

COORDINATING OBSERVATIONS WITH CLUSTER

J. S. Pickett

On behalf of the Cluster WBD Science Team and the Cluster Mission



Department of Physics and Astronomy
The University of Iowa,
Iowa City, Iowa, USA



VAN ALLEN PROBES
Science Working Group Meeting
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The University of Iowa
Iowa City, Iowa, USA

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MOTIVATION

The Cluster mission's 2013 Senior Review Proposal included the following proposals with respect to the Van Allen Probes:

- 1) To coordinate optimal scheduling of operations (compatible wave instrument modes) for studying the global properties of various inner magnetosphere waves, such as chorus, equatorial noise and hiss
- 2) To define magnetic conjunction times of the Cluster spacecraft with the two Van Allen Probe spacecraft to obtain high time resolution waveform data from both missions from which to carry out the study of the fine structure of plasma waves such as chorus, including determining the ideal modes in which to operate the wave instruments for both missions.

The Senior Review Panel's report stated:

“The objective to investigate the spatiotemporal properties of waves at mid-latitudes in the inner magnetosphere (with C3 and C4 at small separations), and their relation to observations of radiation belt particles and waves in conjunction with the Van Allen Probes, is achievable with the Wide Band Data (WBD) and Research with Adaptive Particle Imaging Detectors (RAPID) Imaging Energetic particle Spectrometer (IES) instruments which are working on all spacecraft.... the panel recommends continued funding ... for the U.S. Principal Investigator (PI)--led WBD instrument in the extended mission.”

Summary of Cluster Wide Band Data (WBD) Instrument Design

- WBD instrument designed and built at the University of Iowa
- The digital wideband receiver design provides **continuous one axis waveform capture for periods up to 7 hours** in selected frequency bands up to 577 kHz at **sampling rates from ~27 to 220 kHz**.
- The higher frequency measurements (125 kHz and higher) are obtained via frequency conversion.
- Signal inputs are obtained from the electric field (EFW) and magnetic field (STAFF) WEC sensors.



CLUSTER INSTRUMENT COMPLEMENT

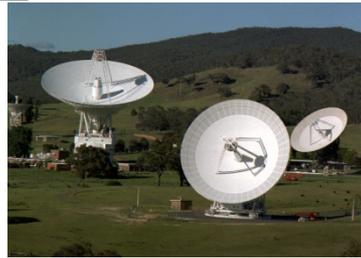
Instrument	Function or Measurement	Normal Mode	Burst mode
ASPOC	Spacecraft potential control	No fuel	No fuel
CIS- HIA	Ions 5 eV/e- 32 keV/e	4 second pitch angle, 3D + moments	4 second pitch angle, 3D + moments
CIS-CODIF	Ion species (H+, He+ and O+)(25 eV/e – 40 keV/e)	4 second pitch angle, 3D + moments	4 second 3D + moments
EDI	Electron drift and electric field	DC electric field from electron drift velocity (1/8 s), ambient electron flux (0.5 and 1 keV) 1/64s	DC electric field from electron drift velocity (1/64 s), ambient electron flux (0.5 and 1 keV) 1/128s
FGM	Magnetometer (0-10 Hz, 0 – 65,536 nT)	22 vec/s	67 vec/s
PEACE	Electrons (0-28 keV)	4 second pitch angle +moments +reduced 3D (4 -160 seconds)	4 second high full 3D + moments
RAPID - IES	Energetic electrons (40-400 keV)	Omni-spectra, reduced pitch angle	3D distribution
RAPID-IMMS	Energetic Ions, H+,He+, CNO (28 -4000 keV)	3D distribution every 32 spins	3D distribution
Wave Experiment Consortium (WEC)			
DWP	Particle correlator – autocorrelation functions (ACFs) of particle counts from PEACE sensor	1 ACF per spin	4,8, 16 ACF per spin
EFW	Electric field	25 vec/s (probe-sc potential 5 /s)	450 vec/s
STAFF	AC B fields	(SC): 25 vec/s, 0.1-10Hz (wave form); (SA): 1-4 second, 8 – 4000 Hz	(SC) 450 Hz, 0.1-180Hz (wave form); (SA): ¼- 1 second, 64 – 4000 Hz (SA)
WBD	Band limited waveforms : 9.5, 19, and 77.0 kHz with Translation, 0, 125, 250, and 500 kHz	Real time TDA-8 mode measurements: E fields: 100 Hz to 577 kHz B fields: 70 Hz to 4.0 kHz ~5 to 36 μ s resolution	Recorded BM-2 measurements: E and B fields: 1/3 to 1/4 nominal bandwidth or 1/3 or 1/4 duty cycle ~5 to 36 μ s resolution
WHISPER	E field spectra 2–82 kHz and electron density.	2–82 kHz spectra (1.7-3.4 s). electron density 2.15 (passive) and 52 (active) second	2–82 kHz spectra (0.3 – 0.66 s). electron density 2.15 (passive) and 52 (active) second

WBD Receiver Measurements



WBD TDA-8 Mode:
Real Time Downlink
at 220 Kbits/s to
NASA/DSN or
Panska Ves

**P
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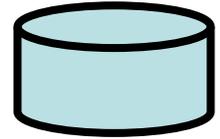


WBD data ftp to Univ. of
Iowa Van Allen Hall for
processing

SECONDARY

WBD Burst Mode 2: WBD data stored on
Cluster spacecraft SSR

**Cluster WBD
Data Chain**



Downlink to ESA
ground station
and ESOC



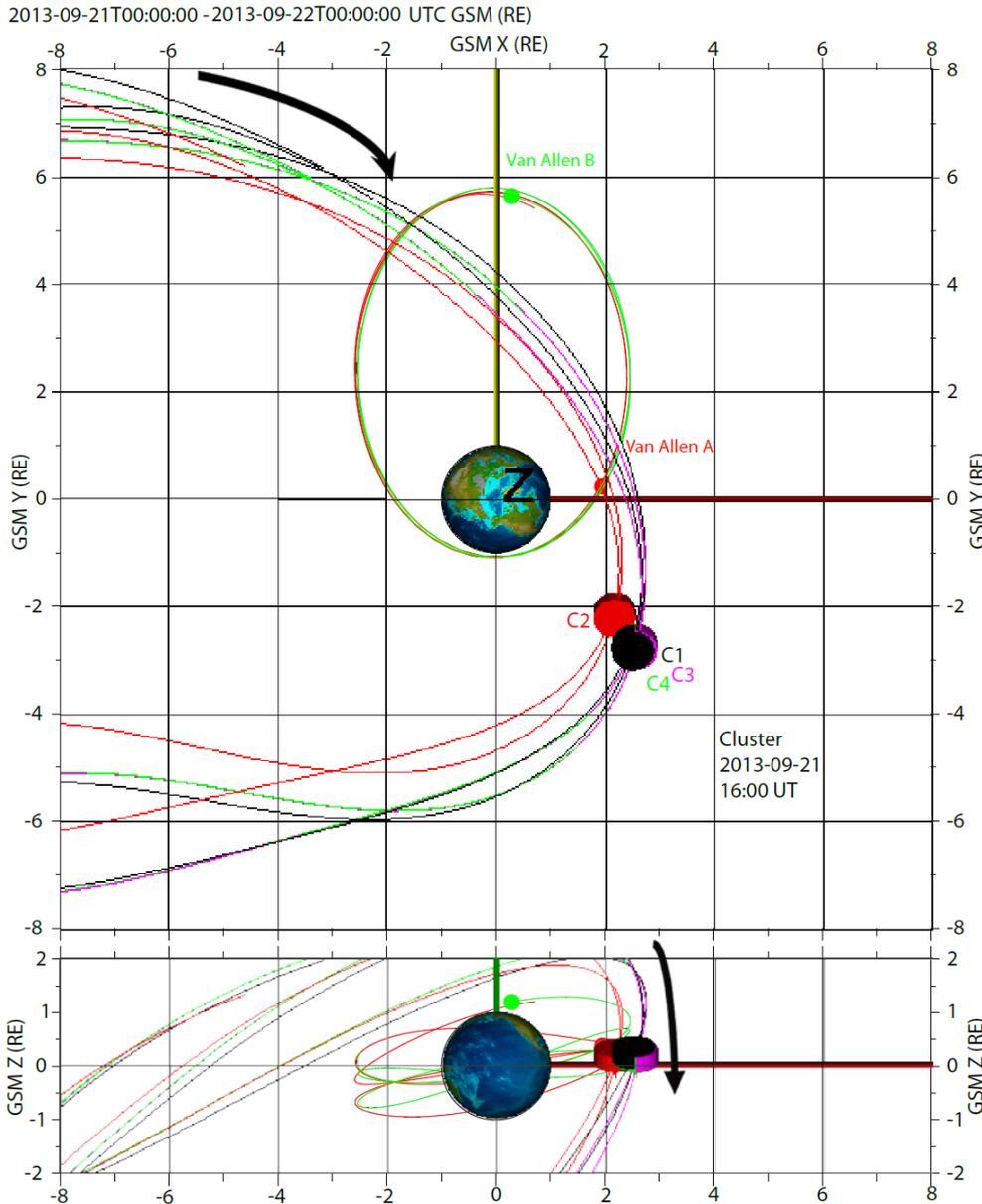
Wave data to
Univ. of Sheffield
for processing



WBD data
to Univ. of
Iowa



CLUSTER ORBIT

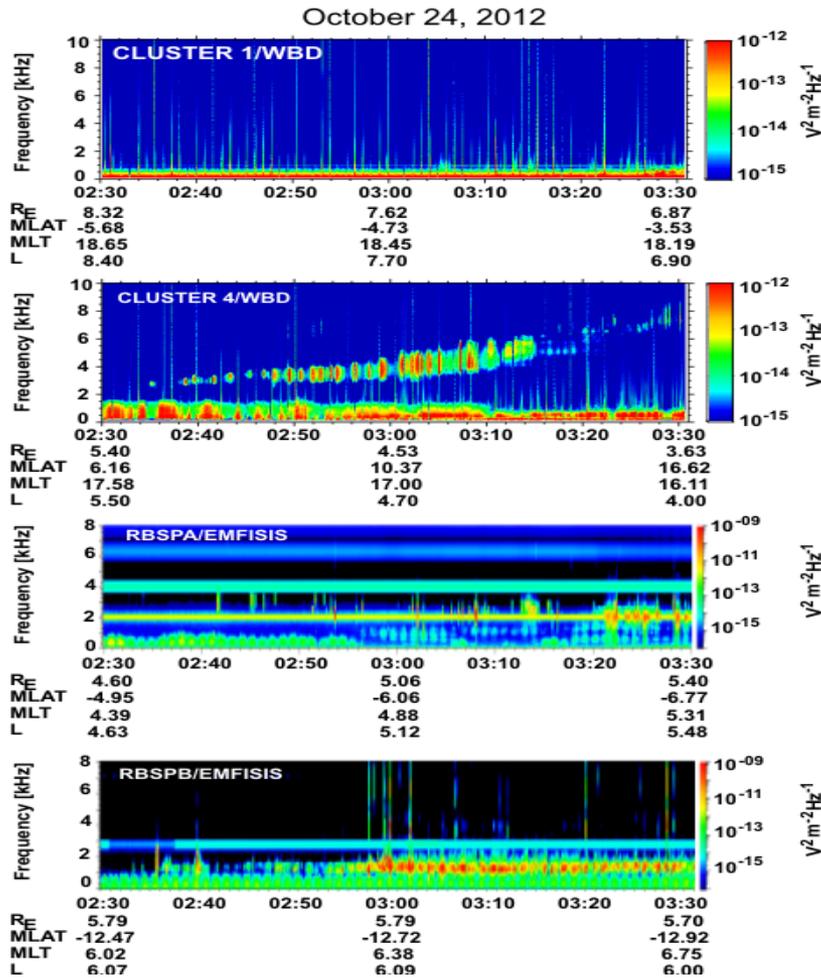


- Example for Sep. 21, 2013
- $\sim 3 \times 20 R_E$
 ~ 54 hour Period
- Until Oct. 16, 2013 C1/C3/C4 separated by < 100 km near perigee while C2 is ~ 4400 km away from the others
- Inner Magnetosphere Equator Crossings:
 - Inbound S-N around 7-9 RE, 21-19 MLT
 - Outbound N-S around 3.5-4.5 RE, 10-7 MLT
- After Oct 16, 2013, larger separations (order of few thousands to 10,000 km) with MLT progressing to dawn

GLOBAL STUDIES OF WAVES - 1

- Data from the Cluster wave instruments WBD, STAFF, WHISPER, and EFW will indicate what wave modes are present.
- Determine for the first time the instantaneous spatial extent of the waves when the same types of waves are detected at Cluster and at the Van Allen Probes.
- Cluster's unique high latitude wave measurements are essential for understanding the propagation and evolution of waves away from their source regions, i.e., evolution from field aligned to propagation at an angle to the magnetic field, as well as the cause of that evolution.
- Cluster data, together with the observed Van Allen Probes wave and radiation belt electron data, can help assess the role of the waves in the heating, acceleration and loss of electrons.
- Cluster WBD will also support the Oct. 9, 2013 Juno Earth fly-by during its inner magnetosphere transit, so instrument mode selection for that will be done in collaboration with the Van Allen Probes EMFISIS Team.

GLOBAL STUDIES OF WAVES - 2



WBD data from C1 and C4 and from the EMFISIS instruments on Van Allen Probes A and B on October 24, 2012.

Multipoint observations will allow us to estimate the MLT-MLAT domain and frequency extent of chorus/hiss waves and global dimensions of their generation region in the magnetosphere.

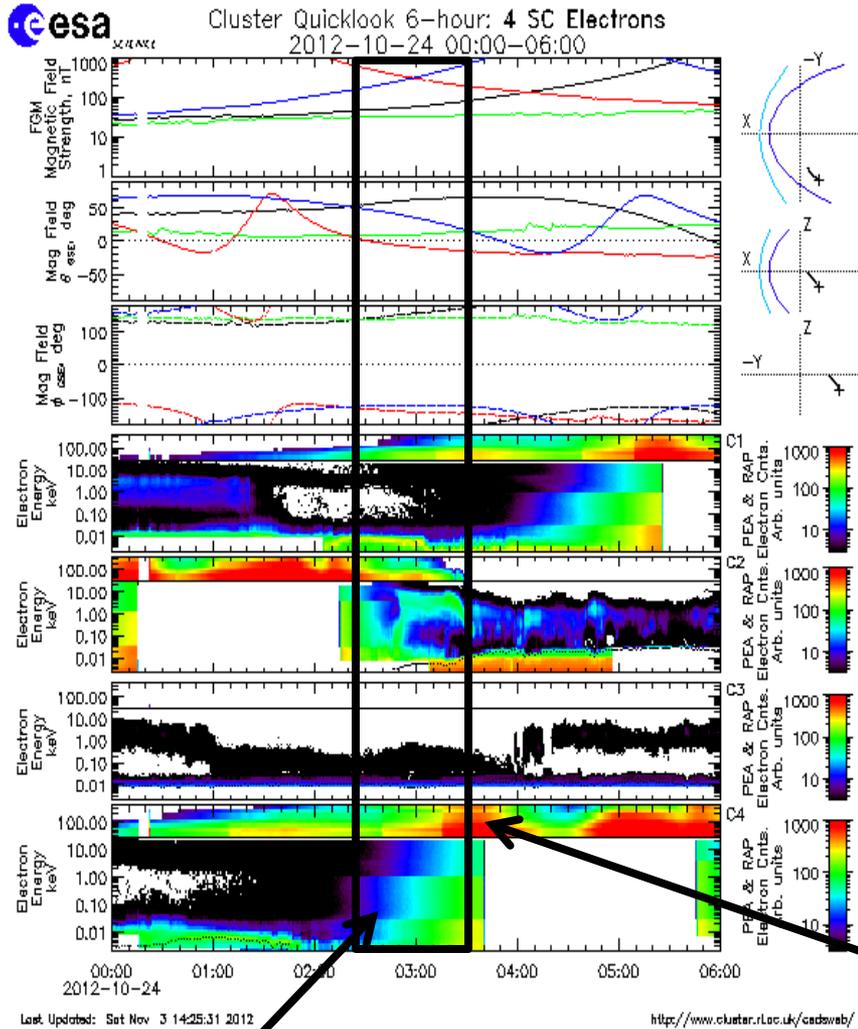
Both the Van Allen Probes and Cluster can determine propagation directions and Poynting fluxes. Multipoint localization of the sources and propagation patterns will therefore be possible.

Example: C4 WBD (left) observes bursty chorus/hiss waves at ~2-6 kHz on the afternoon side in the equatorial, plasmasphere region at a range of R_E from 5 down to 3.5, while C1 is much further away at dusk in the equatorial region and sees no evidence of chorus/hiss waves.

The Van Allen Probes, located on the morning side equatorial region, see LB chorus waves from about 1-3 kHz on Probe A and from 1-2 kHz on Probe B.

Because chorus waves are usually seen on the morning side, as is visible here on the Van Allen Probes, the waves on C4 if chorus are atypical.

GLOBAL STUDIES OF WAVES - 3



The particle data, including PEACE and RAPID/IES electrons (left, bottom 4 panels) show entry into the radiation belts during the end of the WBD wave period.

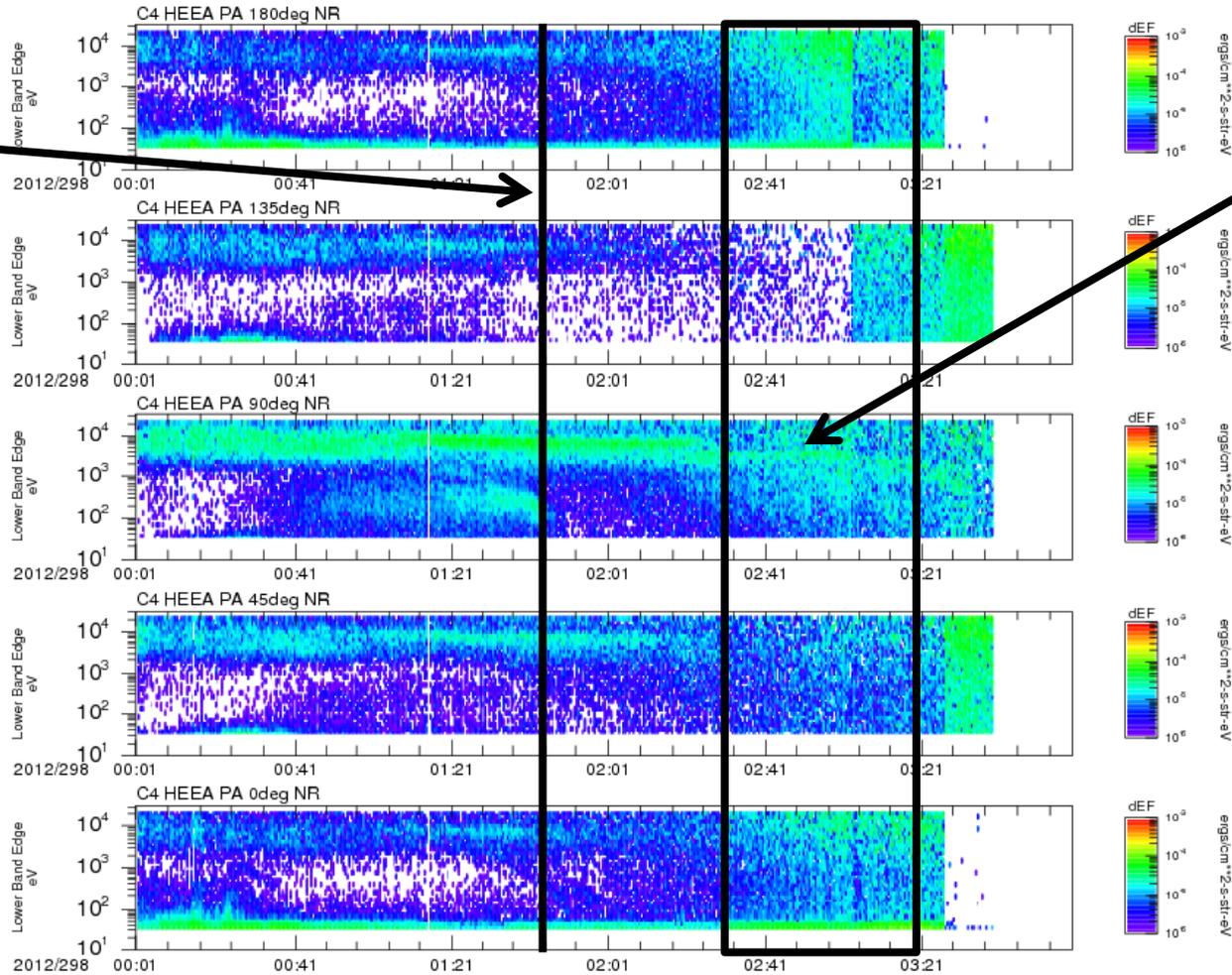
These electron data and ion data from the CIS instrument, including ion composition (not shown) can be used to investigate wave-particle interactions and to determine if the particle distributions may be related to the growth or damping of the observed waves on Cluster.

RAPID/IES high energy electrons

PEACE electrons up to 28 keV

GLOBAL STUDIES OF WAVES - 4

Plasmasphere
Entry



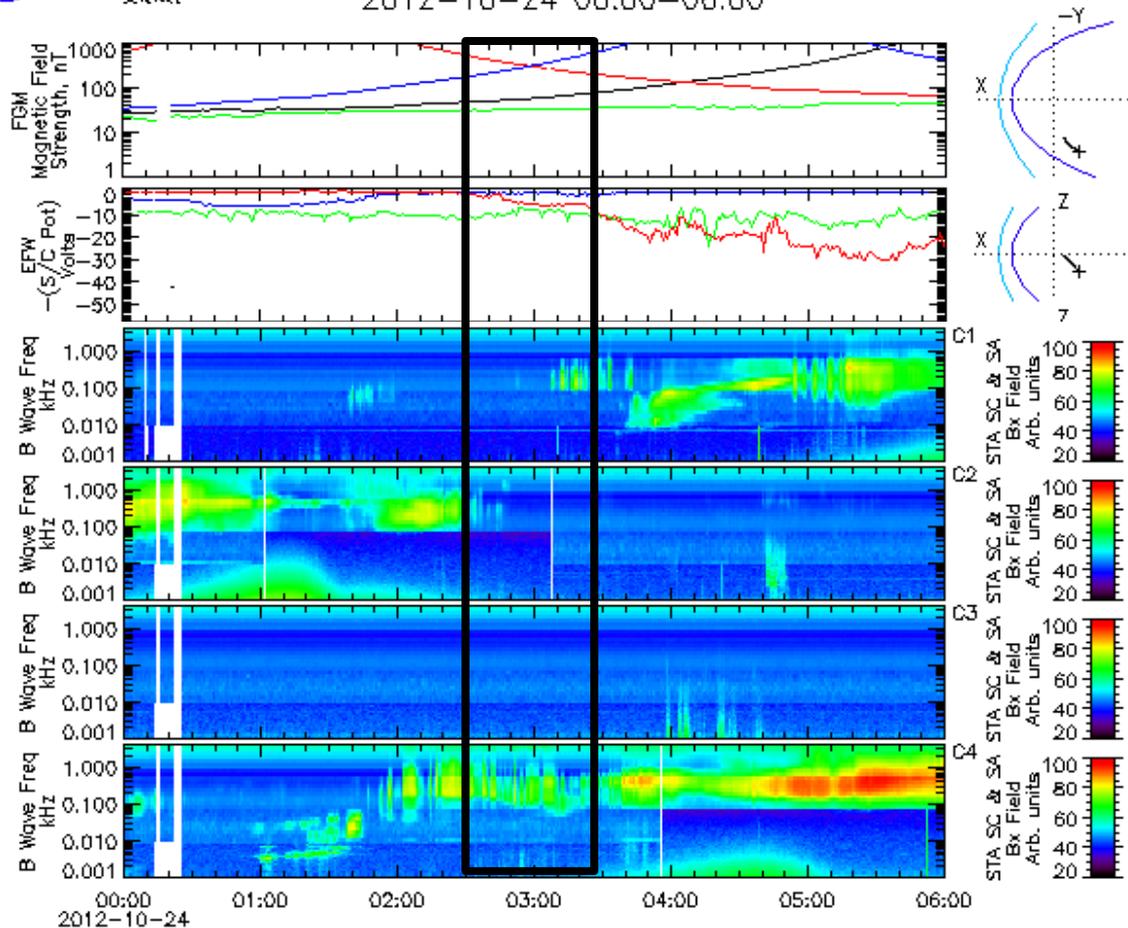
5 keV
electron
population at
90 degrees
during WBD
wave
observations

PEACE electron data (35 eV to 28 keV) with radiation counts removed showing C4 entered the plasmasphere ~01:45. A 90 deg. population is observed around 5-10 keV at the time the WBD instrument shows the bursts of chorus/hiss waves

GLOBAL STUDIES OF WAVES - 5



Cluster Quicklook 6-hour: E Fluctuations
2012-10-24 00:00-06:00

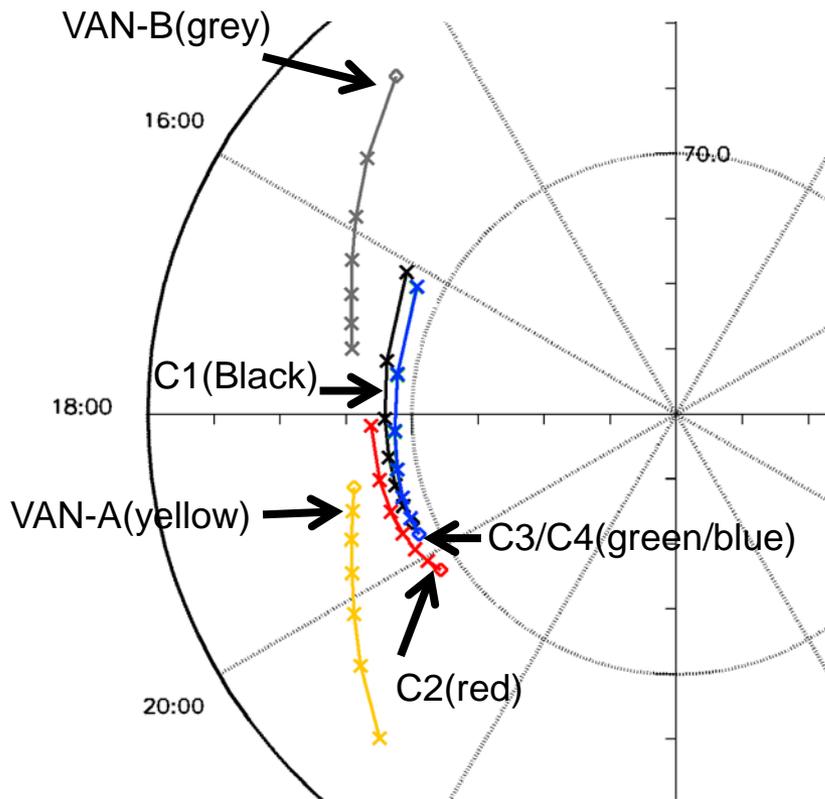


Last Updated: Sat Nov 3 14:25:38 2012

<http://www.cluster.lac.uk/csdswab/>

The Cluster STAFF-Sa wave data for each of the 4 Cluster spacecraft (left, bottom 4 panels) for the chorus/hiss example can be used to determine wave properties (propagation direction, polarization, etc.) provided the frequency is less than 4 kHz

FINE STRUCTURE OF CHORUS WAVES - 1



Predicted magnetic footpoints in CGM coordinates for Sep. 16-17, 2013, 23:30-01:30 UT (diamond is start; crosses every 20 mins)

WBD data will be scheduled for periods when Cluster is in near magnetic conjunction (5 deg. Lat./Long.) with the Van Allen probes to examine the fine structure of chorus waves along a magnetic field line and to determine how chorus waves might interact with radiation belt electrons

Below is an excerpt from the conjunction file for Sep. 16-17, 2013. WBD data will be received at Panska Ves on C1/C4 from 2030-0012/0018 and at DSN on C2 from 2030-0025 (Type A is conjunction with Van Allen Probe A)

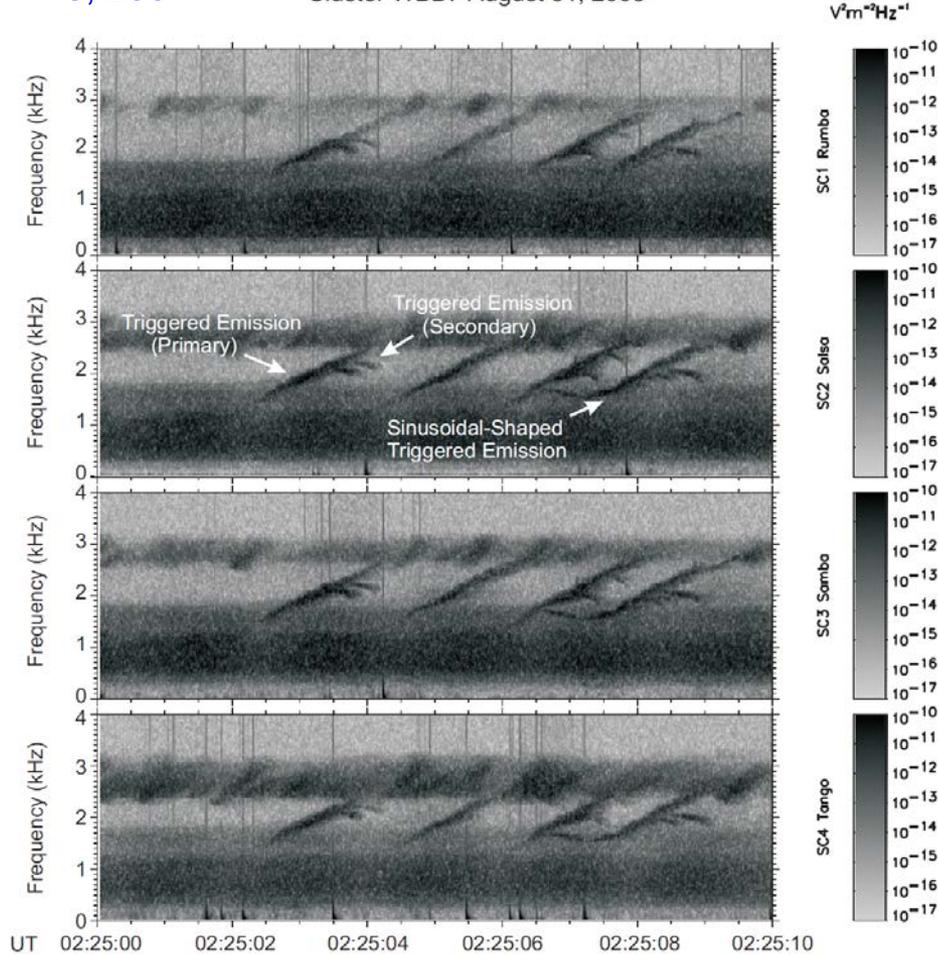
2013/09/16(259)T23:56:00

SC	Type	R(RE)	Mlat	MLT	Foot Mlat	Foot MLT	L
C1	A	5.7	26.6	19:31:54	67.4	18:59:32	7.2
C2		6.3	19.5	20:26:17	67.6	19:53:01	7.1
C3	A	5.7	27.8	19:44:14	67.8	19:11:41	7.3
C4	A	5.7	27.9	19:43:55	67.9	19:11:07	7.3
VA		5.1	8.6	19:36:16	63.1	19:06:00	5.3
VB		3.8	13.7	15:23:24	59.4	15:21:36	4.0

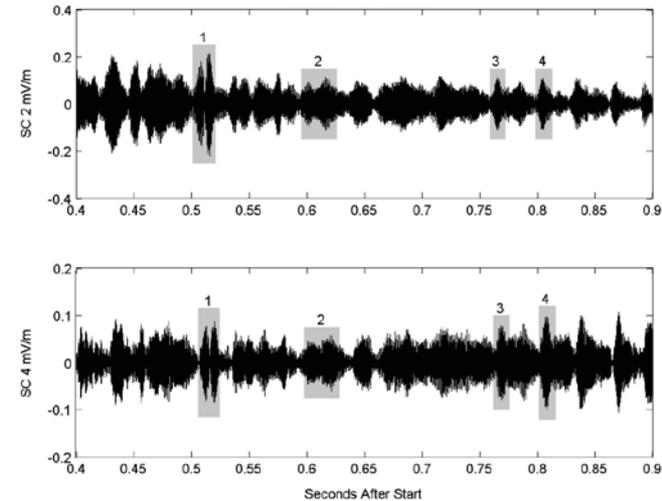
<http://www-pw.physics.uiowa.edu/cluster/VanAllenCollaboration/>

FINE STRUCTURE OF WAVES - 2

Cluster WBD: August 31, 2003



Waveforms will be cross correlated, as shown below where delays of 3-5 ms were observed between s/c.



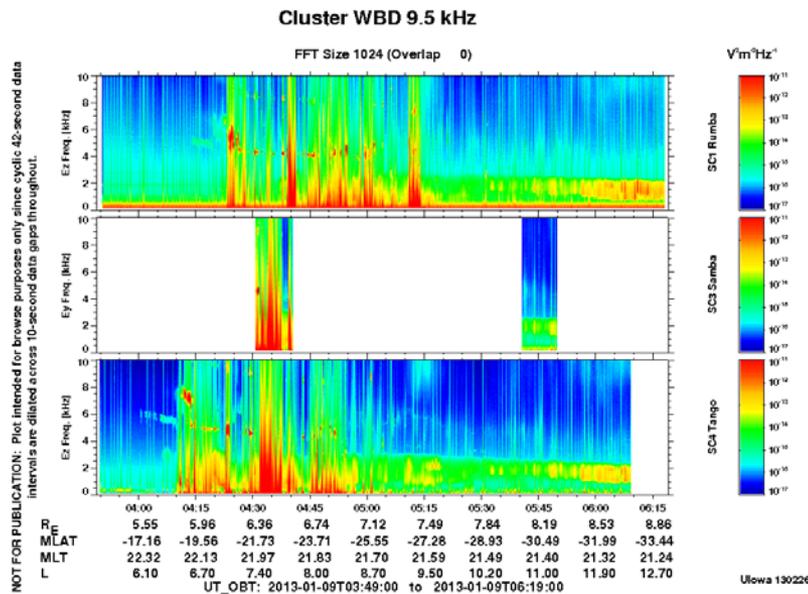
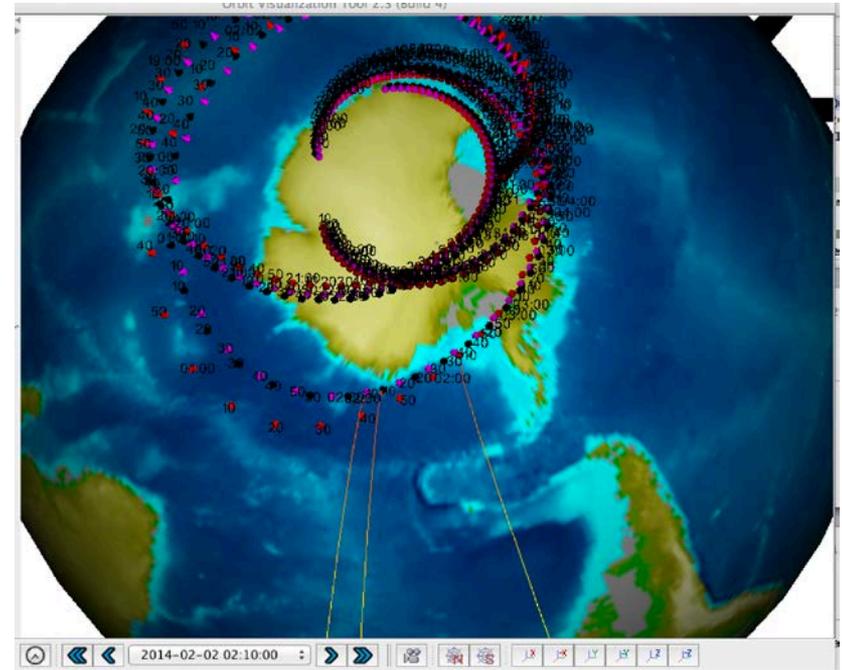
Triggered emissions observed on all four Cluster spacecraft separated by over 800 km near the plasmopause boundary.

WBD data will be scheduled for periods when Cluster is in near magnetic conjunction with the Van Allen probes to examine the fine structure of waves along a magnetic field line and to determine how these waves might interact with radiation belt electrons

COORDINATION WITH BARREL EXPERIMENT

WBD data (below) taken during a BARREL experiment from Halley Bay on Jan. 9, 2013. The Cluster spacecraft locations map to -67 to -70 deg. magnetic latitude.

Electrostatic solitary waves (electron holes), sometimes pulsing at low frequency) are observed as the spacecraft cross auroral field lines



In Feb. 2014 (see example from Feb. 2 above) the Cluster spacecraft will also cross auroral field lines which map to field lines to be probed by BARREL, providing an opportunity to plan joint BARREL observations in concert with the Van Allen Probes.

Cluster WBD Operations - 1

- Management:
 - Principal Investigator: Jolene Pickett, (pickett@uiowa.edu), University of Iowa; 610 Van Allen Hall (319-335-1897), manages the science aspects of WBD operations
 - Operations Manager: Ivar Christopher (ivar-christopher@uiowa.edu), University of Iowa; 651 Van Allen Hall (319-335-1953); manages the planning, scheduling and commanding of all WBD operations
- TDA 8 Mode Ground Station Tracks (~24 hours per week to DSN, ~20 hours per week to Panska Ves):
 - Planning begins 6 months before operations
 - Tracks finalized/negotiated 6-10 weeks before operations (only track deletions or reductions allowed after that)
- Burst Mode 2 Tracks (currently ~ 1-3 hours per week)
 - Planning begins 4 months before operations
 - Tracks finalized 6-8 weeks before operations

Cluster WBD Operations - 2

- Commanding
 - Cycle for a one week interval initiated 5 weeks prior to operations start
 - Finalized 4 weeks prior to operations start, so no changes allowed after that
- Processing of data from
 - Ground stations:
 - received within 3-6 hours after end of track
 - Processed to final state within 3-10 days
 - Validated and made available to the public within ~6 months; much earlier for special campaigns such as this
 - Burst Mode 2:
 - Received within 2-4 days after end of track
 - Processed to final state within 6 days after receipt
 - Validated and made available to the public within ~ 6 months; much earlier for special campaigns such as this

Facilitation of Joint Van Allen Probes/Cluster Operations and Research

- Need access to predictive orbit files at least 5-6 months ahead of real time in order to determine times of magnetic conjunctions
- Need Van Allen Probes/EMFISIS operations contact(s)
 - Provide Information on scheduled WBD tracks which are considered Van Allen Probes/Cluster campaign tracks (i.e., magnetic conjunction expected)
 - Coordinate commanding of the EMFISIS Waves instrument burst data with the Cluster WBD instrument for events selected by the EMFISIS Team
- Cluster WBD data (overview and 30 second high resolution spectrograms) made available on the WBD website:
<http://www-pw.physics.uiowa.edu/cluster/>
- Cluster quicklook data from all other instruments available at CSDS:
<http://sci.esa.int/cluster/52770-csds/>
- Cluster full resolution data from all spacecraft available at the Cluster Active Archive (<http://caa.estec.esa.int>) or Cluster Final Archive later this year approximately 6 months after event data obtained, or contact PI of each instrument to request possible earlier delivery of data