NonThermal Continuum Radiation Observed from the CLUSTER Fleet


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Non Thermal Continuum radiation observed from the Cluster fleet

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5th Anniversary of Cluster in Space
19-23 September, ESTEC
NTC observed from the Cluster fleet

1. Generalities
2. Advances with Cluster observations
   - Ray path from multipoint observatory
   - Sources
3. Summary and perspectives
1.1 What is Non Thermal Continuum (NTC)?

NTC and Type III:
\[ \Delta F \sim F_{ce} \text{ at source} \]

NTC radiations are:
- weak, long lasting, narrow band, EM emissions
- observed (since 1970s), in almost all regions of magnetosphere, they can escape in the interplanetary medium
1.2 What is the source of NTC?

General scheme of NTC generation:

Particles free energy → ES emissions → EM radiation

This happens at the plasmapause boundary layer

NTC formation is largely not understood. How to explain:

- Duration of emissions?
- Spectral characteristics (narrow bands, harmonic structures)?
- Wave intensity?
- Beaming properties?

Models:
- Radio window at grad (Ne)
  - Jones, 1982
- N.L. processes
  - coalescence with LF waves
    - Melrose, 1981
  - decay of Bernstein waves
    - Rönmark, 1985
1.3 Current studies

Sources
Several generation models
Few observations

Remote Observations
Increasing data set:
Injun 5, Hawkeye, ISEE,
GEOS, DE1, Polar, Geotail,
IMAGE, Cluster

Various behaviors

Link to be understood
1.4 How does NTC propagate?

- NTC radiation emerges from sources at PPause boundary layer. It is beaming predominantly near equatorial plane.
- The lower frequency band is trapped inside the magnetospheric cavity, bouncing between MPause(/cusp) and Plasmapause.
2. Advances with Cluster observations

- Ray path from multipoint observatory
  2 examples

- Sources
Example 1: Beaming properties

Test of Jones theory

(ES to EM conversion)

2 narrow beams, symmetric / equator

\[ \alpha = \arctan\left(\frac{f_{ce}}{f_{pe}}\right)^{1/2} \]

- No definitive conclusion has been reached, concerning the validity of Jones theory
- Cluster orbit does not cross a beam pair issued from the same source
Example 2: Observation of narrow band emissions

Far from equator, the four SC see exactly the same emission.

Only part of the constellation is illuminated near the equator.
**Interpretation**

- A small orbit element is illuminated by the direct path.
- A large orbit element is illuminated by the reflected radiation.

**Meridian plane**
Spin modulation as a clue to ray path orientation

The spin modulation gives an estimation of the inclination of the ray wrt the spin plane

It allows to find out if the ray reaches the observatory directly (1) or after a reflection (2)
Compared spin modulations

Modulation values indicate that beams have been reflected

Directivity angles complete the information

CLUSTER-WHISPER Spectrogram / JUL 16, 2005 (Day 197)

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Compared spin modulations

Modulation values indicate that beams have been reflected

Directivity angles complete the information

5th anniversary of Cluster 19-23 Sept. 2005 ESTEC
Triangulation points toward high X value, it is compatible with the proposed scenario.

- Conclusion: the origin of beams observed in the dusk sector is probably a source placed in the dawn sector.
2. Advances with Cluster observations

➤ Ray path from multipoint observatory

➤ Sources
NTC Sources: Which candidate Electrostatic Emissions?

• **Equatorial n+1/2?**
  Too far from density gradient (inside plasmasphere)

• **Intense (saturating) emissions at PPause density gradient?**
  Observed just above Fp (in the band Fp - Fq), close to equator
  Good candidates for the main forms of NTC
NTC Sources

• Intense ES emissions at plasmapause surface are often associated with LF broadband emissions

• More analysis is needed to interpret these observations
Role of Bernstein waves

Several examples show convincing evidence of a link between ES emission at local Fqs (Bernstein mode) and simultaneously observed NTC
Canu et al., 2005
Possibly linked with small density cavities
NTC observed at sources

More from the 16 July 2005 event
EM emissions near density cavities
Ripples in the P Pause boundary (rays aligned with density gradient) could explain different beam orientations.

Study in the spin plane (parallel to XY GSE)

High modulation indices

Beam orientations at about 80°
WBD instrument offers a good time/frequency resolution of ‘micro’ sources

Cluster WBD 77 kHz DSN

\[ R_E \]
\[ \lambda_m \]
\[ \text{MLT} \]
\[ L \]

\[ \text{UT_OBS: 2003-06-30T05:59:20 to 2003-06-30T06:03:35} \]
Other large scale findings

- Simultaneous observations of harmonic ‘large band’ NTC structures
- Different spectral characteristics when viewed from different SC
- Local sources (off equator) are illuminating short orbit elements
5. Summary and conclusion

- Various types of ES emissions observed in the Ppause boundary layer
  - (a) Intense emissions in $F_{pe} - F_q$ band
  - (b) ‘Micro’ sources, in density holes, some at $n F_{ce}$

- Two main types of structured EM radiations observed in magnetosphere:
  - (a) multiple narrow spectral lines, radiating over a long range, having undergone one reflection at Msheath in many cases
  - (b) ‘harmonic wide bands’, structured according to local magnetic field conditions.

Both forms could result from many small size sources. Respective source spatial distribution might be different.

- Challenging question: how to conciliate numerous, micro sources, with well established beams of large aperture?

Perspectives

Close analysis of ES sources (PEACE, WBD, WHISPER) plus simulation, toward a better understanding of source behavior (stability, power)