event is shown in Fig. 6.

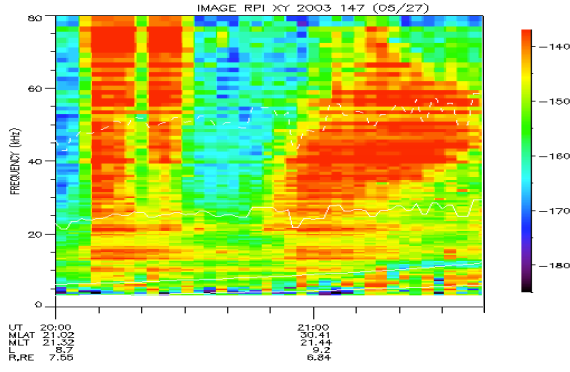


Fig. 6 IMAGE observation of AKR and NTC

The two successive AKR features showing up between 20:00 and 20:40 UT match in time the two main AKR occurrences observed on C3 (Fig.2). The emissions observed after 20:50 UT match in time and frequency the intense NTC occurrence observed by C1, C2 and C4. The orbit configuration of the four observatories between 20:55 and 21:40 UT is shown in Fig. 7.

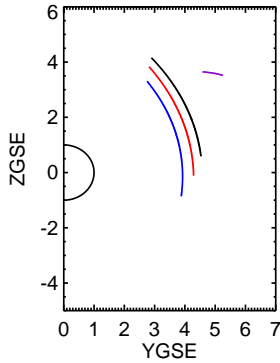


Fig. 7 Orbit configuration of C1, C2, C4 and IMAGE (deep purple) in GSE coordinates (20:55 – 21:40 UT)

A blow up of WHISPER observation of NTC is shown in Fig. 8. NTC appears after the plasmasphere crossing: between 20:50 and 21:50 UT for C1 and C2 in a large and energetic form covering the 20 to 80 kHz band. C4 observes the same phenomenon for a shorter time period. The extinction of the waves below the plasma frequency (plotted as a white line in the figure) indicates a cut off frequency of the ordinary mode. IMAGE observation of the continuum, displayed in Fig. 6, shows the same large and energetic band. NTC observation by IMAGE is made at the same time as by CLUSTER. Moreover, Fig. 7 indicates that it is observed at the same magnetic latitude range. We interpret this as all four observatories, C1, C2, C4 and IMAGE being placed in the same large scale NTC beam.

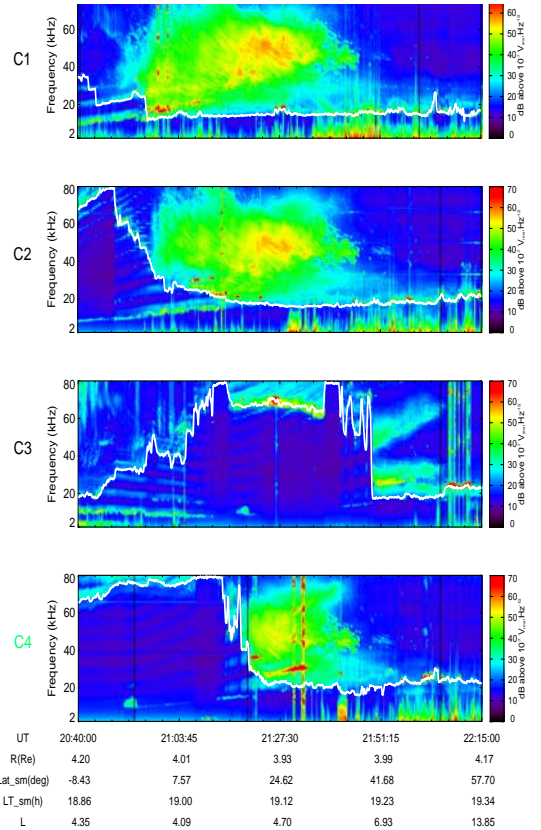


Fig. 8 Blow up of NTC emissions observed by CLUSTER

One hour later C3, going out from the plasmasphere, encounters an NTC beam with different spectral characteristics, as indicated in section 2. Such spectral forms, i.e. smooth frequency bands at weak intensity are observed more frequently. A close look at NTC forms observed on C4 around 21:30 UT (Fig. 8) indicates that C4 observes both types of NTC superposed: the intense beam (with falling frequency tunes), and the weaker form (above 60 kHz, with globally rising frequency tunes). The latter form does not match (in time and frequency) similar features shown on C3. It is likely, thus, that the second type of NTC is linked to spatial properties of the beams, rather than to temporal properties.

5. CONCLUSION

Several kinds of natural emissions have been observed during the 27th May 2003 plasmasphere crossing. Emissions related to the local gyrofrequency f_{ce} have been observed near equatorial regions at $(n+1/2)f_{ce}$ and at higher magnetic latitude at $(n+1.1)f_{ce}$. Intense NTC continuum features have been observed in conjunction with IMAGE satellite, i.e. at the same time and at the same magnetic latitude, showing that all SC are placed inside the same beam. Further analysis is needed to explore possible relationships between some of the

various electrostatic emissions observed and the generation of NTC.

6. REFERENCES

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