Spectral shapes of whistler-mode chorus emissions

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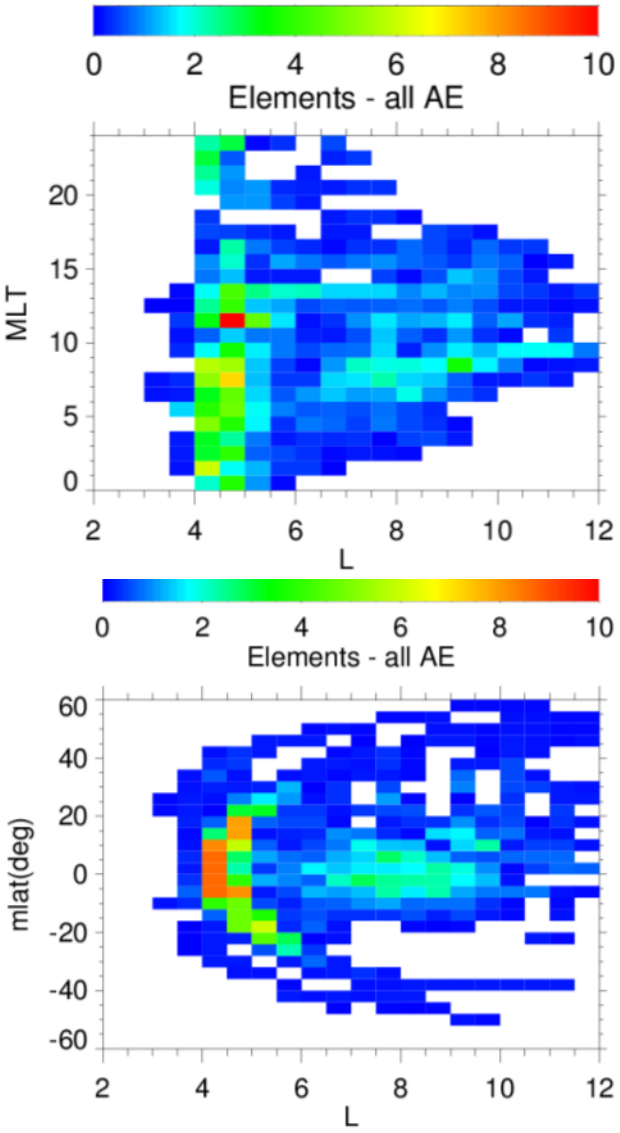
SFAFF-SA and WBD instruments (Cluster spacecraft)



Hours of detected chorus emissions with discrete structure.

Data set

- 11 years of Cluster measurements (2001-2012)
- list of visually selected banded emissions from the STAFF-SA instrument measurements (fulfilling a set of conditions) – almost 6000 hours
- list of visually selected chorus emission with the discrete structure from the WBD instrument measurements – almost 1300 hours

STAFF-SA

- frequency coverage up to 4 kHz
- time resolution – 4 seconds (0.125s)
- 3 components of **B**; 2 of **E** (EFW)

WBD

- frequency coverage up to 9.5 kHz (continuous waveforms - the instrument mode used for this analysis)
- time resolution – 37μs
- 1 component of **B** or **E**

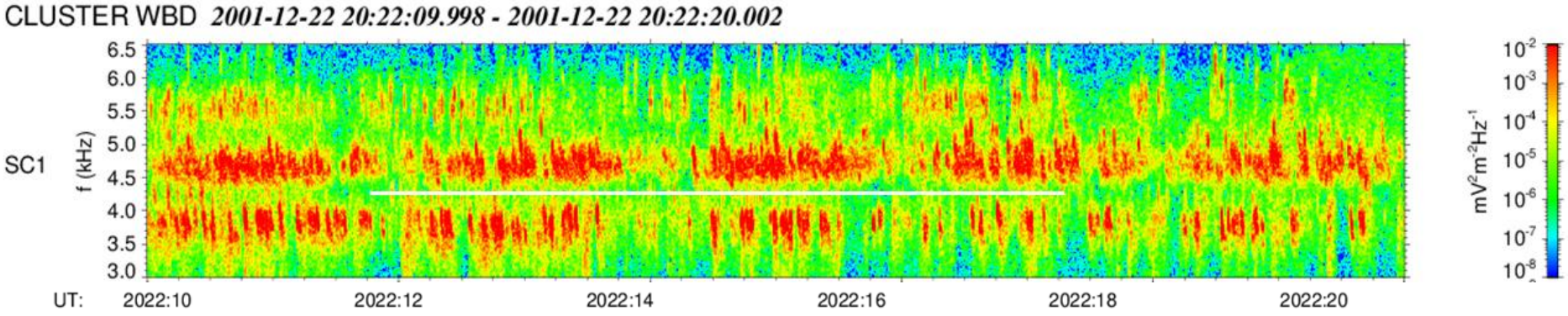
Distribution of chorus spectral shapes

Number of frequency bands

- one frequency band (12 %)
- two frequency bands (83 %)
- multi-banded emissions (three or more frequency bands) (5 %)

Banded emissions consisting of two frequency bands

- combination of individual wave packets and hiss (54 %)
- frequency bands contain hiss (25%)
- **frequency bands contain wave packets** (21 %)



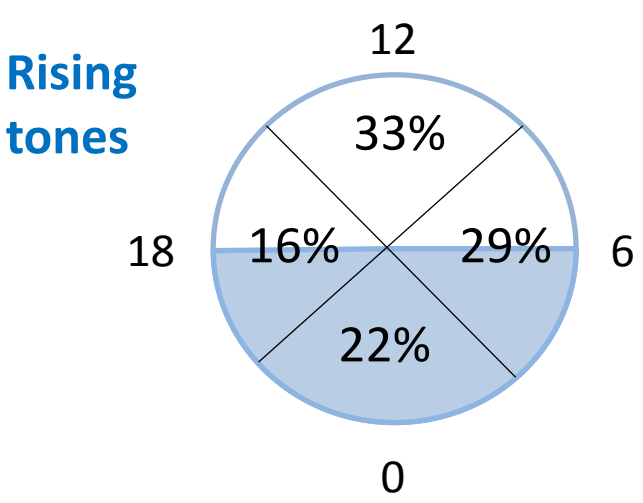
An example of time-frequency spectrograms of power spectral density (PSD) of electric field fluctuations measured by Cluster 1 on December 22, 2001. The white line corresponds to the one half of the electron cyclotron frequency. The spacecraft position is: $\lambda_m = 2.2^o$, R = 4.4 R_E and MLT = 4.6

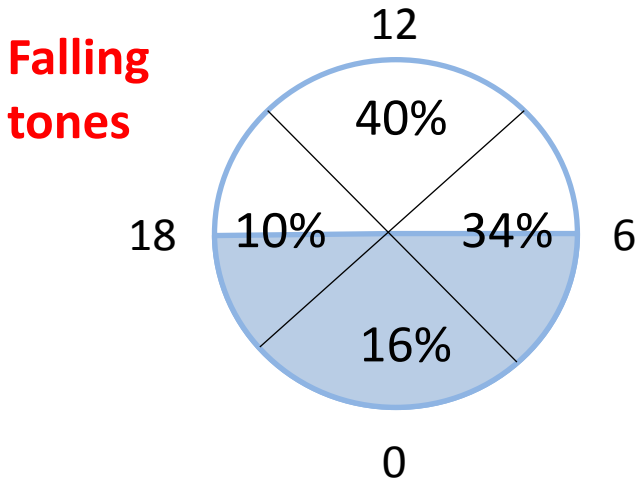
Distribution of chorus spectral shapes, cont.

Different types of spectral shapes of the **discrete wave packets**:

- **Rising tones (RT) – df/dt > 0 (51 %)**
- **Falling tones (FT) – df/dt < 0 (22%)**
- Broadband vertical wave packets df/dt (BL) → ∞ (5 %)
- **Hooks (H) (9 %)**
- Noisy elements (BP) (11%)
- Other types (mainly partly composed of combination of previous types) – (17 %) - rising and falling tones observed simultaneously (4 %) …

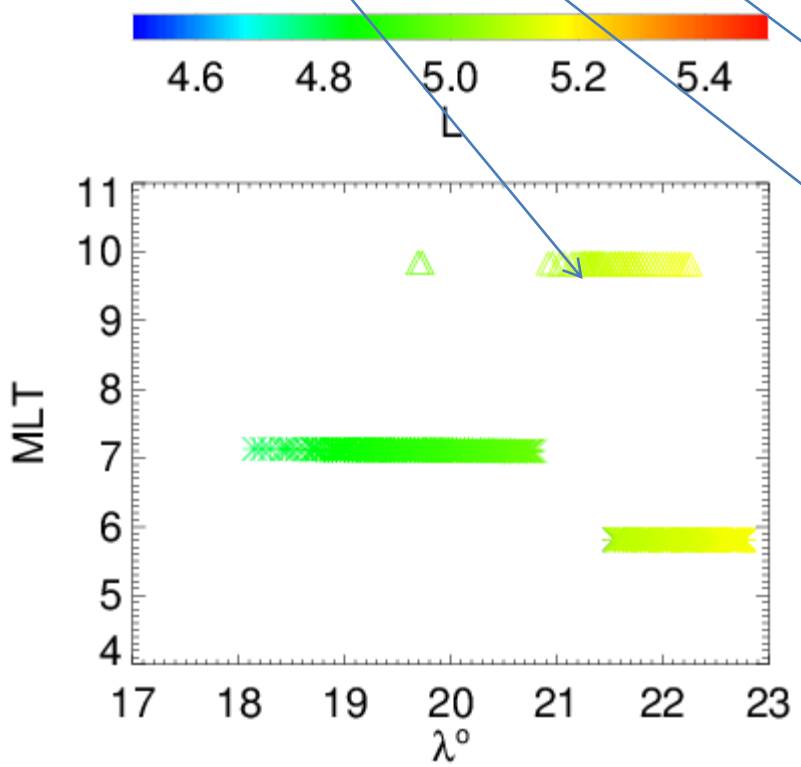
Distribution of RT and FT in the MLT sectors



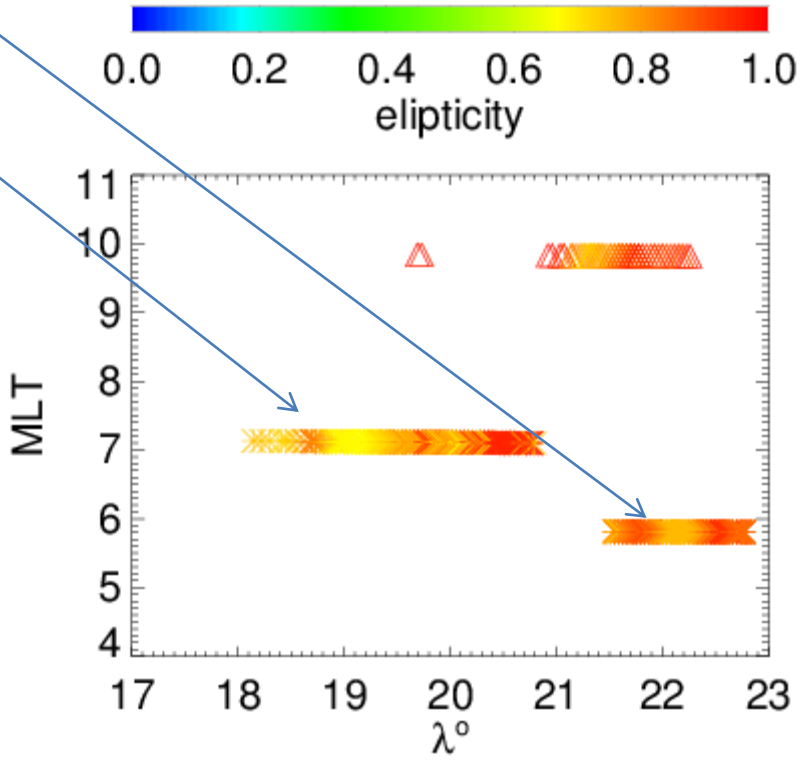


Example events

Rising tones : 2001-12-03
Falling tones: 2001-11-14
Hooks: 2001-11-07



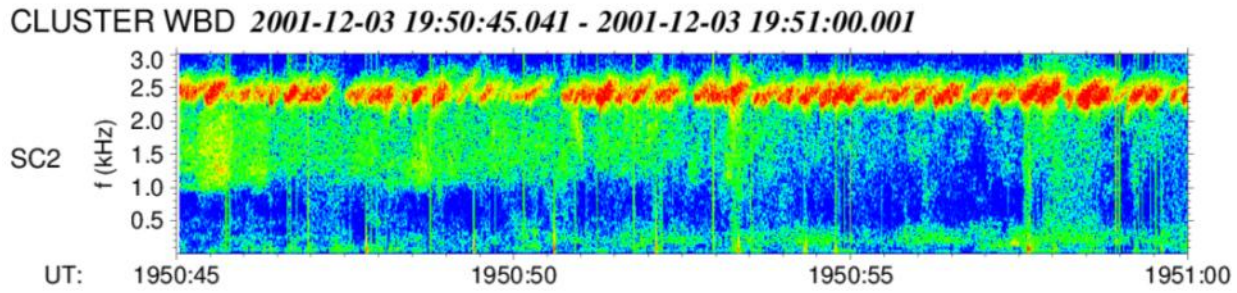
Position of the 3 events as a function of λ and MLT and L.

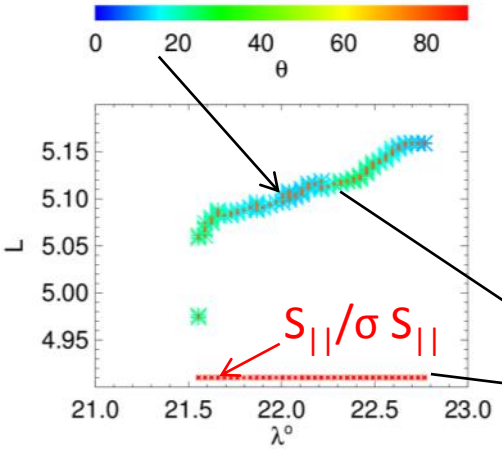


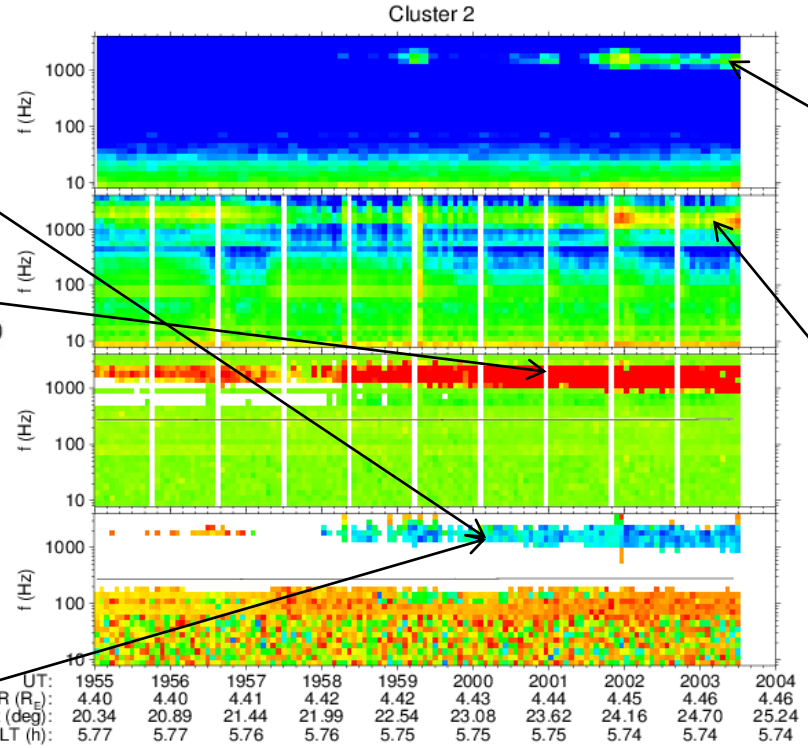
Ellipticity of the 3 events.

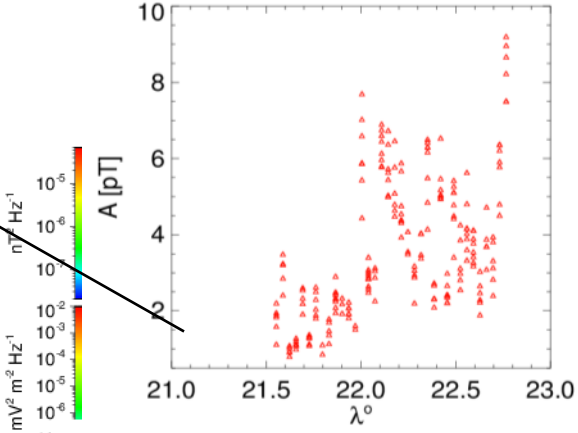
Rising tones (2001-12-03)

time: 19:58 – 20:04
AE index: 379-416 [nT]
Spacecraft: C1,C2 and C4
Source position: close to the geomagnetic equator

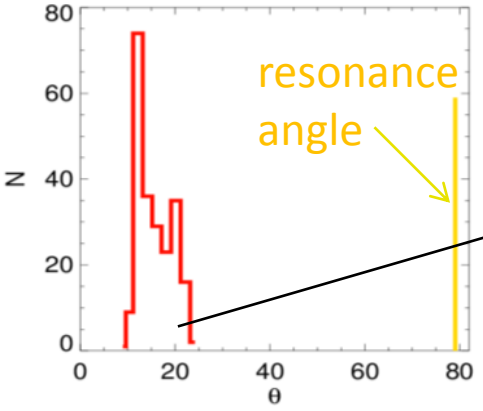




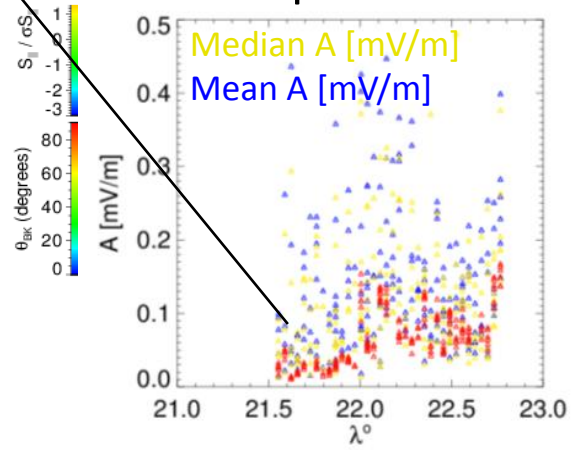




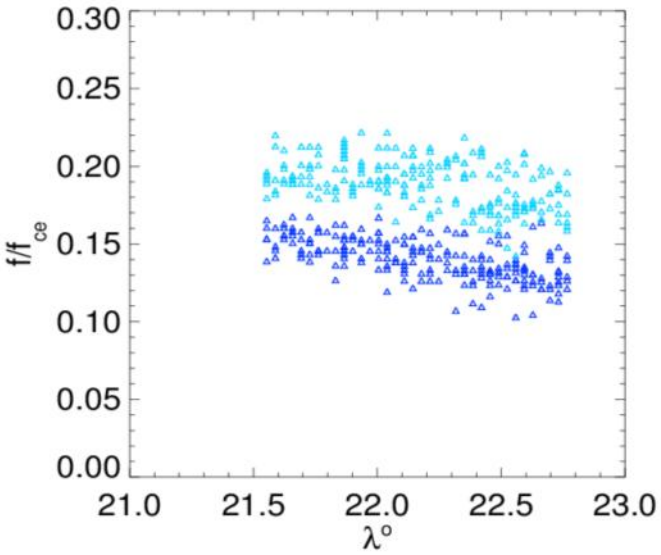
Wave normal angle

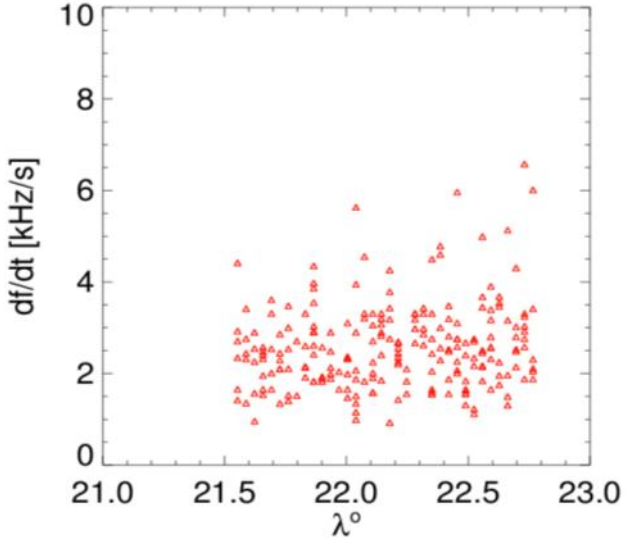


Amplitude



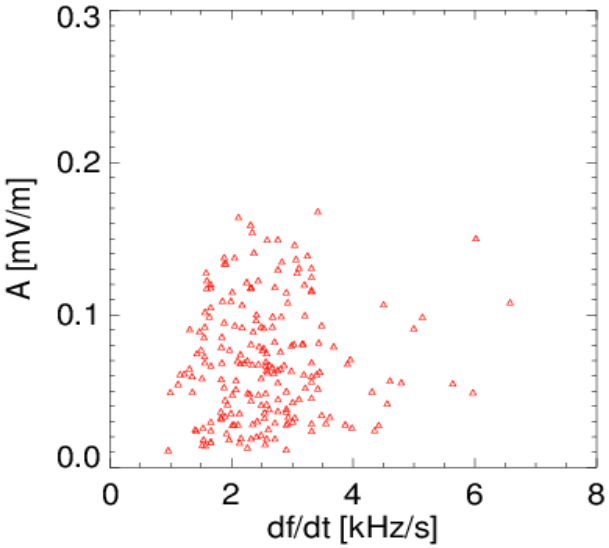
Rising tones (2001-12-03), cont.

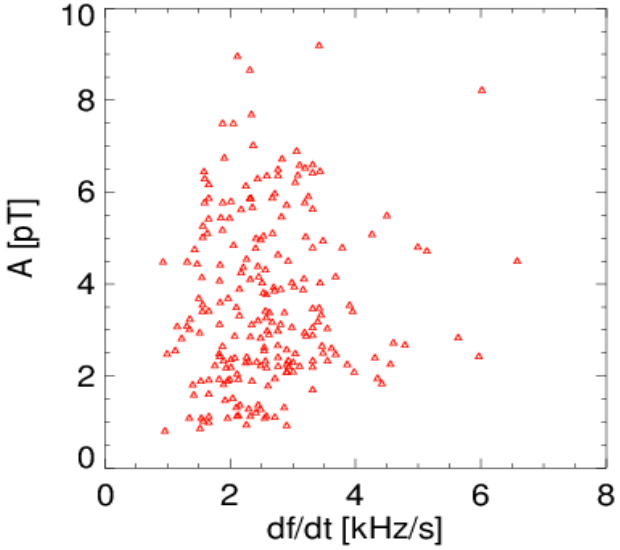




The frequency sweep rate (df/dt) of detected elements.

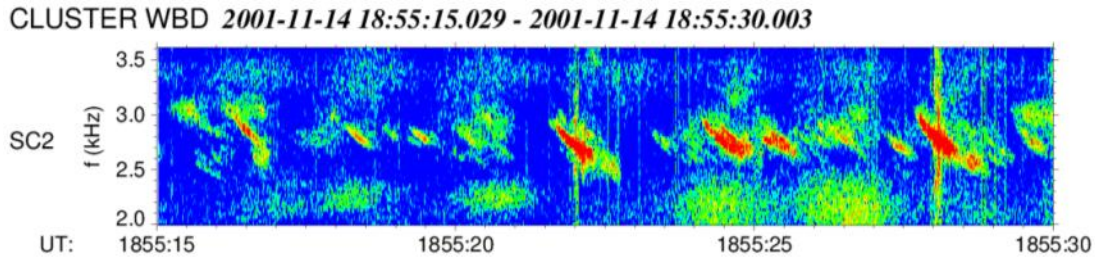
Starting and ending frequencies of each individual wave packet, normalized to the local f_{ce}, as a function of λ.



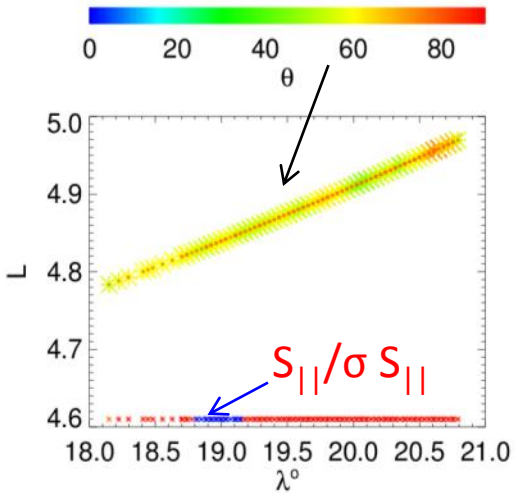


Amplitude as a function of df/dt.

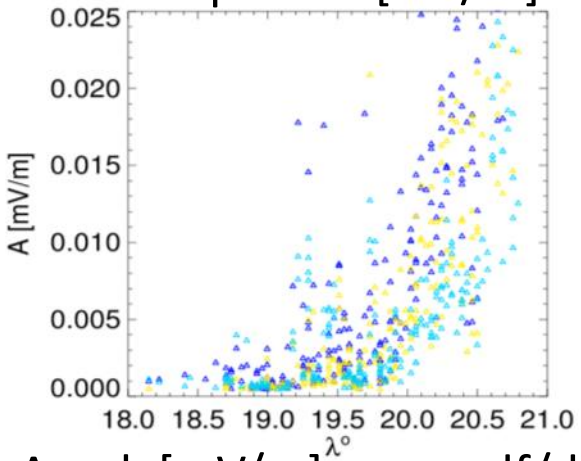
Falling tones (2001-11-14)



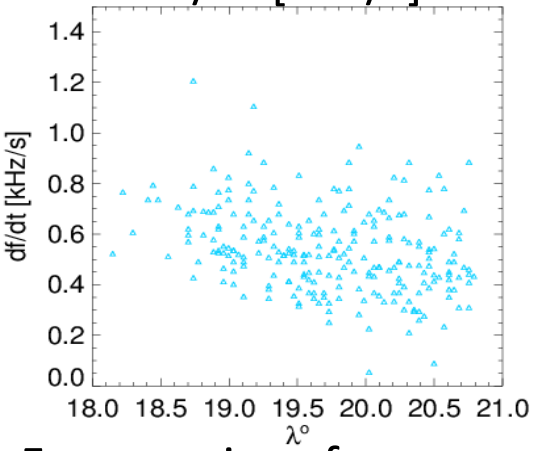
time: 18:53 – 18:58
AE index: 43 [nT]
Spacecraft: C2
Source: close to the geom. eq.



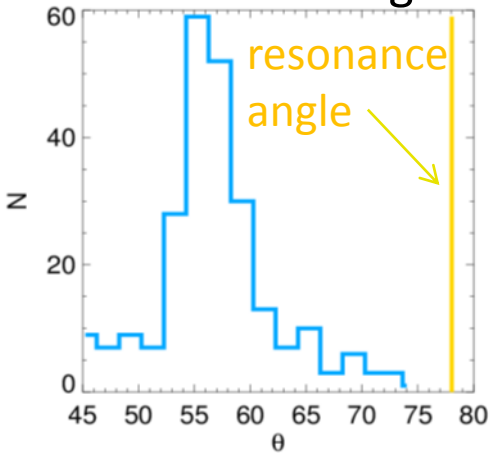
Amplitude [mV/m]



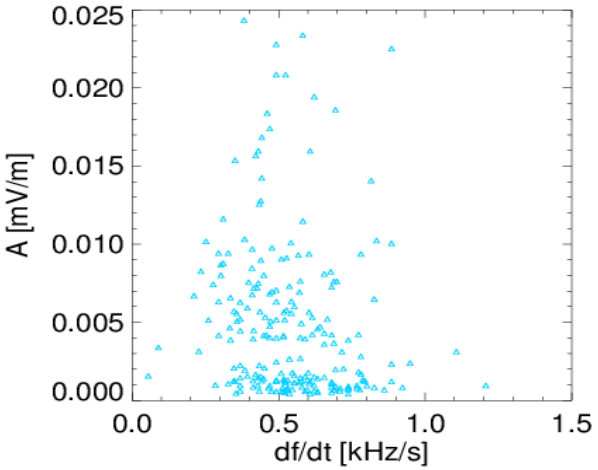
df/dt [kHz/s]



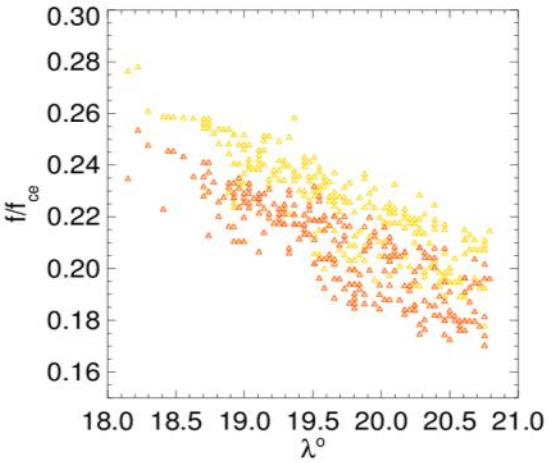
Wave normal angle



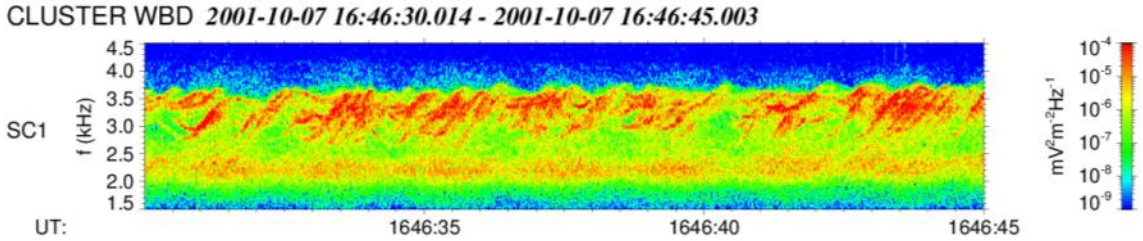
Ampl. [mV/m] versus df/dt



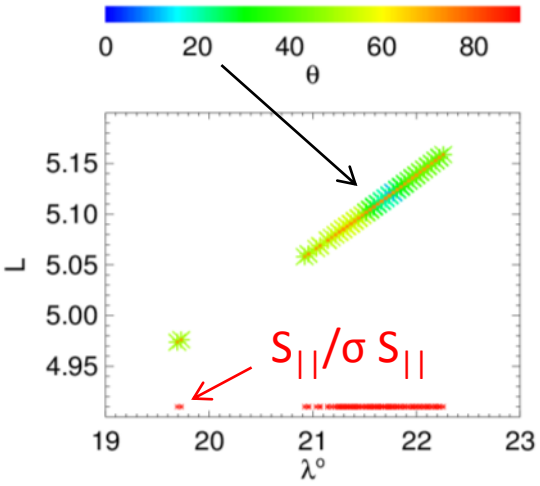
Frequencies of wave packets

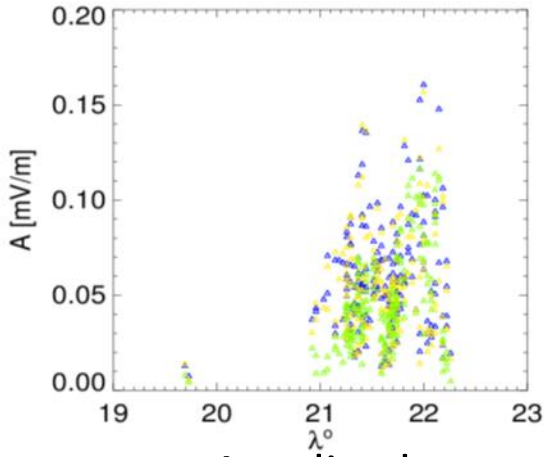


Hooks (2001-10-07)

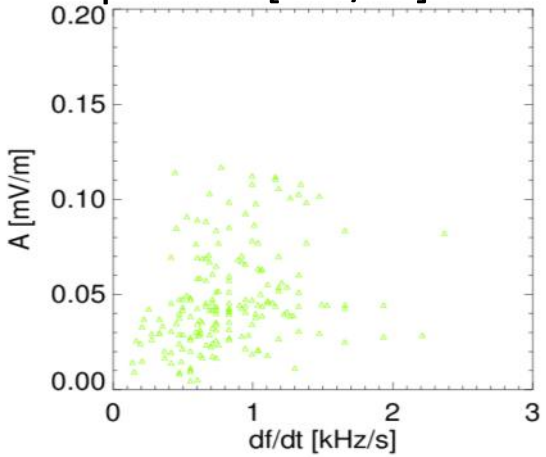


time: 16:42 – 16:49
AE index: 54 [nT]
Spacecraft: C1

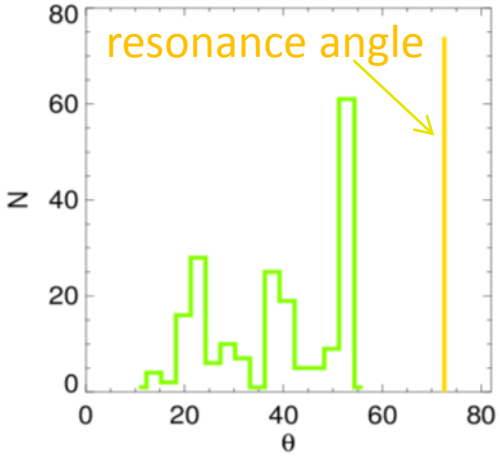




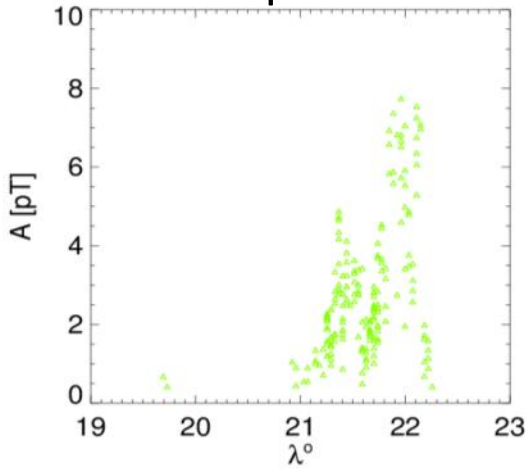
Amplitude [mV/m] versus df/dt



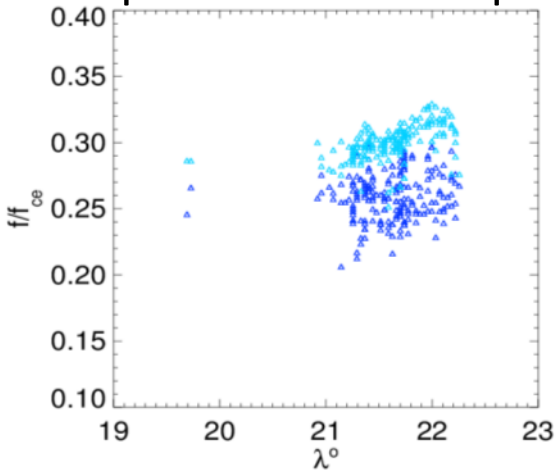
Wave normal angle



Amplitude



Frequencies of wave packets



Results

Spectral shapes of chorus emissions have been systematically analyzed using the data of the WBD instrument on-board Cluster

The corresponding integrated amplitudes of the electric field fluctuations, the magnetic field fluctuations, the polarization, and propagation properties have been obtained from the STAFF-SA multicomponent measurements in appropriate time and frequency intervals

Rising tones were observed in 51% of cases, almost twice more often than falling tones, and five times more often than hooks or noisy elements.

Different types of spectral shapes were observed simultaneously in more than 10% of events

Examples of rising tones show quasi-parallel propagation, examples of falling tones and hooks give higher wave vector angles.

These examples also show increasing average amplitudes as a function of the magnetic latitude

Thank you for your attention