

**Continuum Workshop  
Orléans - 6-7 April 2004**

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## Cluster II Continuum Events

**Features:** Sudden commencement of continuum in a relatively limited range of frequencies, followed by development of banded frequency emissions with an increase in band separation and an increase of maximum frequency with time.

**Banding as a result of ECHW waves in source?**

**Band Separation = Fce in source?**

**Associated particle injection event around magnetic midnight?**

**Rarely seen simultaneously on Cluster (because of orbit geometry?)**

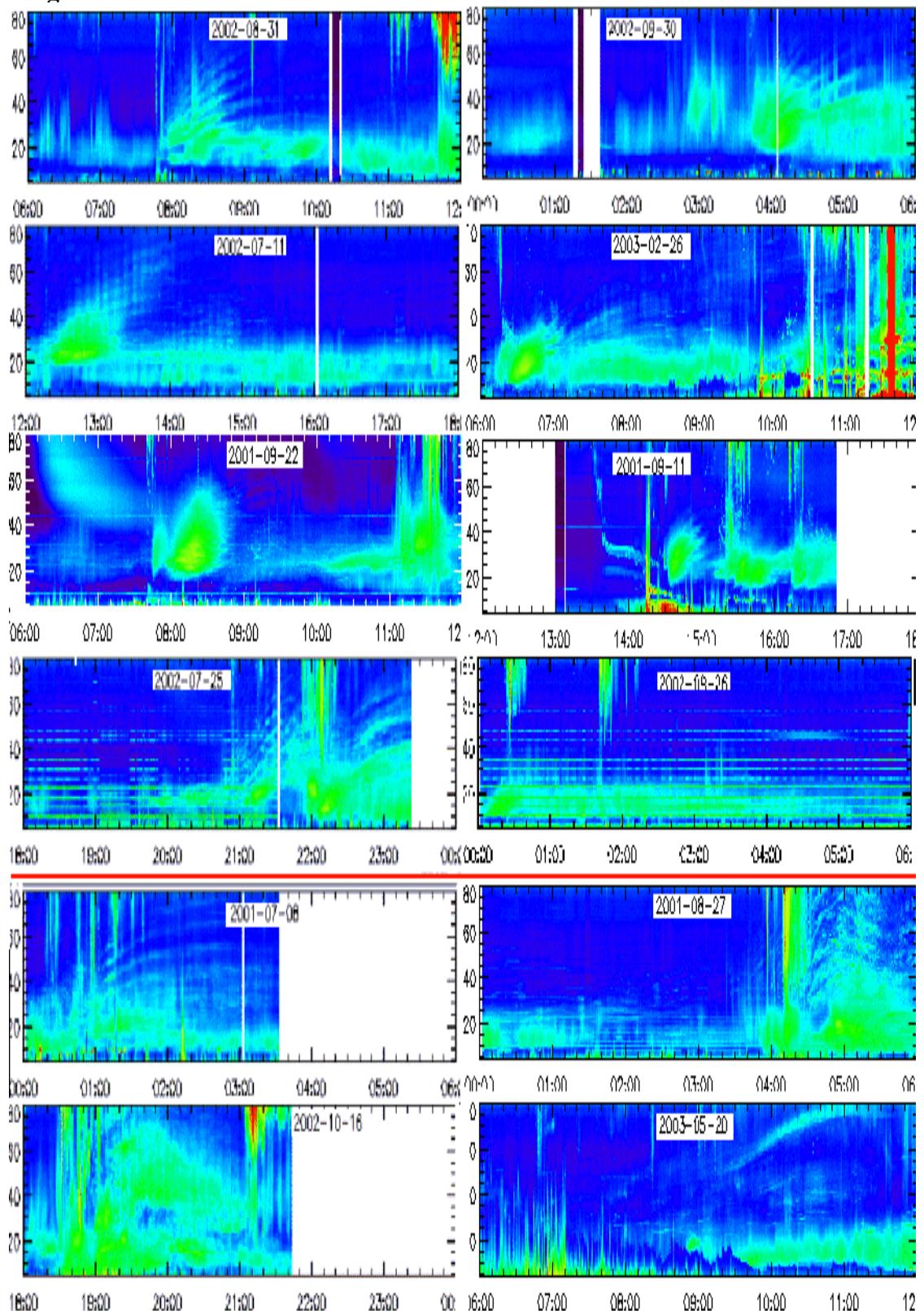
**Increase in band and upper frequency separation as injected electrons (free energy source) moves to lower L values, and/or as plasmapause moves inwards during activity increase.**

**Direction Finding:** Advantages of 4 spacecraft over earlier measurements - limit source to a volume. Disadvantage of unknown polarisation, and of out of spin plane source locations.

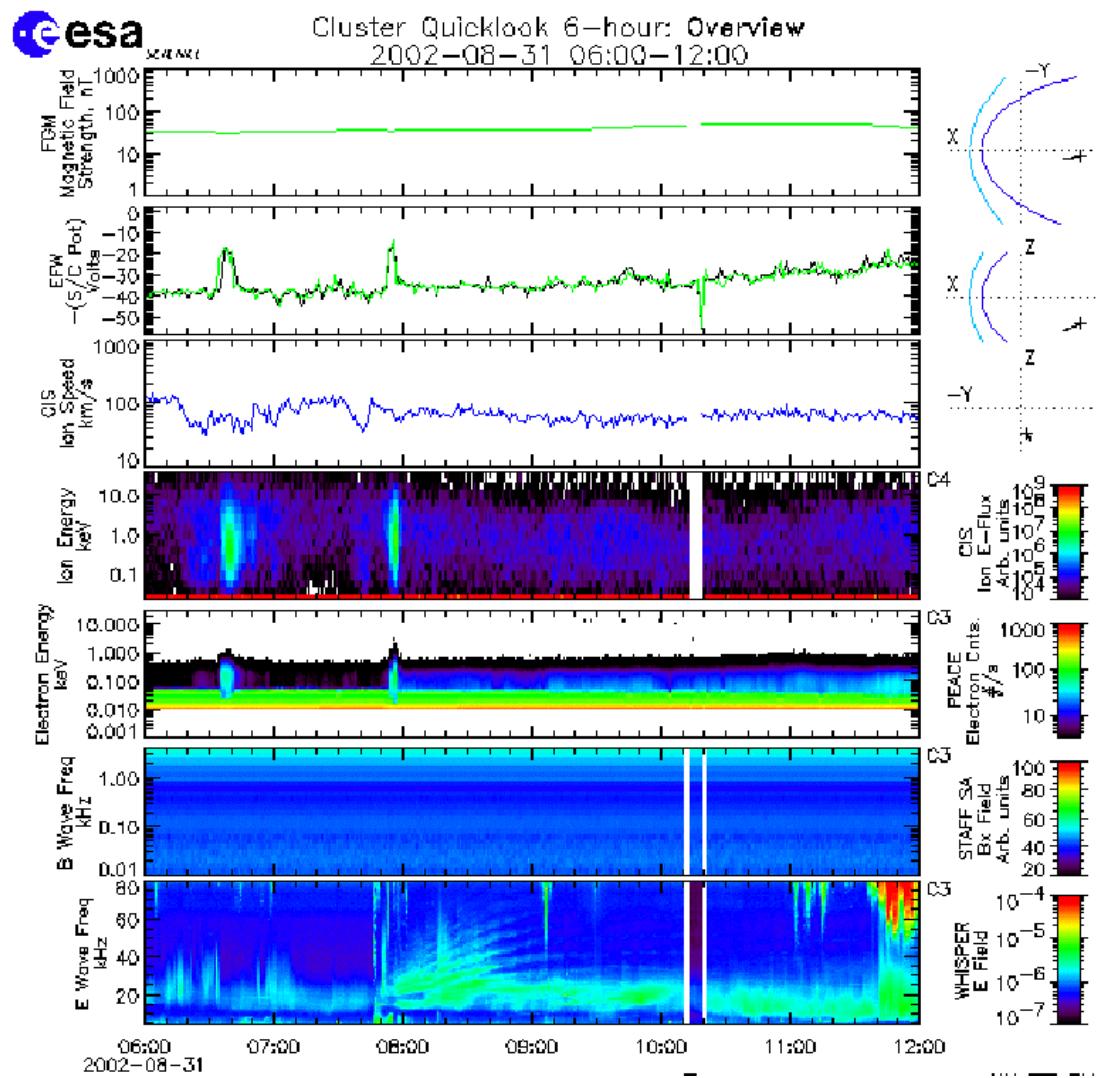
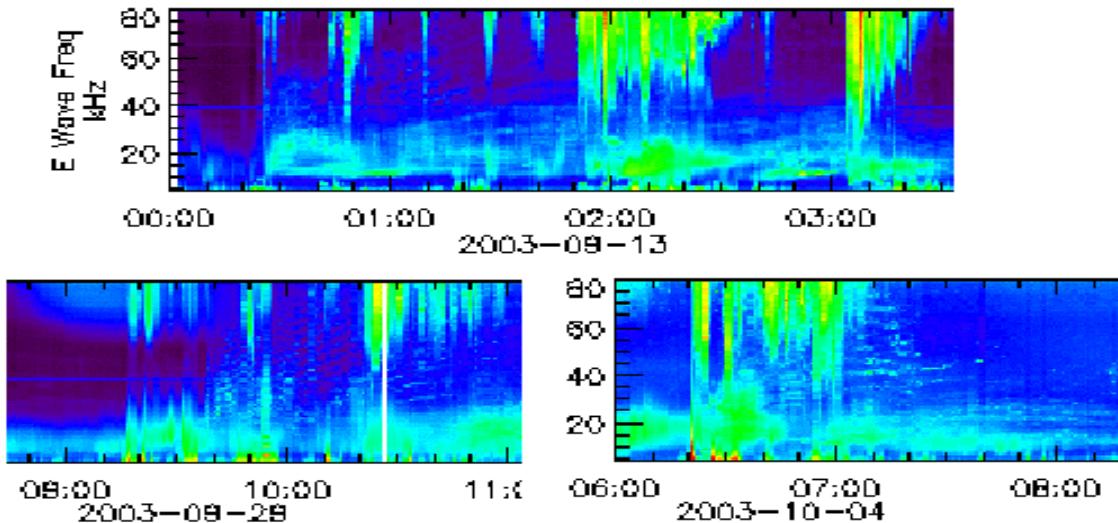
**Need to study cases where Cluster flies close to source (e.g. 30/12/03) to ascertain polarisation and associated out of spin plane effects**

Strong Events	Day	Approx time	S/C data available	Mode
1	31/08/02	0745-1000	1,2,3,4	N
2	30/09/02	0250-0600	1,2,3	N
3	26/02/03	0610-0950	1,2,3,4	?
4	11/07/02	1200-1500	-	N
5	11/09/01	1430-1650	3,4	N dayside
6	22/09/01	0745-1200	-	N
7	25/07/02	2050-2320	1,2,4	N -> B
8	26/09/02	0005-0400	1,2,3,4	N
<b>Weakly related Possibles:</b>				
9	20/05/03	0850 +		
10	08/07/01	0050-0330		B
11	16/10/02	1830-2140		N
12	27/08/01	0350-0600		B -> N
<b>Recent</b>				
1	13/09/03	0025-0200+		
2	29/9/03	0940-1050		
3	04/10/03	0628-0720		

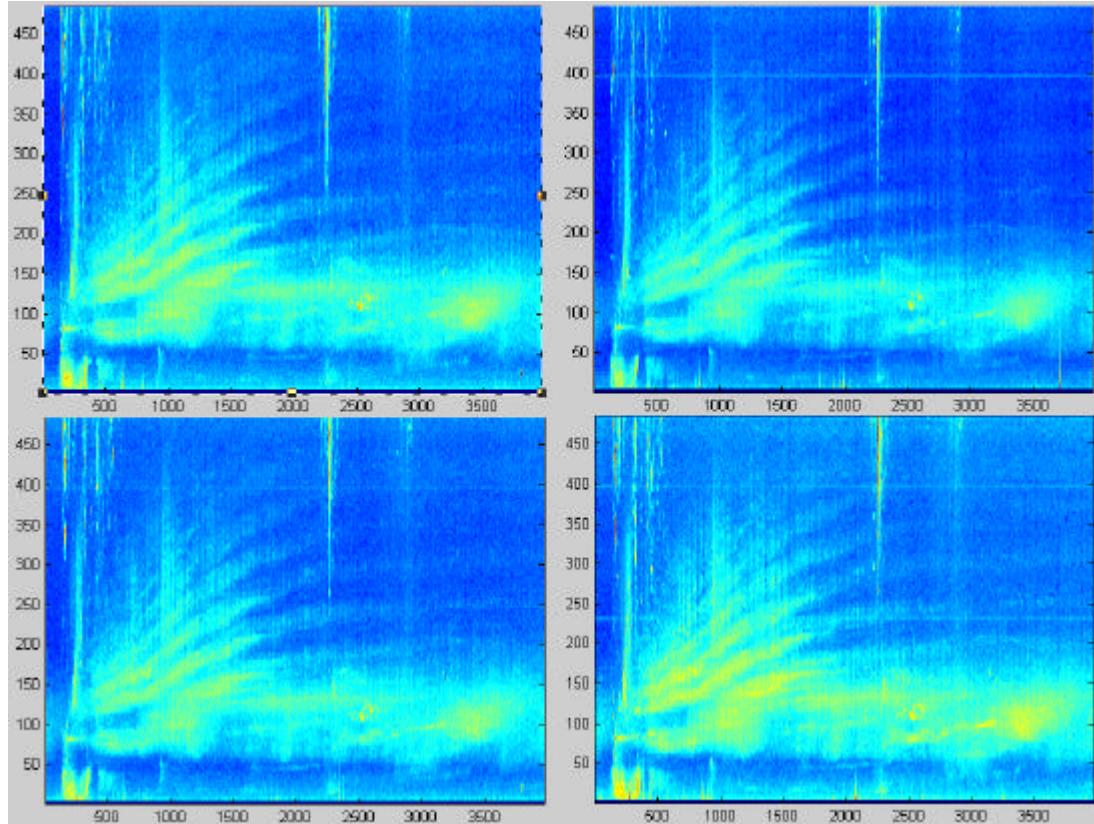
### Original Events



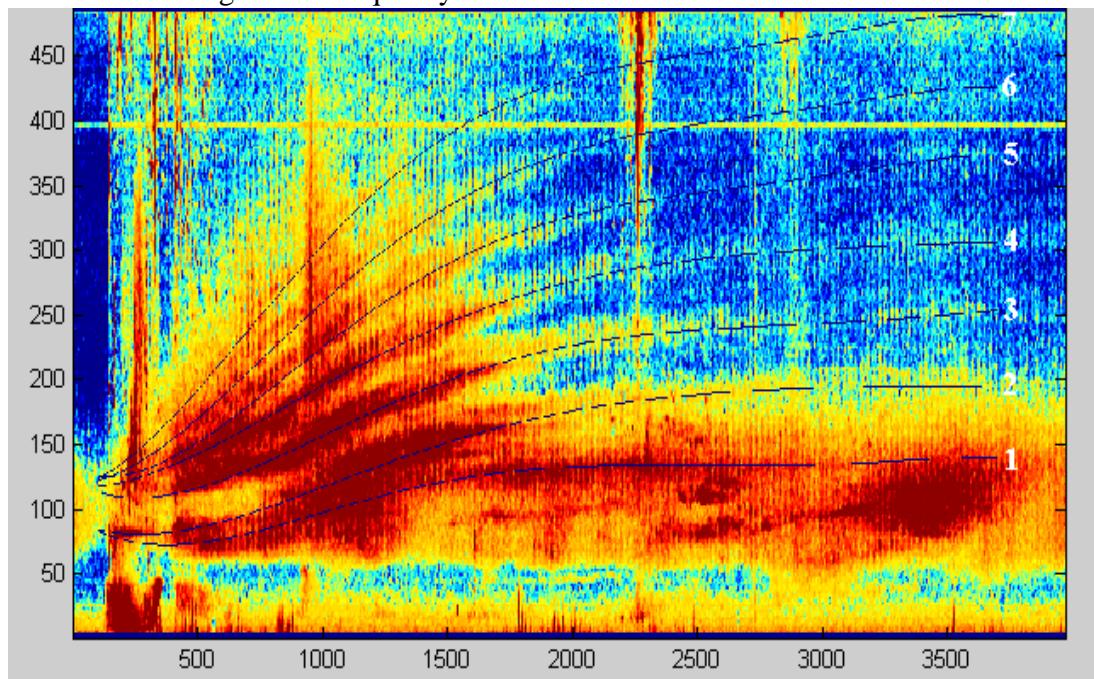
### Recent Events:

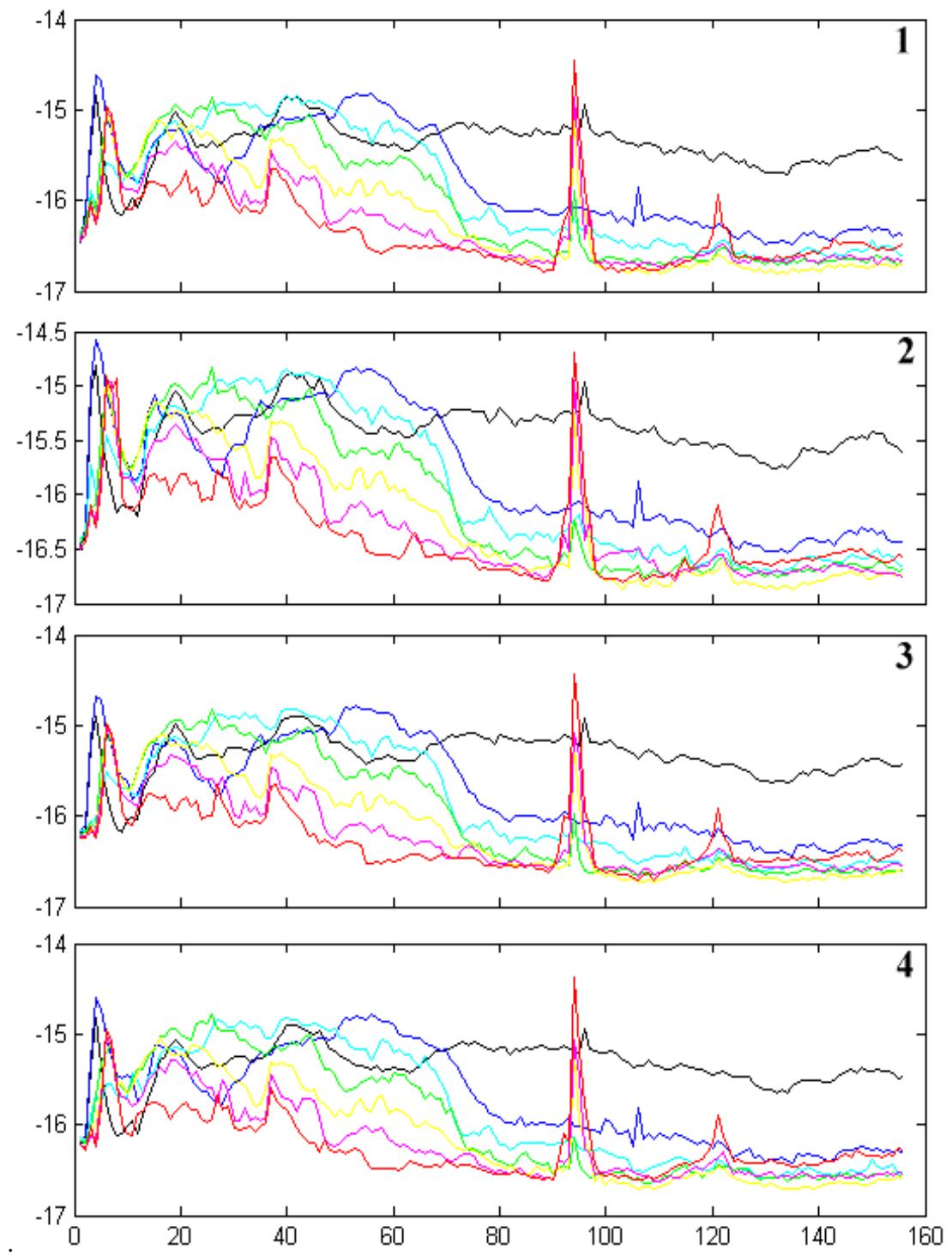


### Event of 31/08/02

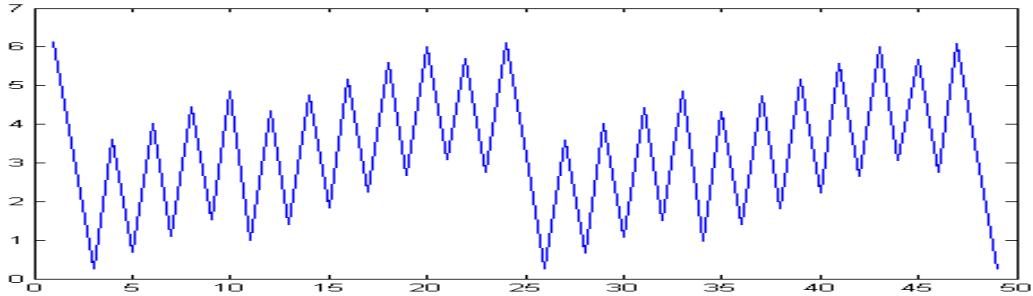


Divide into 7 specific frequency bands and an eighth which was the sum of the other 7. In each PSD the value for each band is the average of the seven frequency bins centred about the defining line in frequency-time for that band.

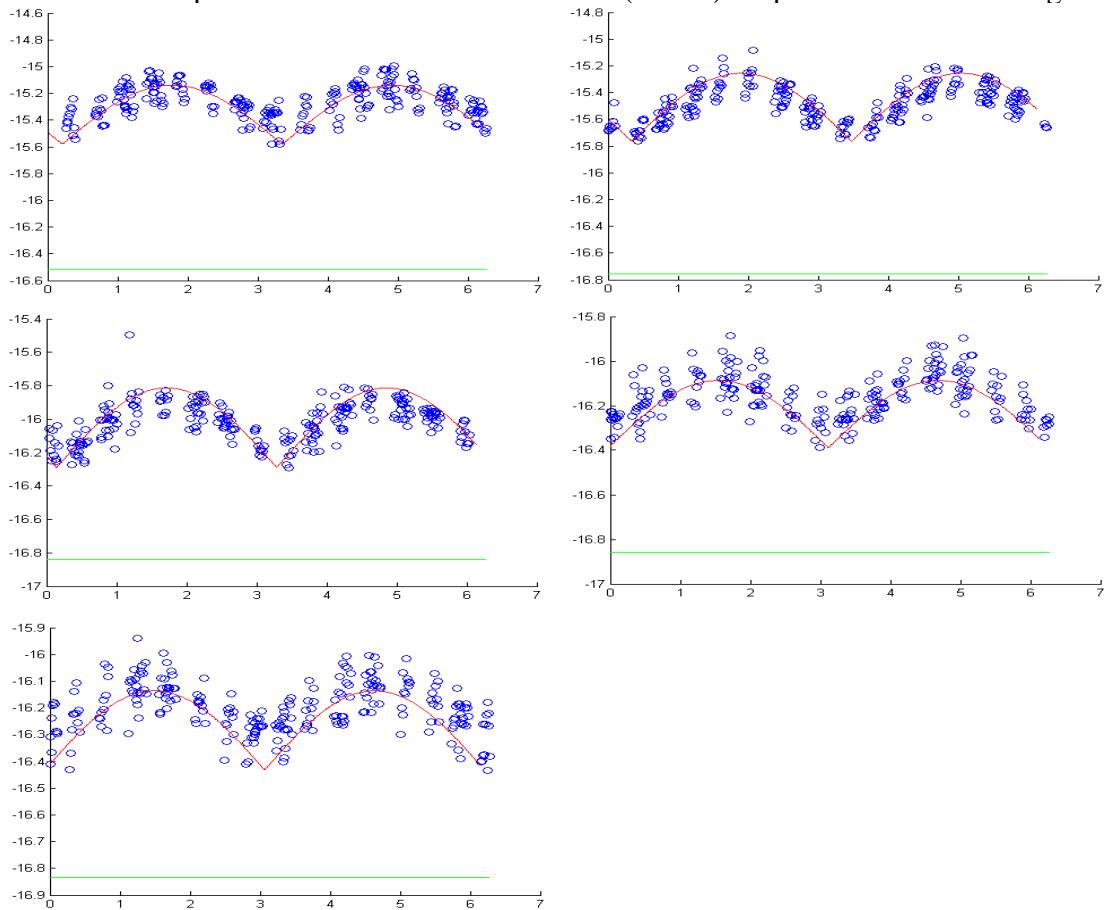




Power intensity- time of Bands 1-7 for the four spacecraft averaged over the 25 point angular sequence cycle. Bands 1 through 7 are coloured respectively: black, blue, cyan, green, yellow, magenta, and red. Band 8 is the sum of bands 1 through 7. Spikes around 5 and 95 affecting the higher frequency plots are AKR. Band 1 clearly remains high throughout suggesting perhaps a more local source contributes to this band throughout.

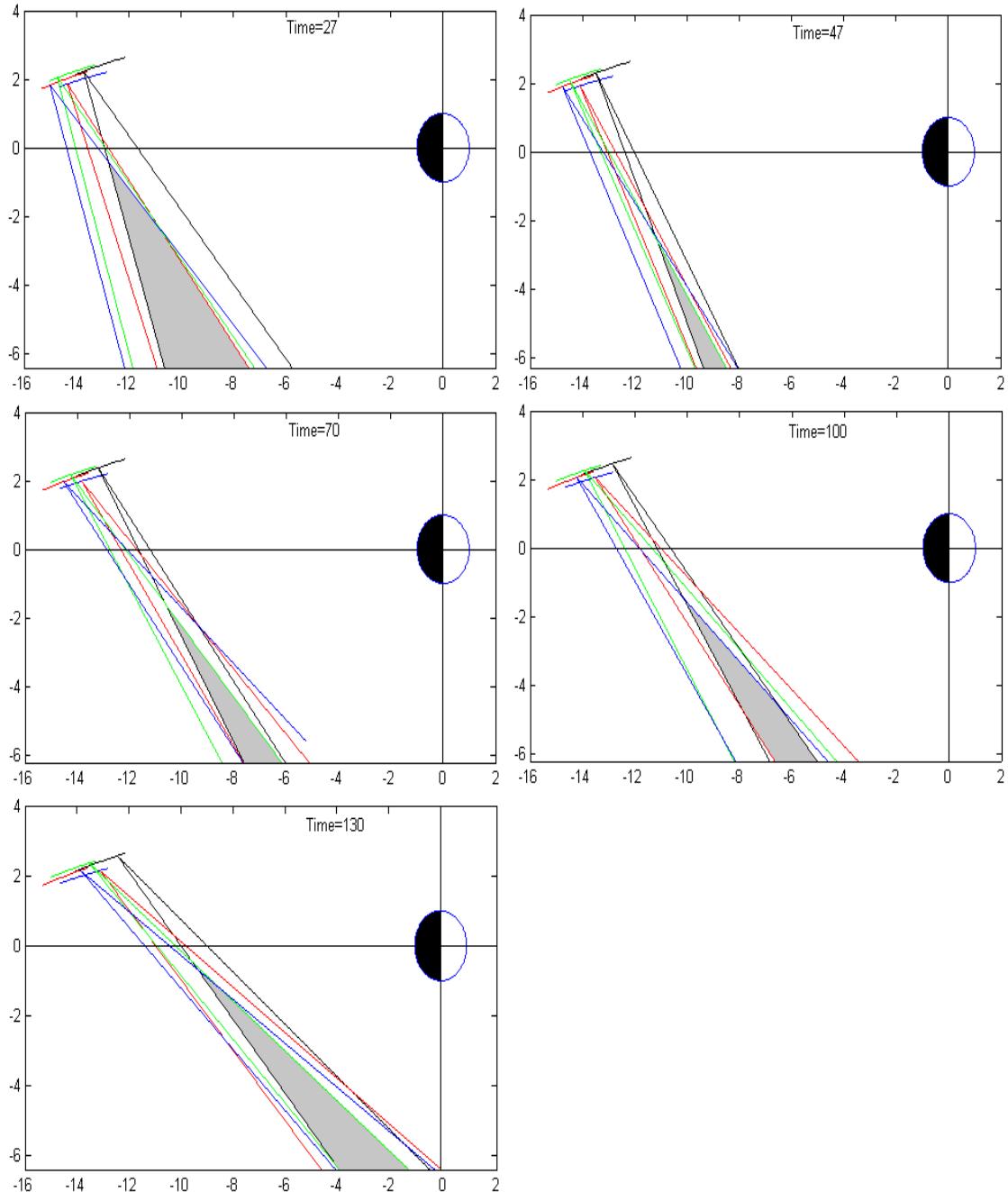


Spin phase angle versus number of PSD sequence showing a repeating structure of 23 spectra for spacecraft 1, corresponding to 11.5 spins of the spacecraft. The four spacecraft have structures that repeat in the range 23-25 spectra (at least for this event/mode). Approx 2 spectra per spin. In the following plots the timeline axis is in numbers of power spectral density spectra for 25 spectra (angular coverage sequence) for consistency across all four spacecraft. We have fitted to an  $\text{abs}(\cosine)$  shape for direction finding:



(Band 8) Summed frequency bands sequence times starting at 27 (top left), 47 (top right), 70 (middle left), 100 (middle right), 130 (bottom) (these values  $\times 25$  spectra) and summed over 10 ( $\times 25$  spectra) for S/C 1. Log10 of the signal intensity is plotted against spin phase. The red  $\text{abs}(\cosine)$  is the best fit in phase (here we have concentrated on fitting the angle and not fitted perfectly the amplitude). The green line is the pre-event background signal intensity for comparison. These show a clear drop in intensity with increasing depth of modulation and a (small) continuous change in direction from 47 onwards.

Direction for groups of 10 angular sequences (i.e. 250 PSD per group). For each group, and for each spacecraft, we have taken the mean and standard deviation of the ten individual directions. Plotted below the mean +/- standard deviation, This gives us a fan of angles from each spacecraft in which the source should lie. Below are the results with the overlap region within the standard deviations of all four spacecraft shaded grey.



(Band 8) Summed bands sequence for start times 27/47/70/100/130 each derived from 10 angular sequences

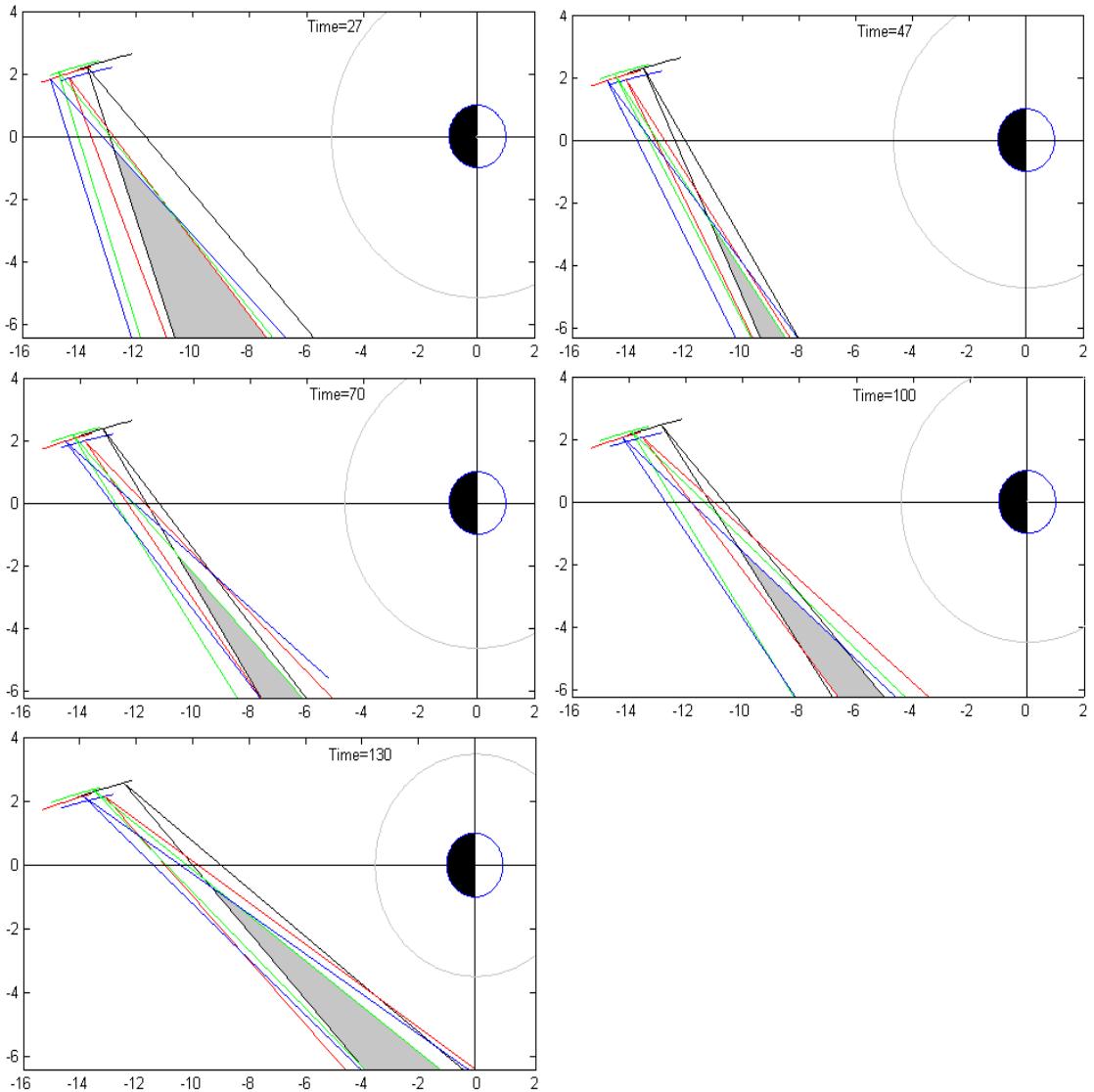
Average SD were 0.2, 0.06, 0.08, 0.1, 0.08 radians for these times respectively.

Initial high intensity and lower initial depth of modulation, suggests a source which moves in the equatorial plane below Cluster towards the Earth:

Higher initial Z offset, towards the spin axis, at the beginning  $\nwarrow$  lower depth of modulation, & high SD.

Later the source moving away along the equatorial plane increases X-Y  $\nwarrow$  higher depth of modulation, weaker signal, but better, low SD.

Add a circle to mark the expected position of the source using a simple approximation of equating the field at  $6\text{Re}$  to 100nT and assuming a dipole inverse cubed law inside.



### Problems with Interpretation

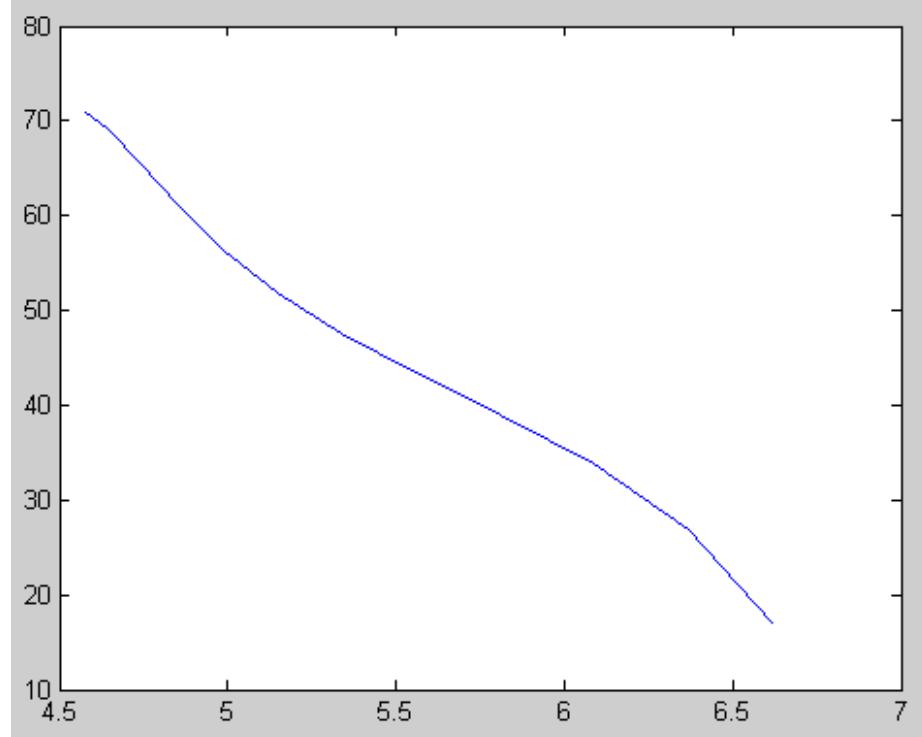
Directions do not fit the expected source by an average of around 20 degrees.

Error difference changes from around 30 degrees to around 15 degrees at the end  
Physical explanation rather than an engineering explanation?

- 1)Continuum radiation from magnetopause? The measured bands go up to 80(+) kHz -too high for magnetosheath plasma frequencies. Does not fit in with time variation of bands
- 2)Plasmapause source reflected from the magnetopause. Normal reflection not possible from considerations of magnetosheath plasma frequencies. Oblique reflection at frequencies above the magnetosheath plasma frequency is possible, but at first sight the angles do not appear oblique enough. Also any reflection would be specular and lead to a wide spread of angles corresponding to a wide area of reflecting magnetopause and larger standard deviations than observed?
- 3) Cluster is well above the equatorial plane. There have been some (theoretical) papers that suggest that continuum is initially beamed preferentially from the plasmapause in the plane of the equator radial from the source. This would require some detailed wave tracing to identify how the radiation gets to Cluster. But here again, at first sight, the amount of subsequent refraction required does not at first hand seem plausible. Problem of direction finding interpretation for sources out of spin plane
- 4) Unknown polarisation effect on Direction Finding interpretation

### Remote Sensed Plasmapause?

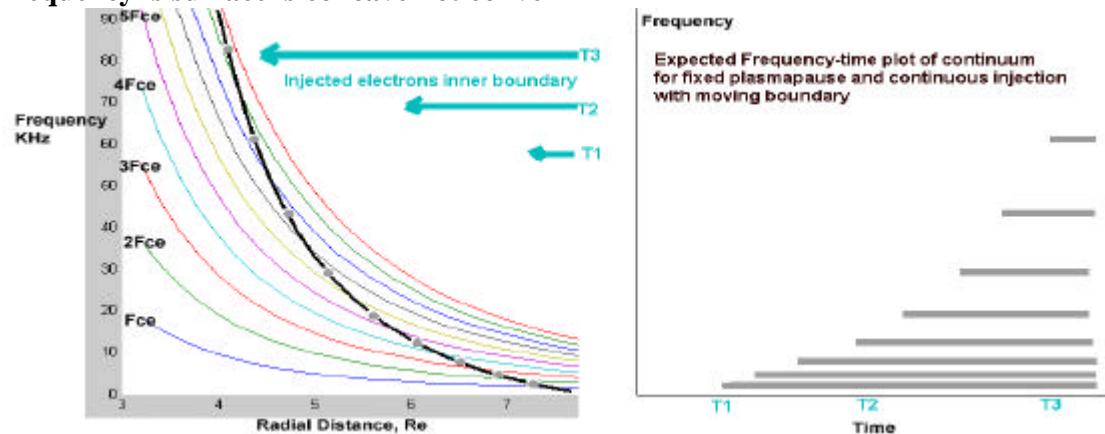
Assuming a plasmapause source we can take the initial nose of the event and at each time equate the maximum frequency to source plasma frequency and convert the band separation into source gyrofrequency. Using the crude model field we obtain the plasma frequency (KHz) versus radial distance ( $R_e$ ) plot below as a plasmapause profile.



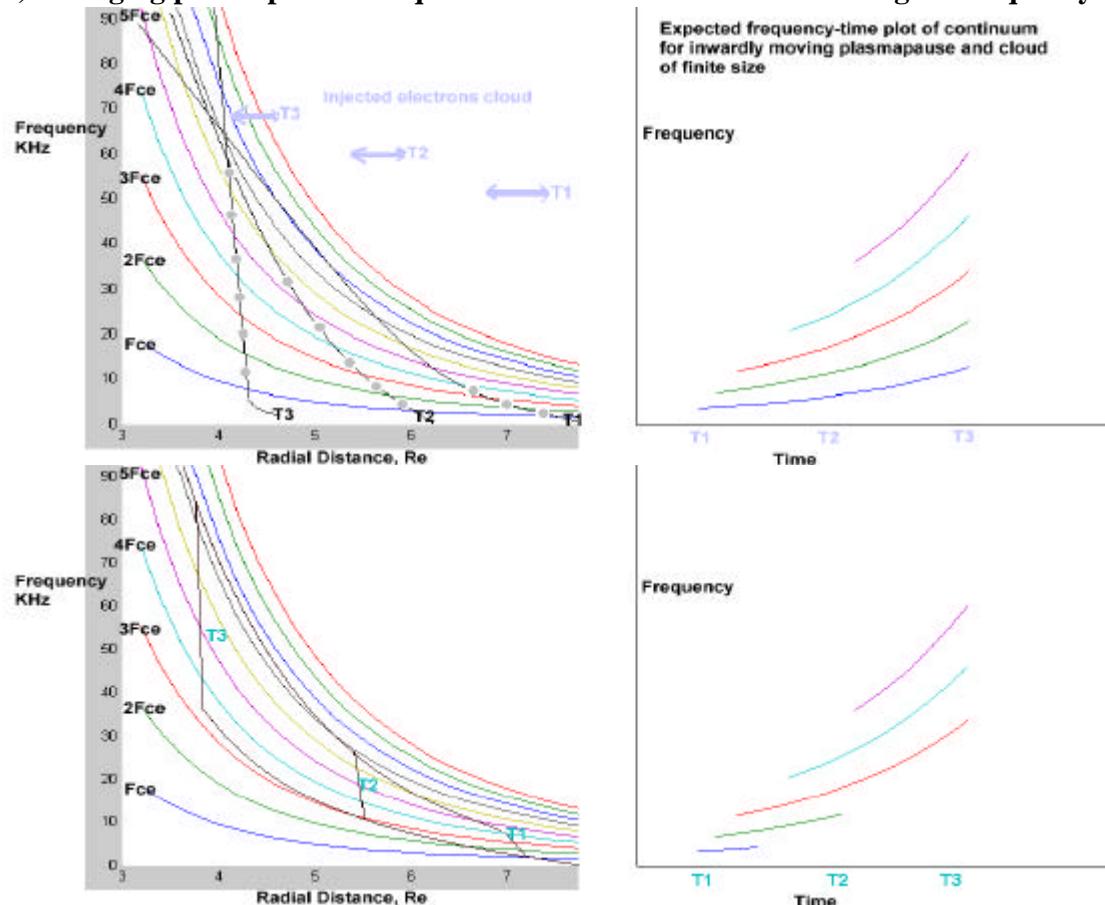
**Attempts at explaining observed convex banded frequency-time profile:**

Assume injected electrons & free energy for ECHW growth & continuum.

- 1) If plasmapause fixed + free energy source moves inwards, line separations increase with frequency but individual lines do not change with frequency and start frequency is surface is concave not convex-

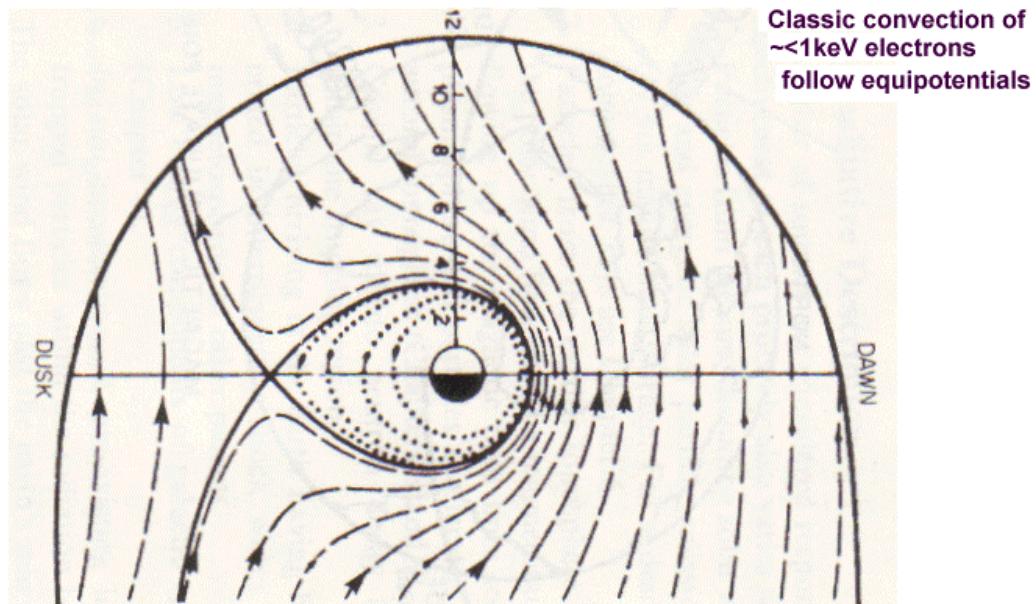


- 2) Changing plasmapause is required for continuous lines that change in frequency:

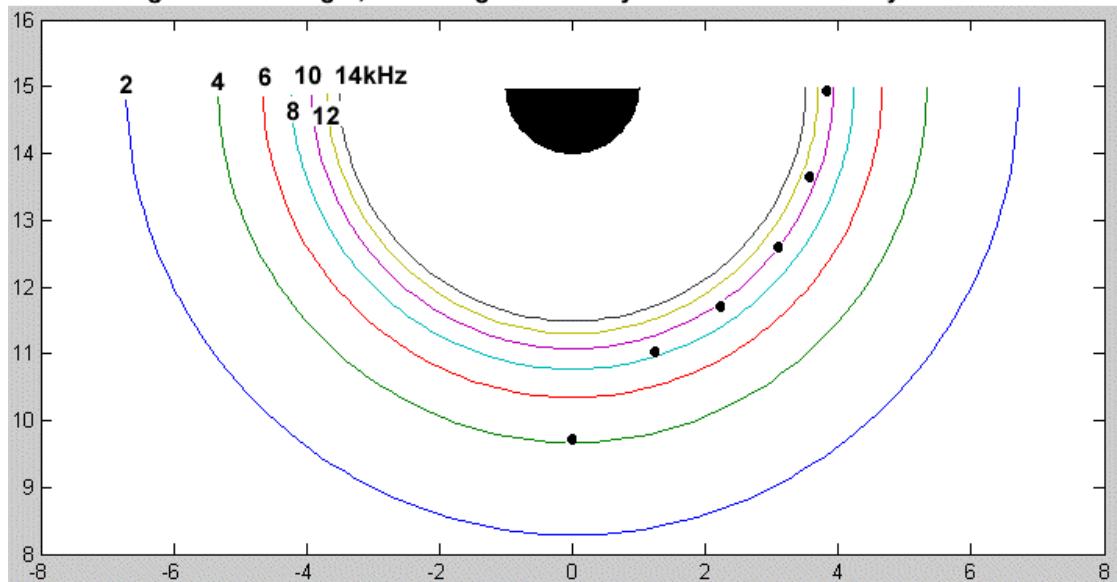


However frequency shape tends to be concave- not the observed convex frequency-time curve shapes

**3) Convection of electrons to different plasmapause regions- different B fields:**



Plotting frequency band separation radially as gyrofrequency versus time as angle from midnight, assuming an arbitrary constant drift velocity



**Injection = Inward Convection + drift could explain convex frequency -time shape**

**Angular Drift Velocity above ~80keV similar to GEOS observed correlation**

**But too high for ECHW- expect ~keV**

**Need to study Continuum events near the source (e.g. 30/12/03)**

## Appendix: Old GEOS Particle Injection Events

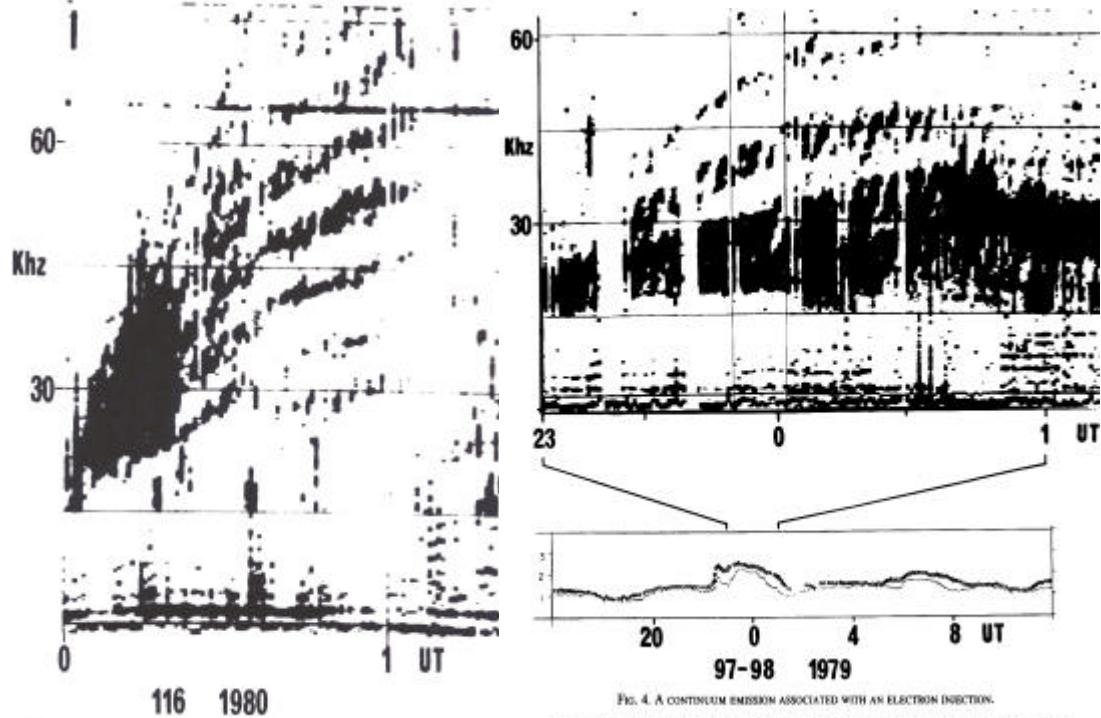


FIG. 3. A CONTINUUM EMISSION ASSOCIATED WITH A PARTICLE INJECTION EVENT AROUND LOCAL MIDNIGHT.

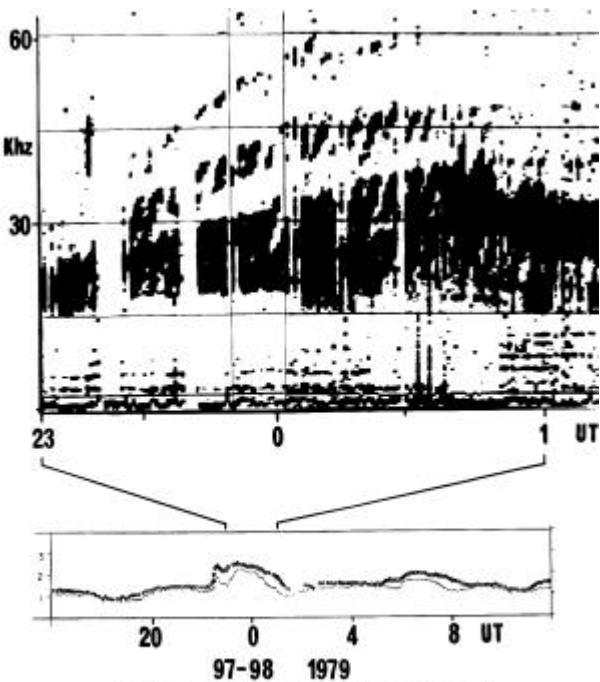


FIG. 4. A CONTINUUM EMISSION ASSOCIATED WITH AN ELECTRON INJECTION.

Below is plotted the count rates on a logarithmic scales for electrons in the energy range 30-37 keV both perpendicular to  $B$  (○) and parallel to  $B$  (—).

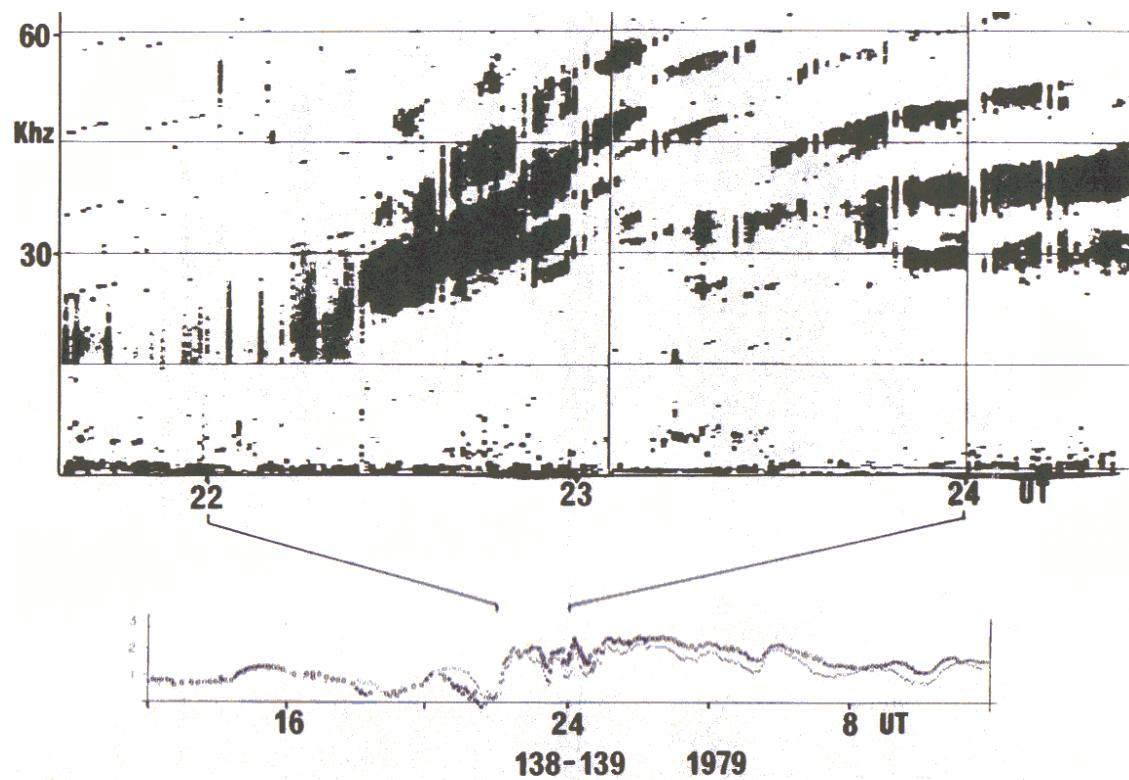
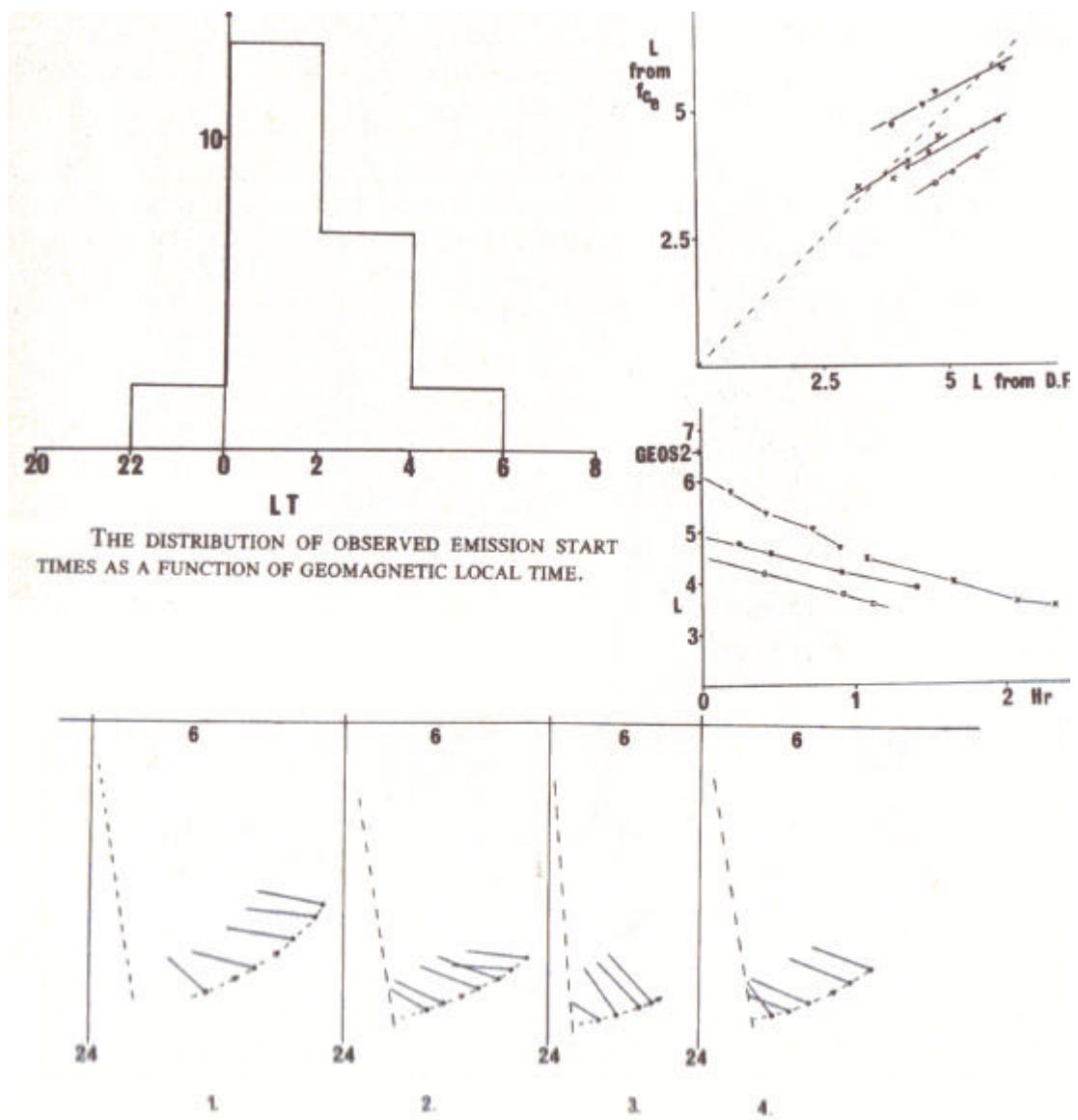


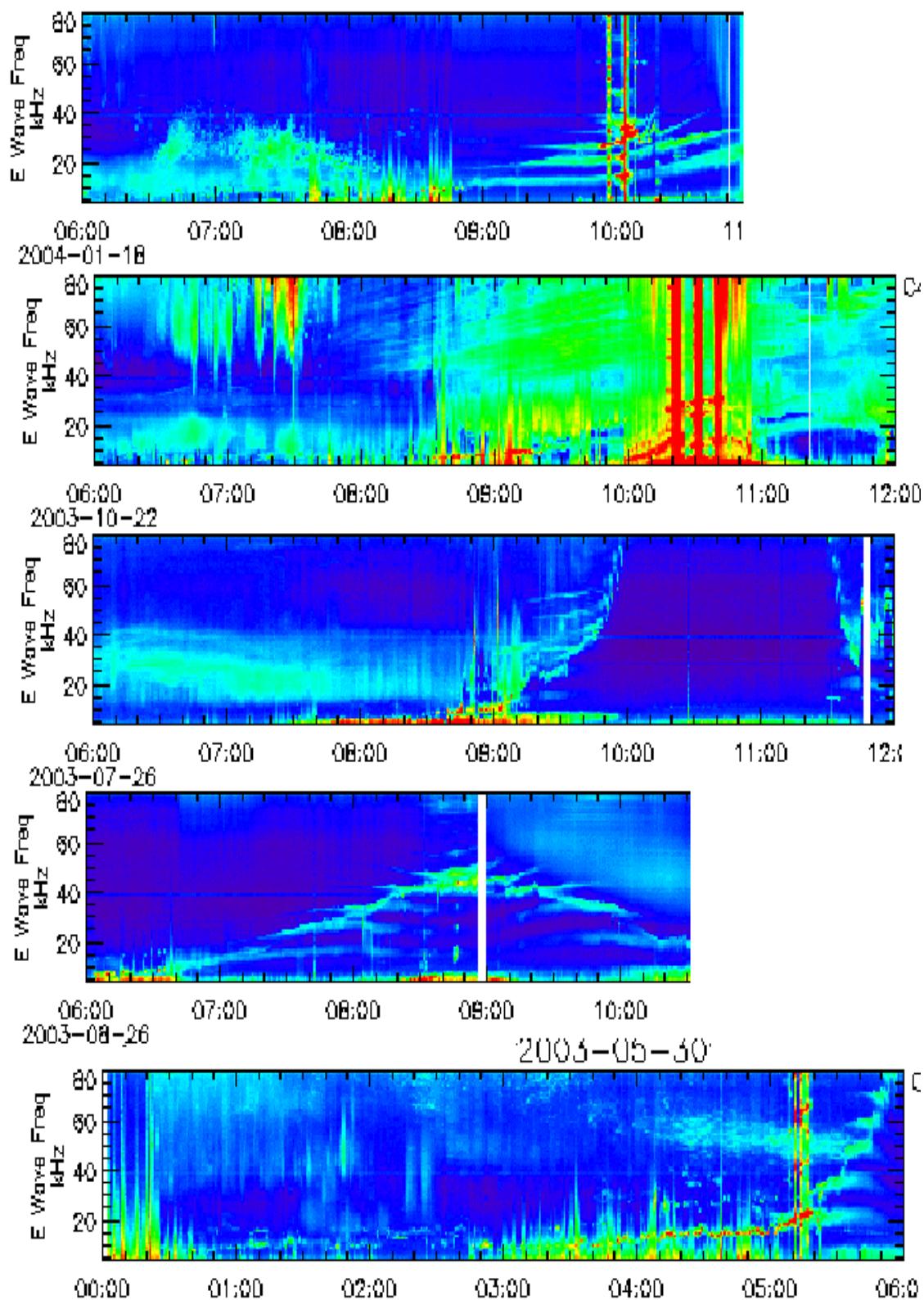
FIG. 5. A THIRD EXAMPLE OF INJECTION ASSOCIATED CONTINUUM.



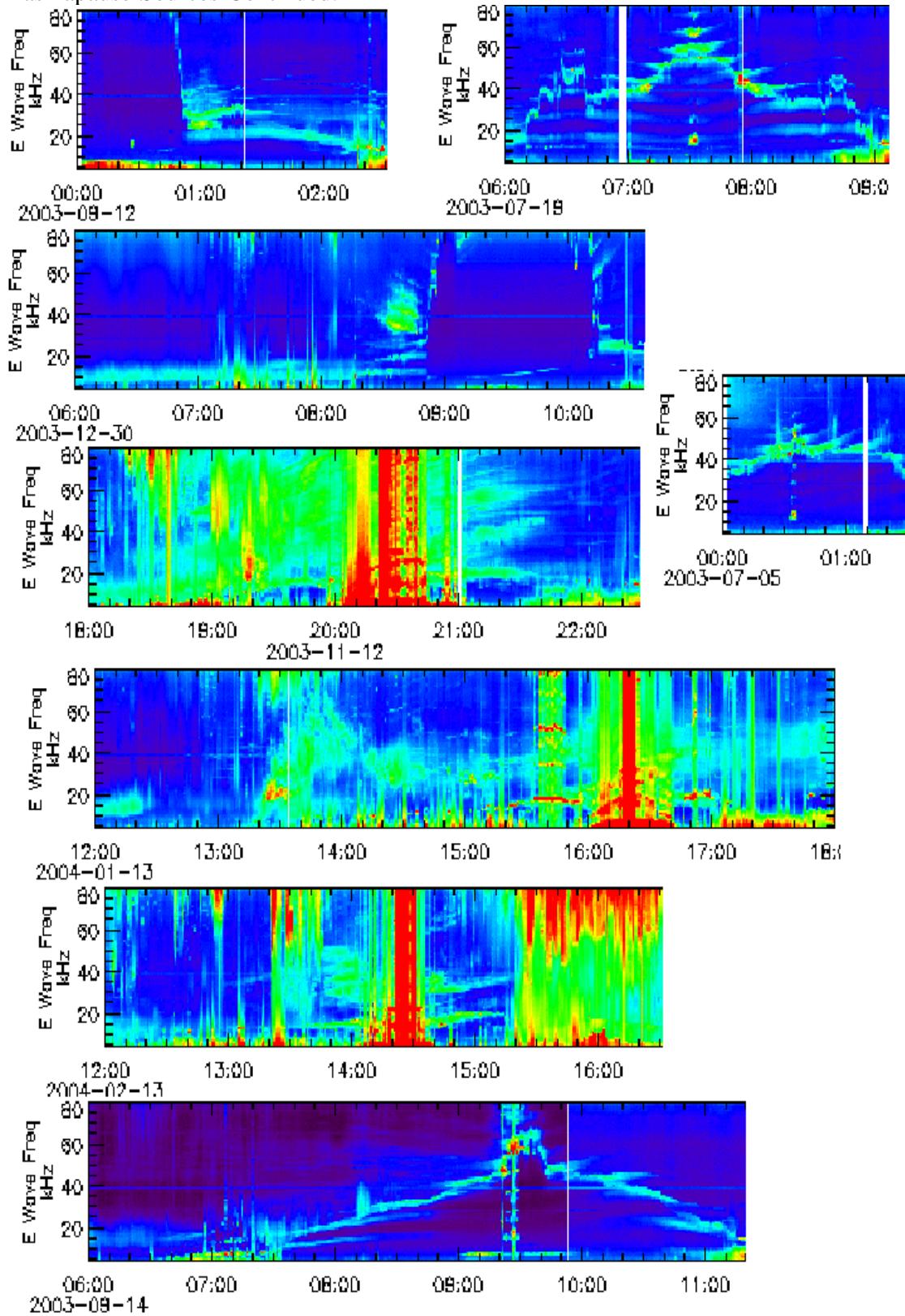
DISTRIBUTION FINDING DETERMINATION OF THE SOURCE LOCATION FOR THE FOUR EVENTS STUDIED ARE

- 1) Remote Sensing of Plasmasphere boundary during injection events
- 2) Injections occur near magnetic midnight
- 3) Assuming(2) Comparison of DF to injection line fits source B from  $t_{ce}$  finger separation.
- 4) Inwards movement  $\sim 1$  Re/hour

### Some Examples of Emission of Continuum close to plasmapause

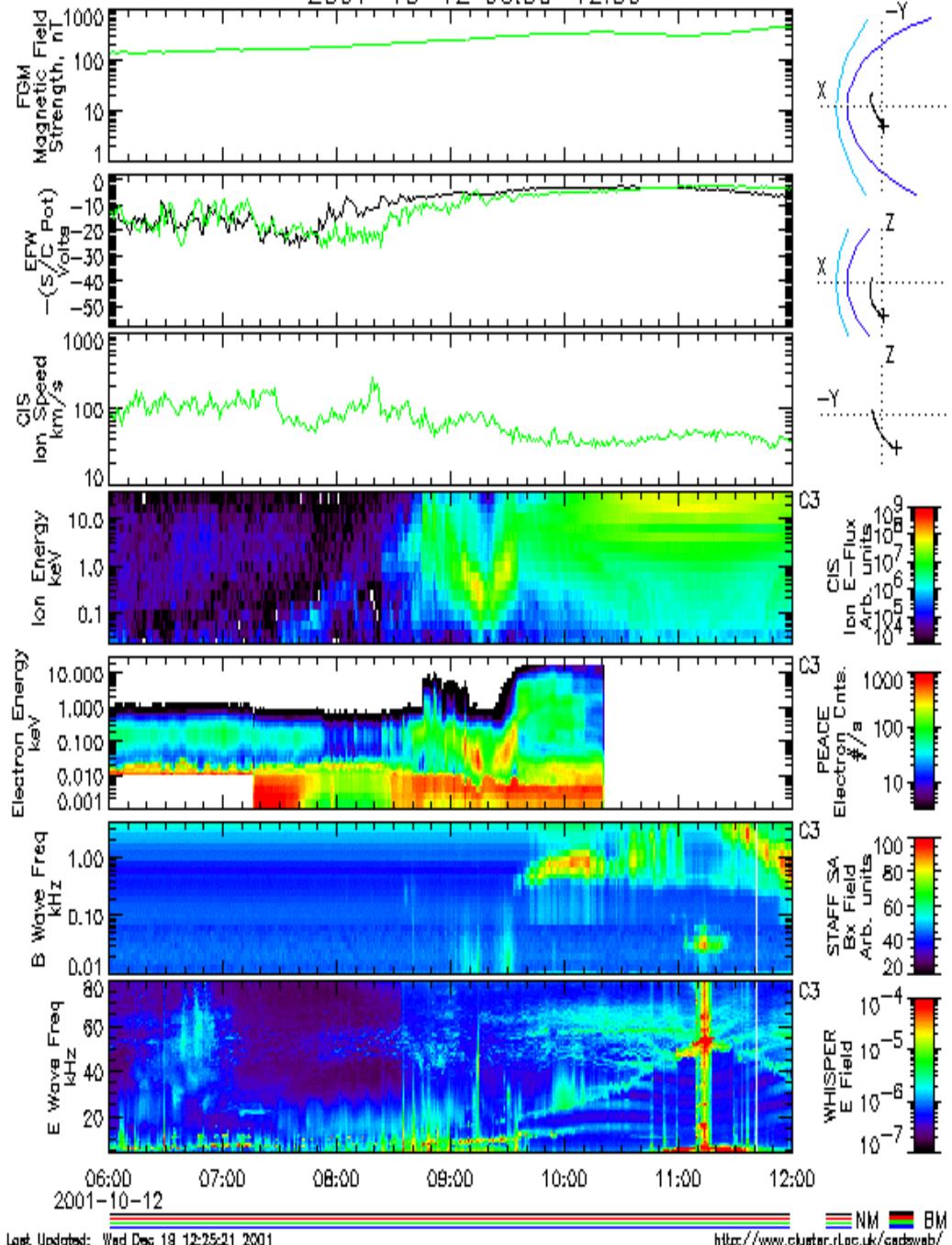


Plasmapause Sources Continued:





## Cluster Quicklook 6-hour: Overview 2001-10-12 06:00-12:00



Last Updated: Wed Dec 19 12:25:21 2001

<http://www.cluster.rl.ac.uk/cadweb/>

NM BM