Multipoint Observations of the Source Region of Whistler-mode Chorus events

O. Santolik^{1,2}, D.A.Gurnett², J.S.Pickett², M. Parrot³, N. Cornilleau-Wehrlin⁴, E. Macúšová¹

¹ Charles University in Prague ² University of Iowa, Iowa City, IA ³ LPCE/CNRS, Orleans ⁴ CETP/IPSL, Velizy

Thanks to:

P. Décréau, LPCE Orleans, and P.Canu, CETP Velizy (WHISPER density data) N. Meredith (BAS Cambridge), A. Fazakerley, MSSL London (PEACE electrons) Q.-G. Zong, Boston University (RAPID particle data)

Outline

- **1. Substructure of chorus wave packets**
- 2. Position and size of the chorus source region
 - Central position of the source region from multipoint measurement of the Poynting flux
 - Size of the source region along the field line from multipoint measurement of wave propagation
 - Size of the source region perpendicular to the field line from correlation analysis of chorus elements
 - Average source position: Accumulated observations from Cluster and Double Star 2001-2005
- 3. Wave- particle interactions in the source region
- 4. Propagation of chorus from its source

1. Substructure of chorus wave packets

Whistler-mode chorus on 31 March 2001 Cluster 3



Detailed spectrograms





Amplitudes and delays of the local maxima



2. Position and size of the chorus source region

Multipoint measurements: central position of the source

Parallel component of the Poynting vector _______ normalized by its standard deviation.

 Z_{SM} coordinate (perpendicular to the geomagnetic equatorial plane) of the four spacecraft.

Typical speed of motion:<u>100 km/s.</u>



Parallel dimension of the source region

Regions of large values of the electromagnetic planarity



18th April 2002 Cluster 4

Power spectrogram of the electric field fluctuations.

Power spectrogram of the magnetic field fluctuations.

Parallel component of the Poynting vector normalized by its standard deviation.

Angle deviation of the wave vector from the static magnetic field.

Electromagnetic planarity.

Kp: 7° Dst: -126 nT AE: ~1100 nT PLASMA DENSITY~2/cc



Detailed spectrograms 18th April 2002





 \boldsymbol{D}_{\perp} (km)

Average latitude-frequency spectrograms Accumulated STAFF-SA observations 2001-2004

Source of chorus is located within a few degrees

of the magnetic equator



Parallel component of the Poynting vector normalized by its standard deviation.

<u>Average</u> of data recorded along the 2001-2004 Cluster orbits close to the perigee <u>Standard deviation</u> of data recorded along the Cluster orbits close to the perigee

Power-spectral density spectrogram of magnetic field fluctuations measured by Double Star TC-1

Jun 28, 2004.



DATA SET : Orbits of TC1



Orbits of the TC1 spacecraft during the selected chorus events (thick blue lines). The polar plot represents the McIlwain's *L* parameter and the magnetic local time (*MLT*).



Spectrogram of average power spectral density as a function of the McIlwain's *L* parameter and the wave frequency *f* normalized by the *equatorial* f_{ce0} .

3. Wave- particle interactions in the source region

Power spectrogram of the electric field fluctuations. (WBD)

Power spectrogram of the magnetic field fluctuations. (STAFF-SA)

Parallel component of the Poynting vector normalized by its standard deviation. (STAFF-SA)

Angle deviation of the wave vector from the static magnetic field. (STAFF-SA)

Electromagnetic planarity. (STAFF-SA)

Kp: 4 (9) Dst: -68 nT (-320 nT) AE: ~500 nT PLASMA DENSITY~10/cc

31 October 2003 Cluster 1



-2 -3

0



SOURCE OF CHORUS

PEACE instrument: electron energy spectrograms

ergs/cm**2-s-str-eV

ergs/cm**2-s-str-eV

ergs/cm**2-s-str-eV

ergs/cm**2-s-str-eV















4. Propagation of chorus from its source







DEMETER 13 June 2005 19:11:54

Freja 8 April 1995 15:53:05







Summary

- The chorus wave packets show an embedded fine structure of **subpackets** at time scales from units of ms to a few tens of ms and with maximum amplitudes of a few tens of mV/m.
- Poynting flux measurements show that the source of chorus is located within a few degrees of the geomagnetic equator. Maximum intensity is observed by Double Star at radial distances of 8 Earth radii.
- The central position of the chorus source region fluctuates within a distance of **several thousands of km** along the field line, moving at typical speeds of **hundreds of km/s**.
- The size of the source region is also a few thousands of km along the filed line. Multipoint correlation analysis of separate chorus elements shows that the correlation coefficients decrease at scales of 100 km across the field lines.
- Simultaneous measurements of distribution functions of energetic electrons by the PEACE and RAPID instruments will allow us to analyze the source mechanism of chorus and its possible connection to highly accelerated particles.
- Unducted chorus can propagate down to the ionospheric altitudes