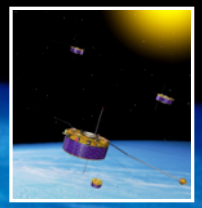
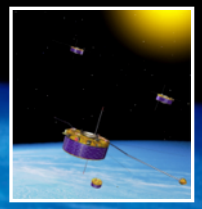
CLUSTER



Highlights from Cluster
First 3D mission

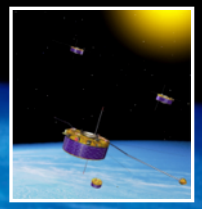
C. P. Escoubet, A. Masson, H. Laakso, M. G. G. T. Taylor, ESA/ESTEC
J. Volpp, D. Sieg, ESA/ESOC
M. Hapgood, RAL, UK,
M. Goldstein, NASA/GSFC



Outline

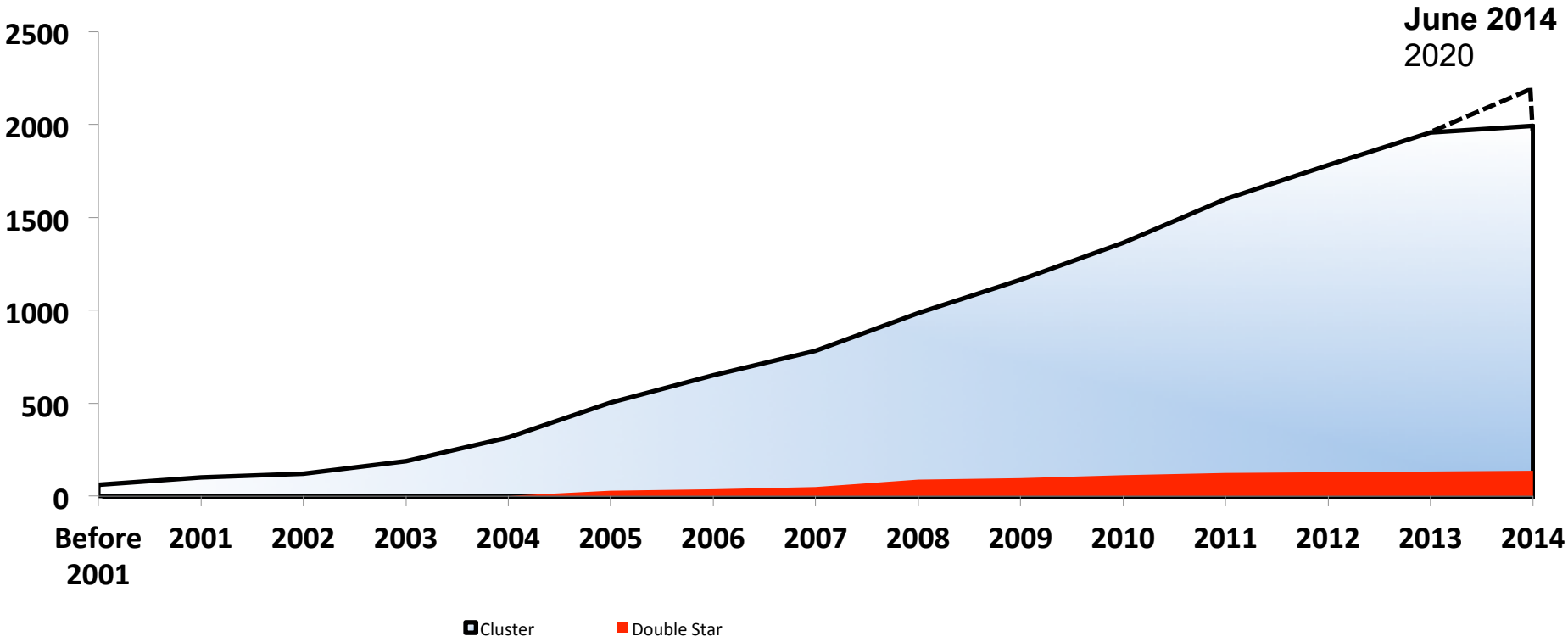
- Highlights (inner magnetosphere):
  - Chorus: source motion and size
  - First direct measurements of the ring current
  - Interplanetary shock and ULF waves
  - Plasmasphere continuous leak
  - Non-thermal continuum radiation with spacecraft tilt
  - Plasmasphere versus electron radiation belt position
- Cluster-THEMIS-Van Allen Probes future opportunities
- Cluster Science Archive
- Summary and conclusions

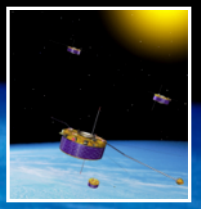
CLUSTER



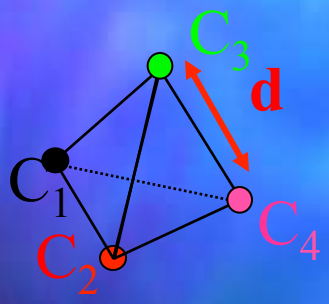
Cluster publications June 2014
2020 refereed papers

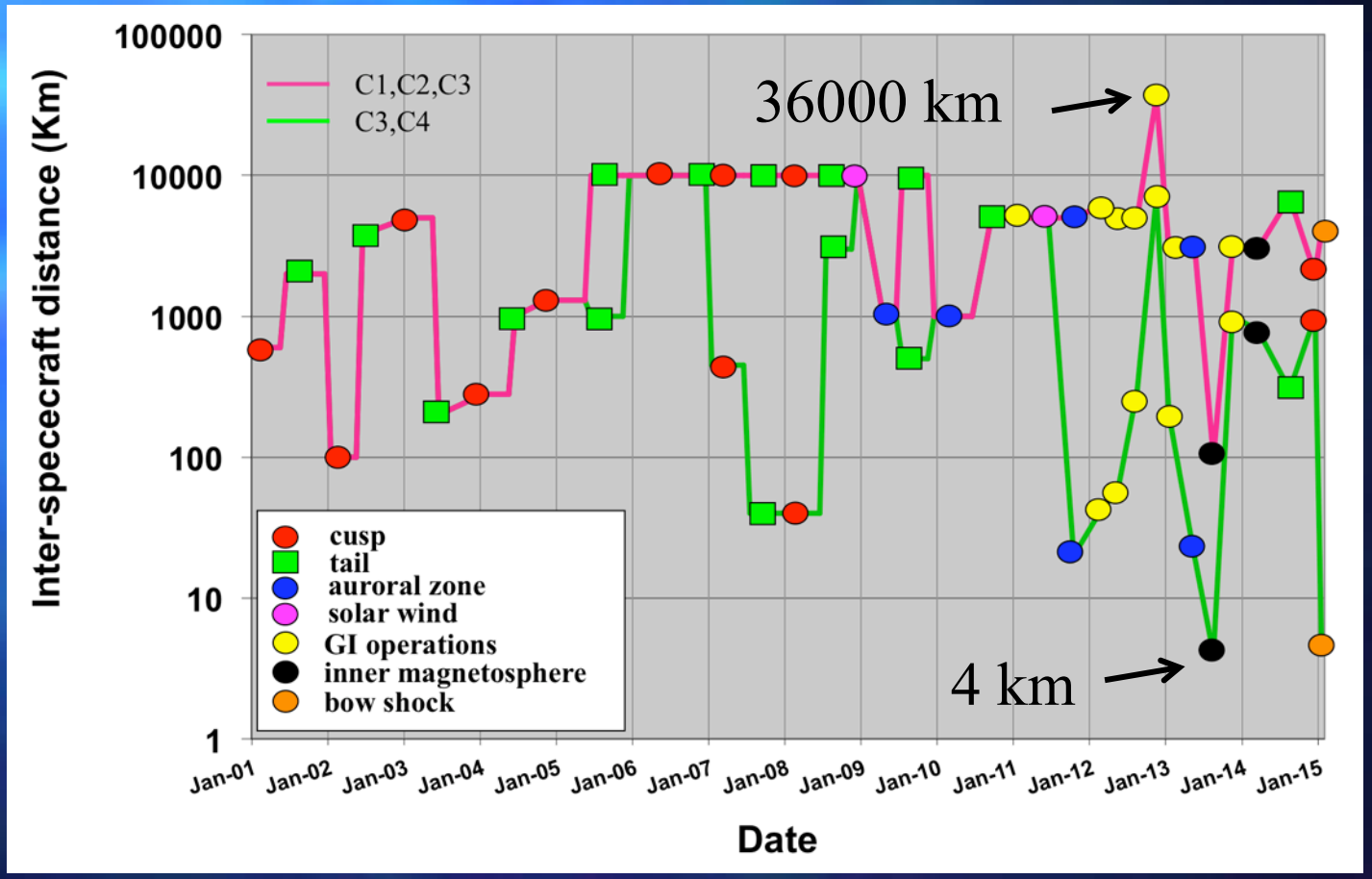
Cluster and Double Star refereed publications

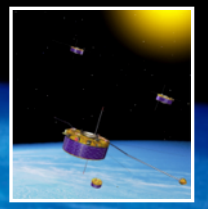




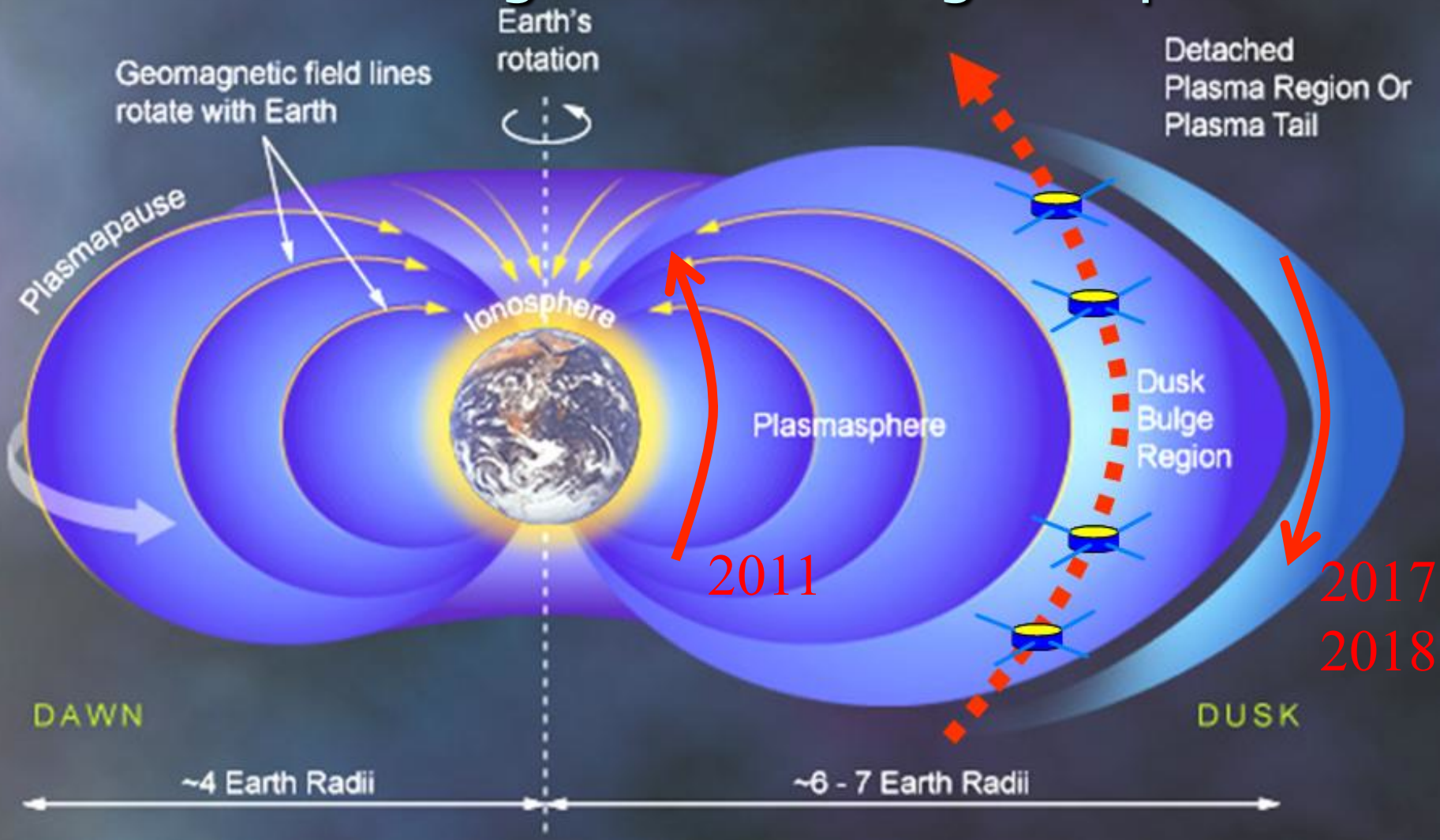
Cluster constellation evolution



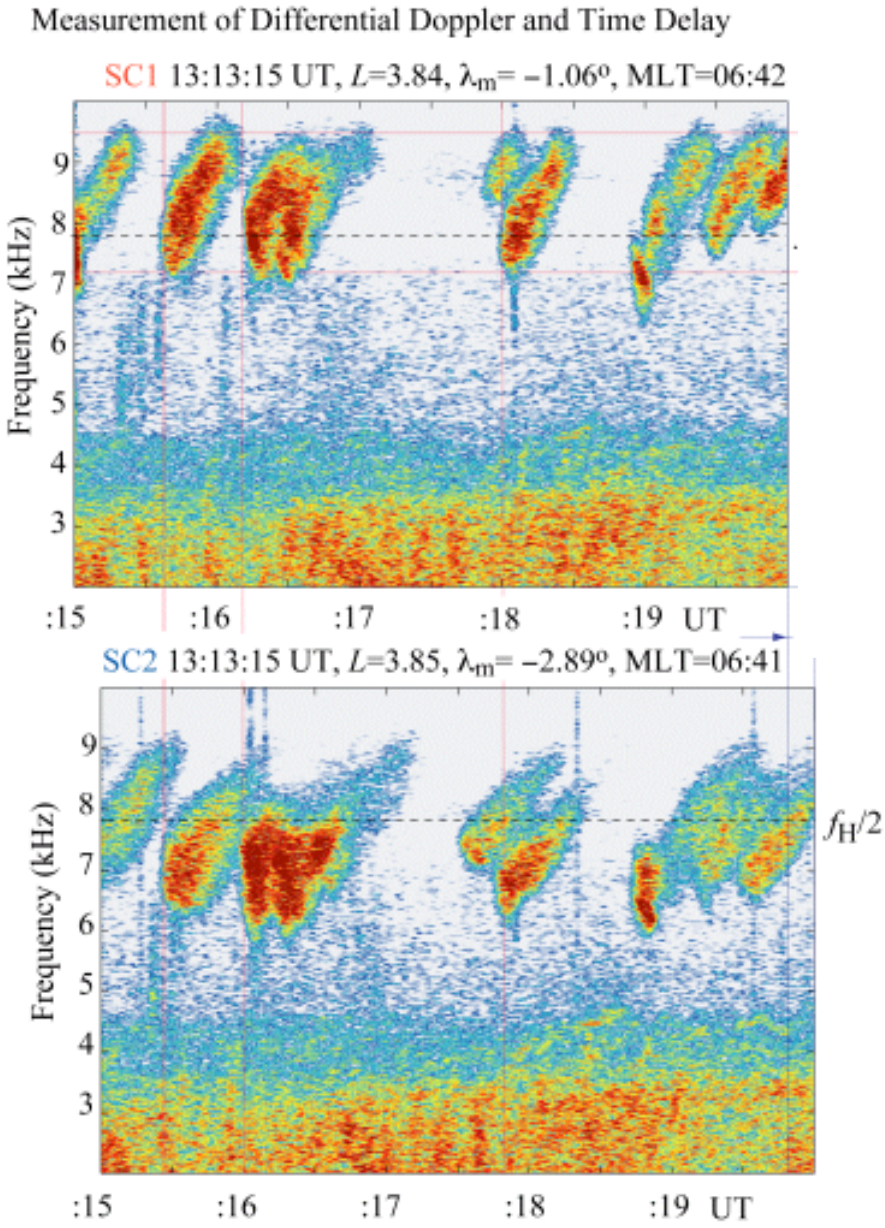


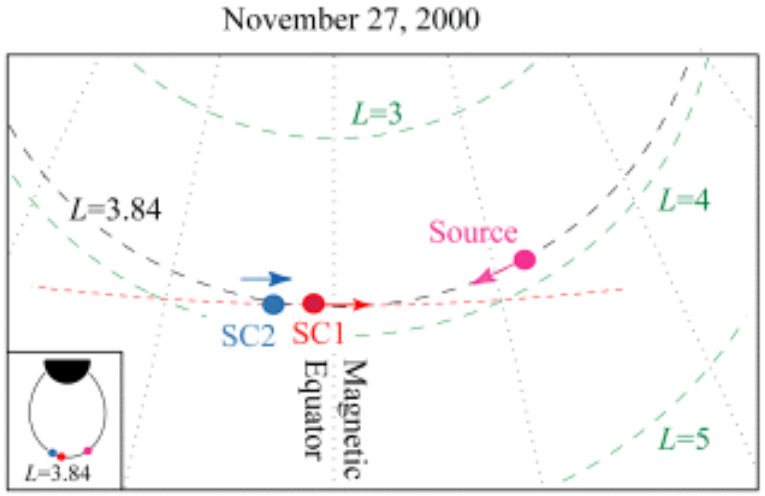


Cluster crossing the inner magnetosphere



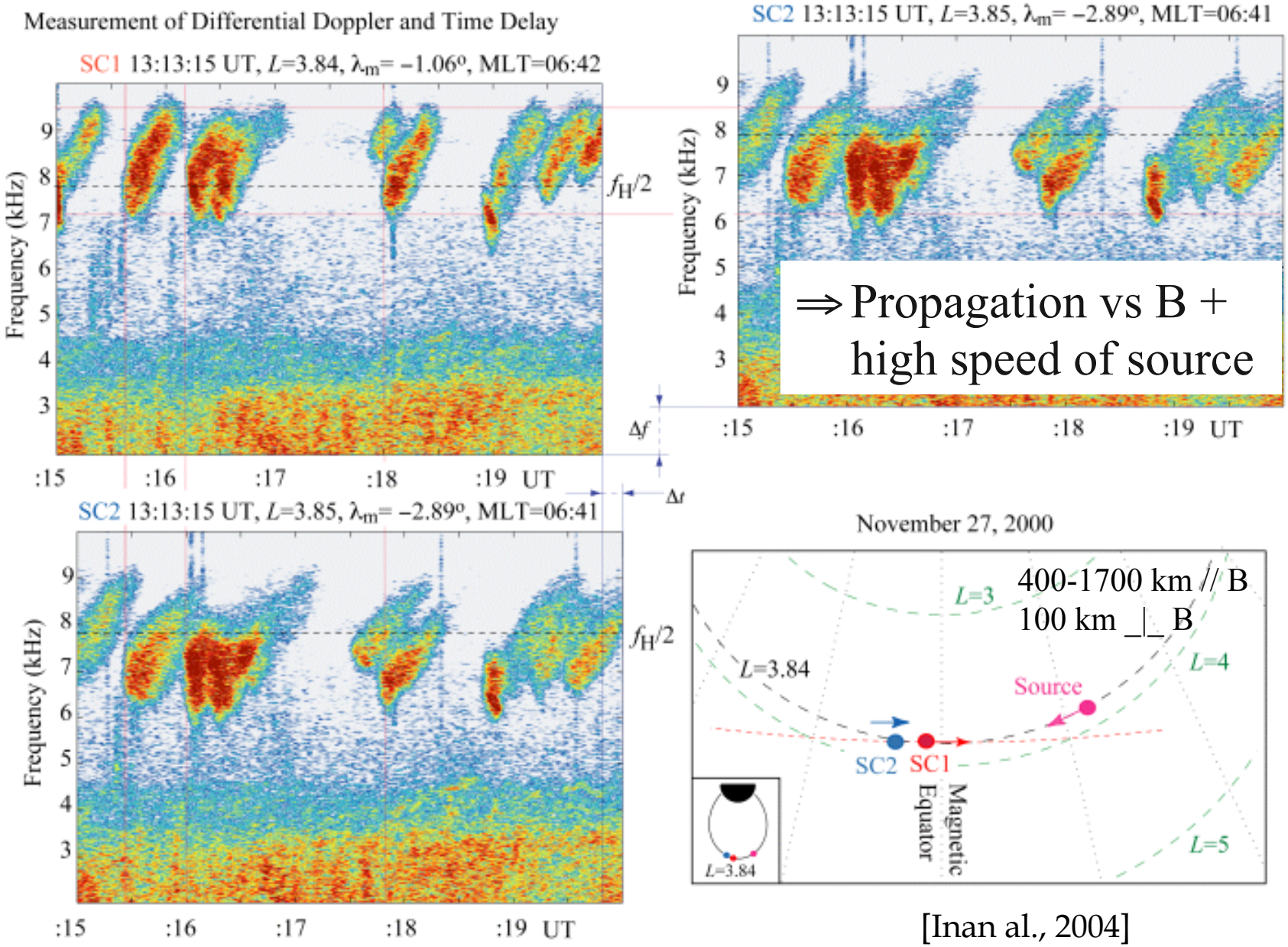
Chorus observations Doppler shifted





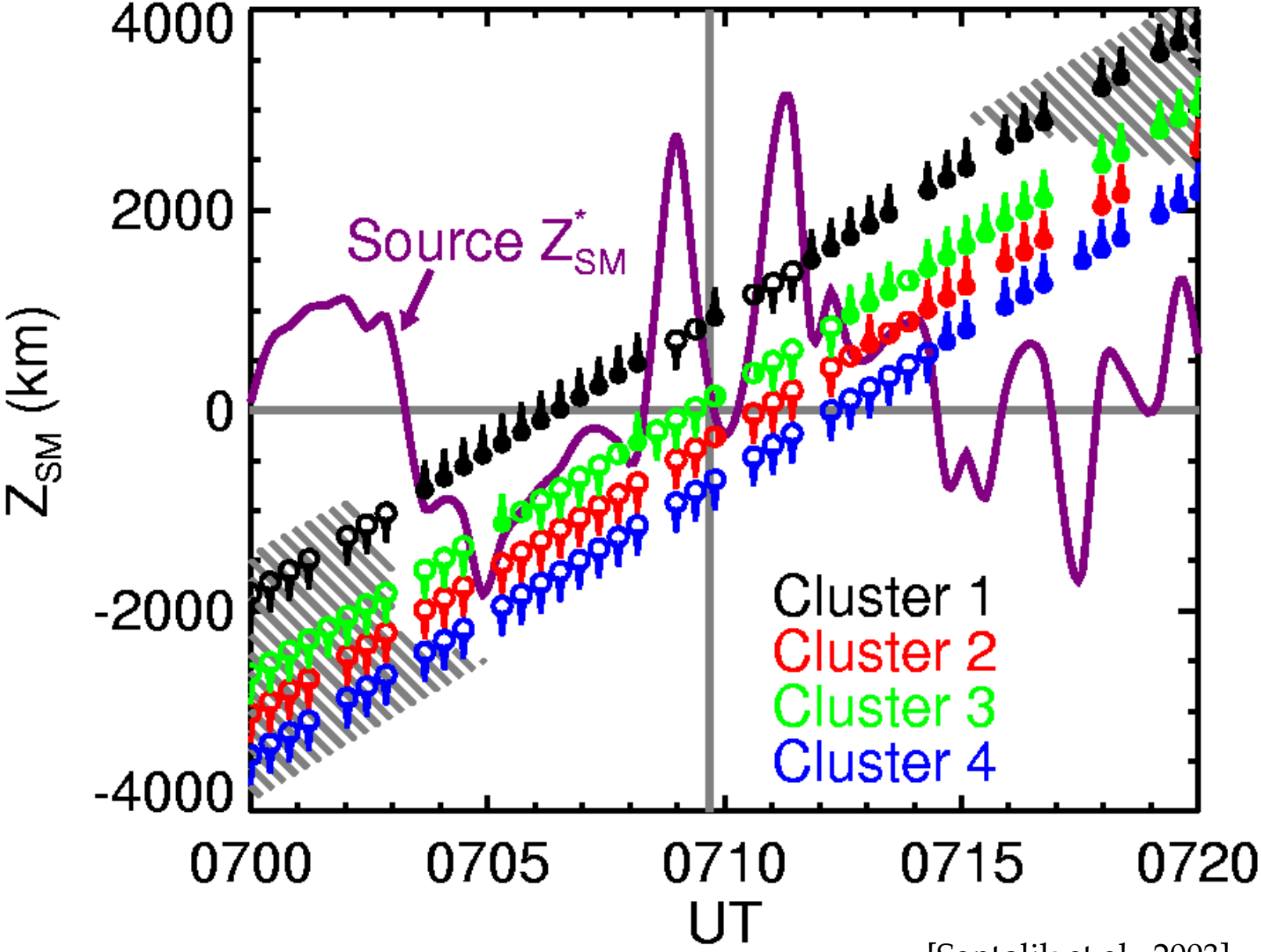
[Inan al., 2004]

Chorus observations Doppler shifted



[Inan al., 2004]

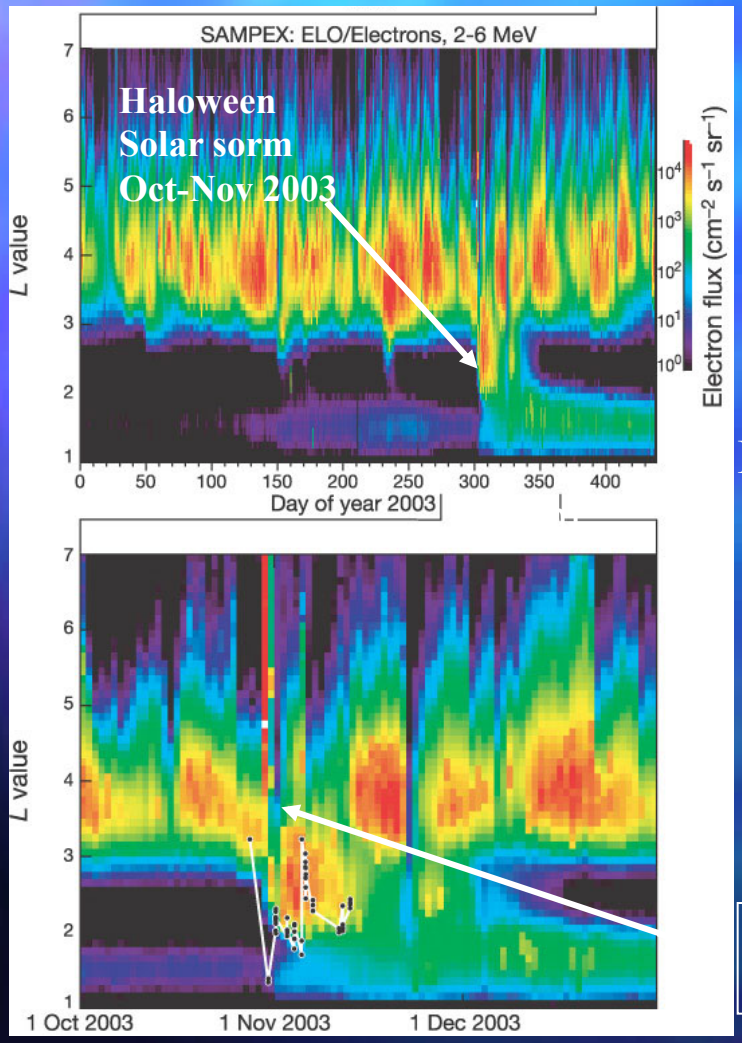
Motion of chorus source: 31 March 2001



[Santolik et al., 2003]

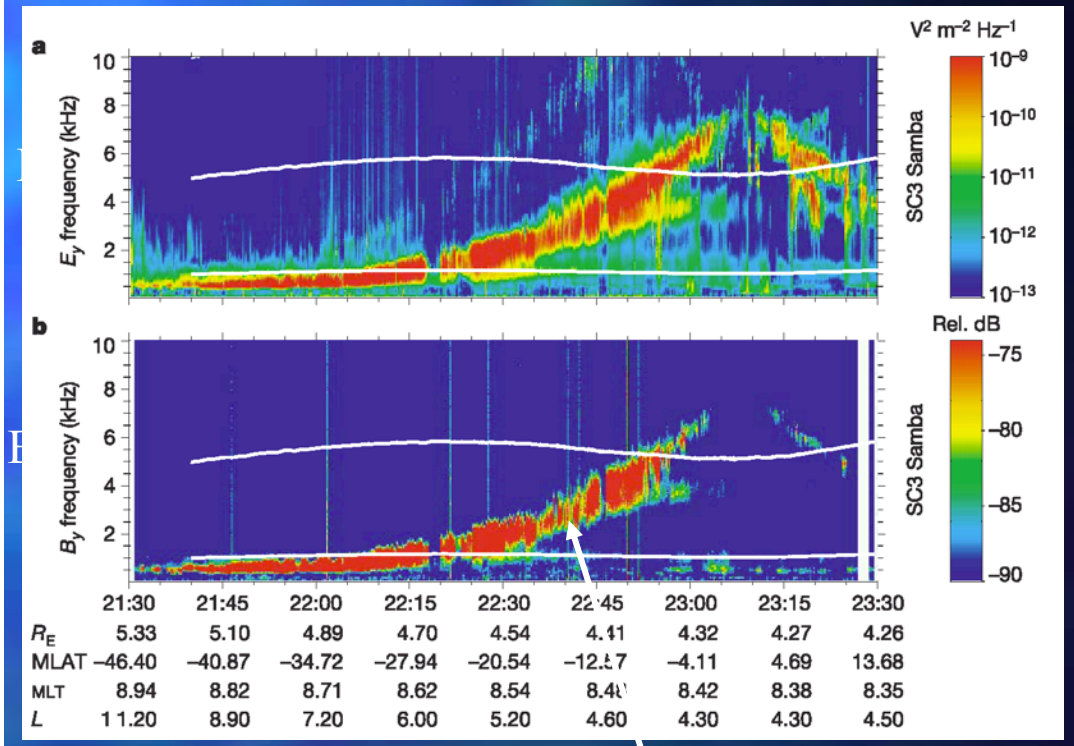
Radiation belts electrons produced by Chorus emissions

SAMPEX 2-6 Mev e⁻



[Baker et al., Nature, 2004]

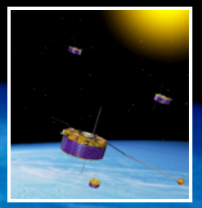
Cluster wave data



Chorus emissions accelerate electrons to MeV energies

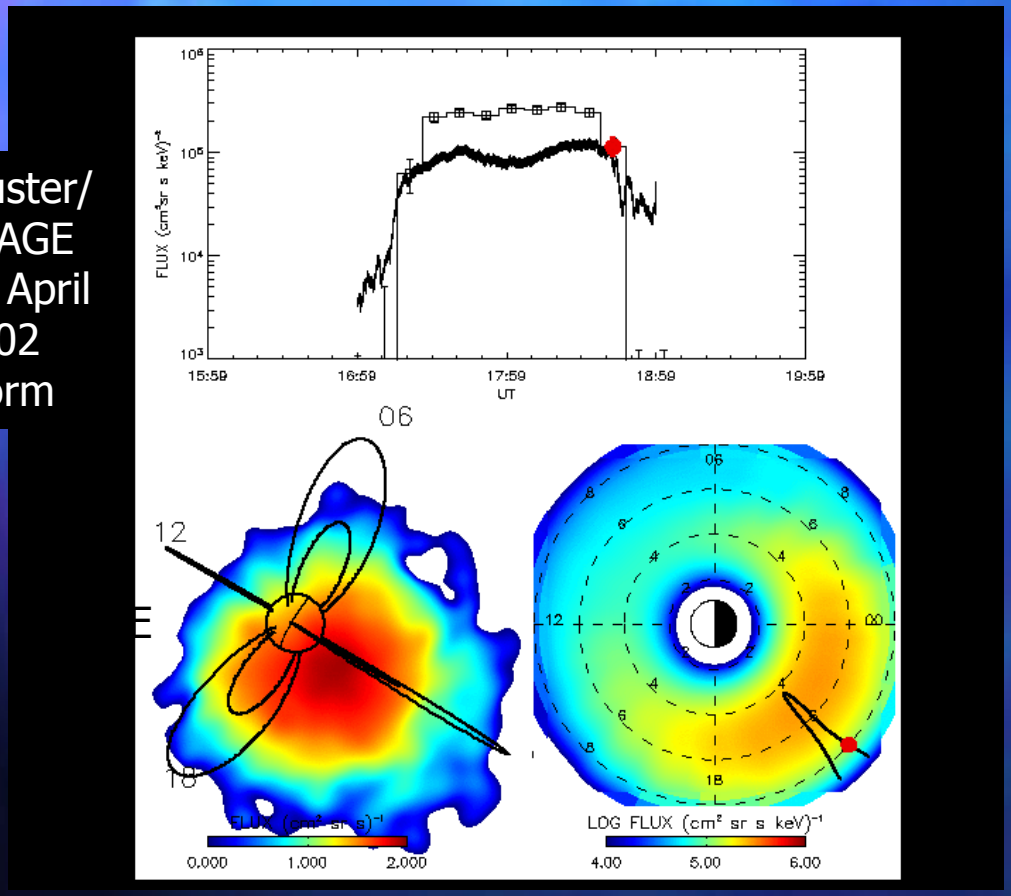
Rad belts disappear and reform closer to Earth

[Horne et al., Nature, 2005]

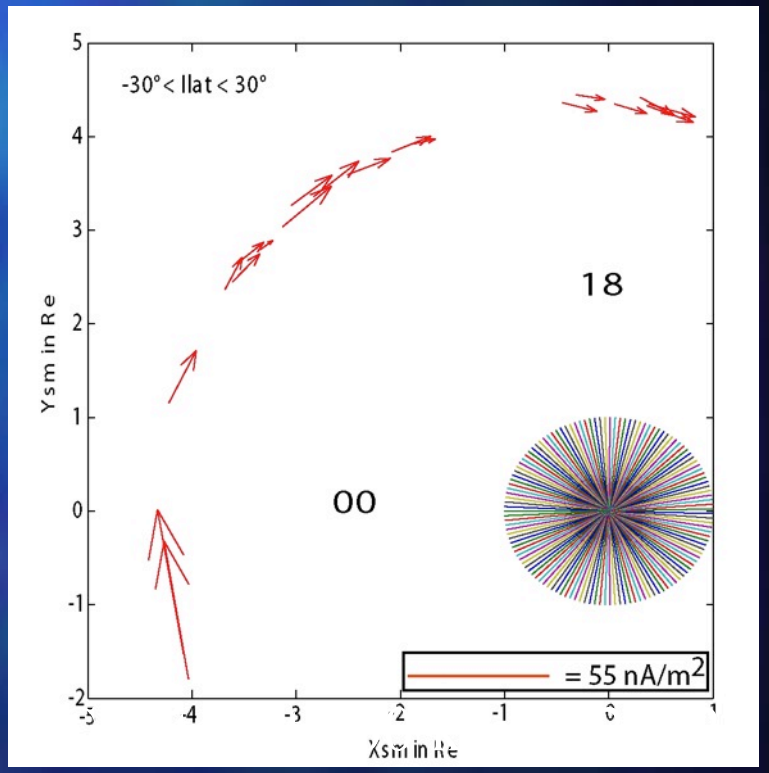


First direct measurement of ring current

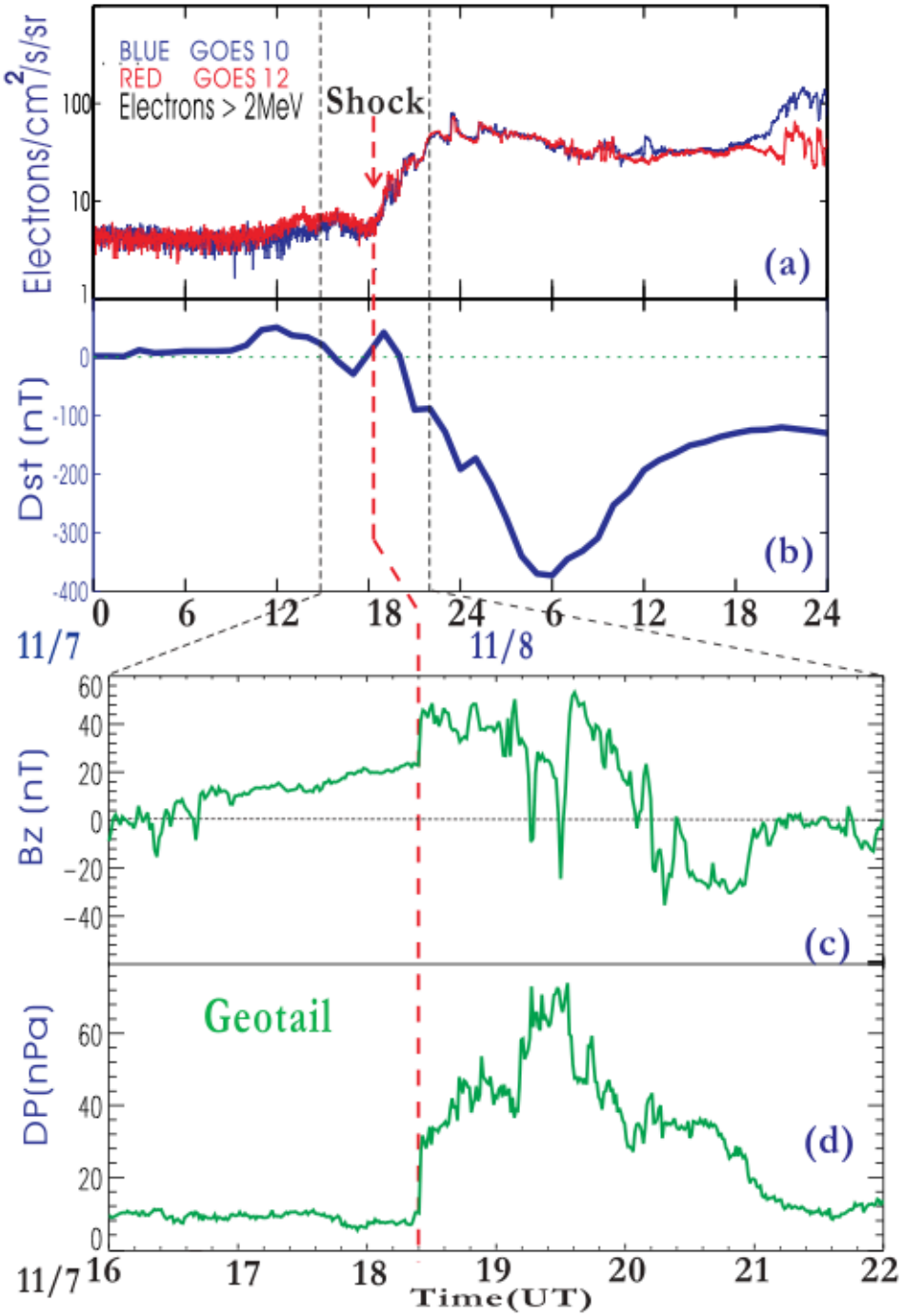
Cluster/ IMAGE 18 April 2002 storm

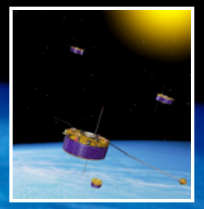


[Brandt, 2005]



[Vallat et al. 2005]
[Grimald et al., 2012]
[Shen et al., 2014]

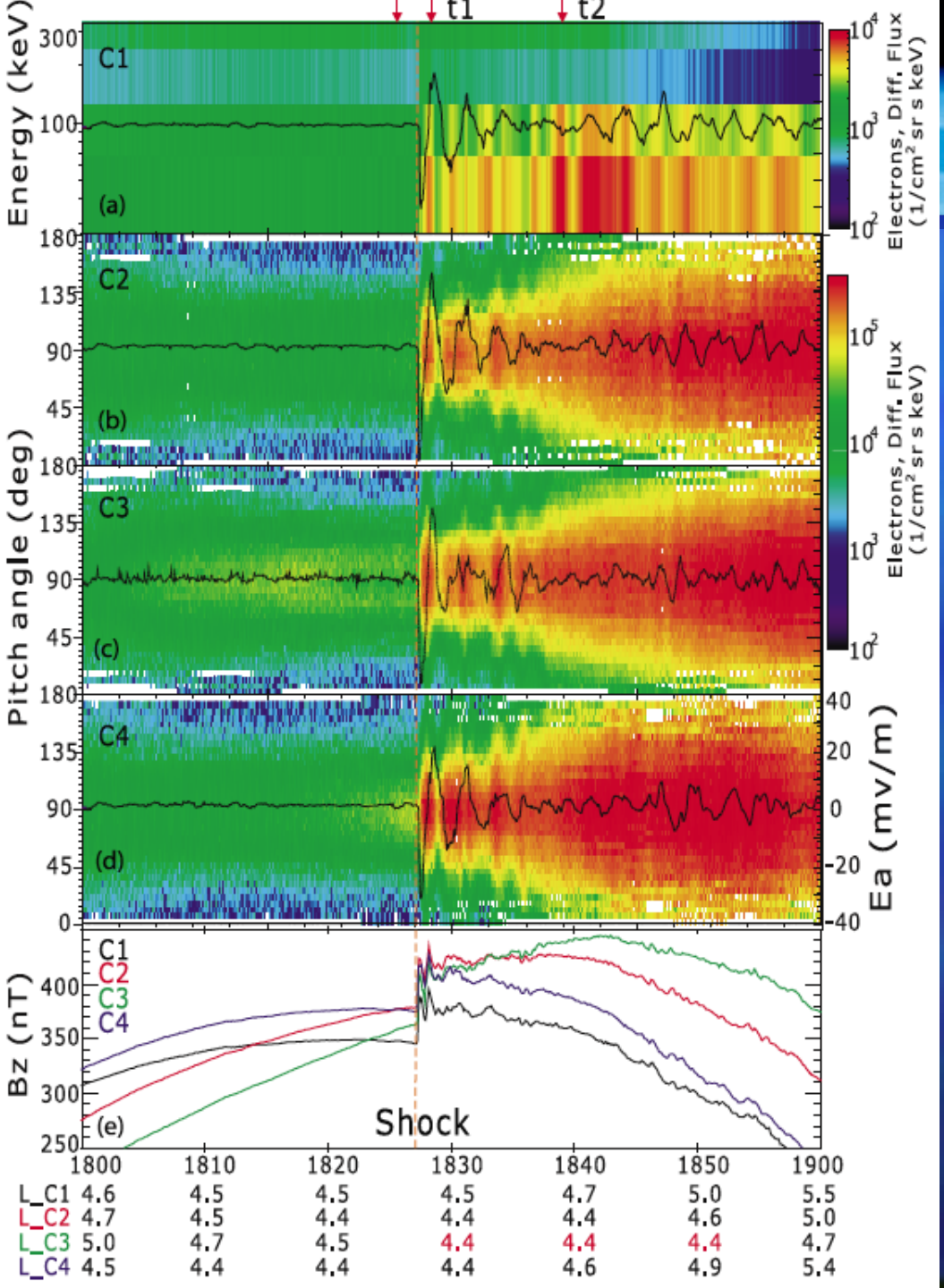




Interplanetary shock: effect on Magnetosphere

- 7 Nov 2004
- Solar wind pressure: 10 nPa -> 70 nPa
- Density: 20 cm-3 -> 40 cm-3
- Velocity: 400 km/s -> 700 km/s

[Zong et al., JGR, 2009]



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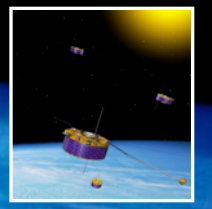
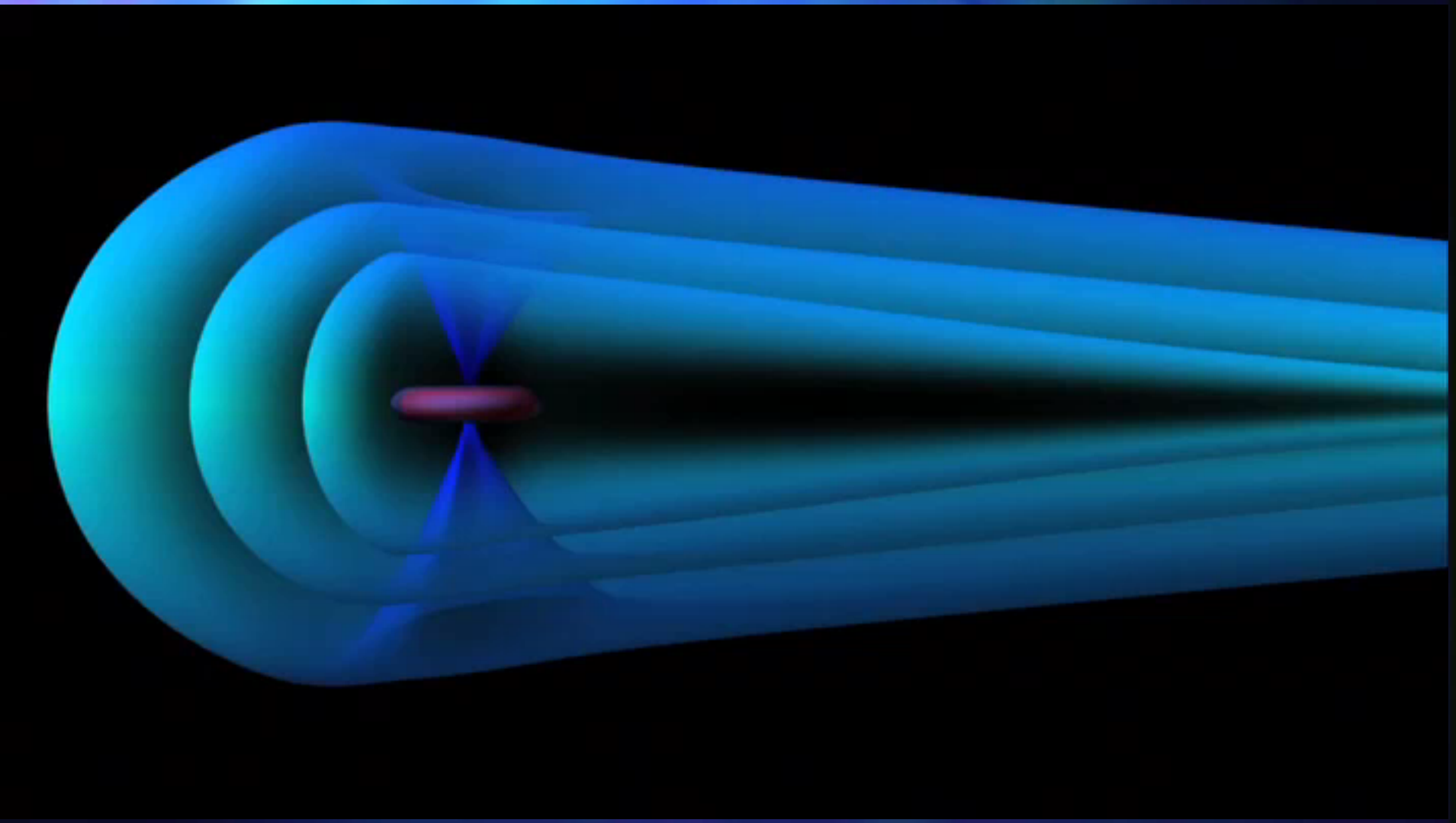


- Acceleration of electrons when shock arrives
- ULF waves accelerate electrons: E field (black line) correlates with electron flux

[Zong et al., JGR, 2009]

Plasmasphere vs Radiation belts

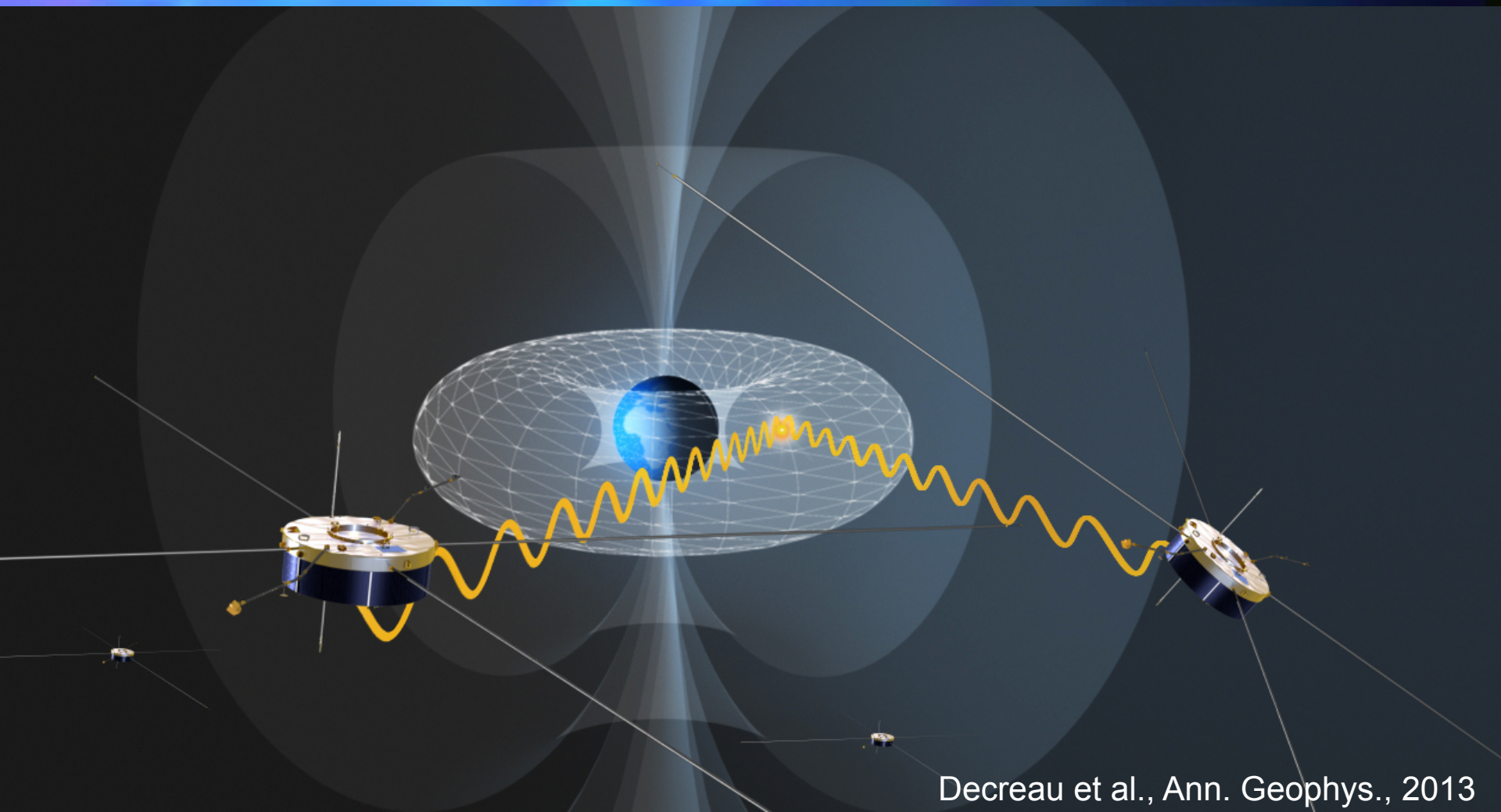
CLUSTER



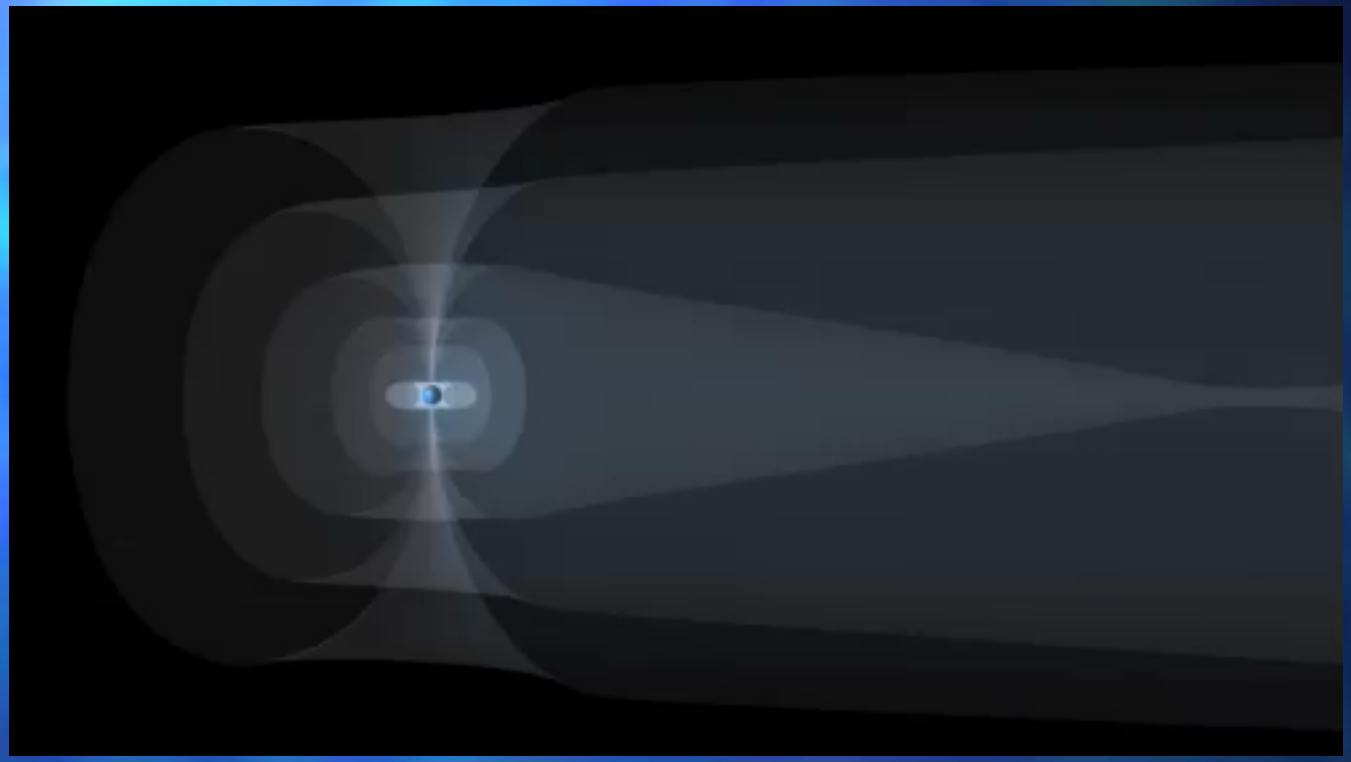
[Darrouzet al., 2013]

CLUSTER

One Cluster at 45° to locate NTC source

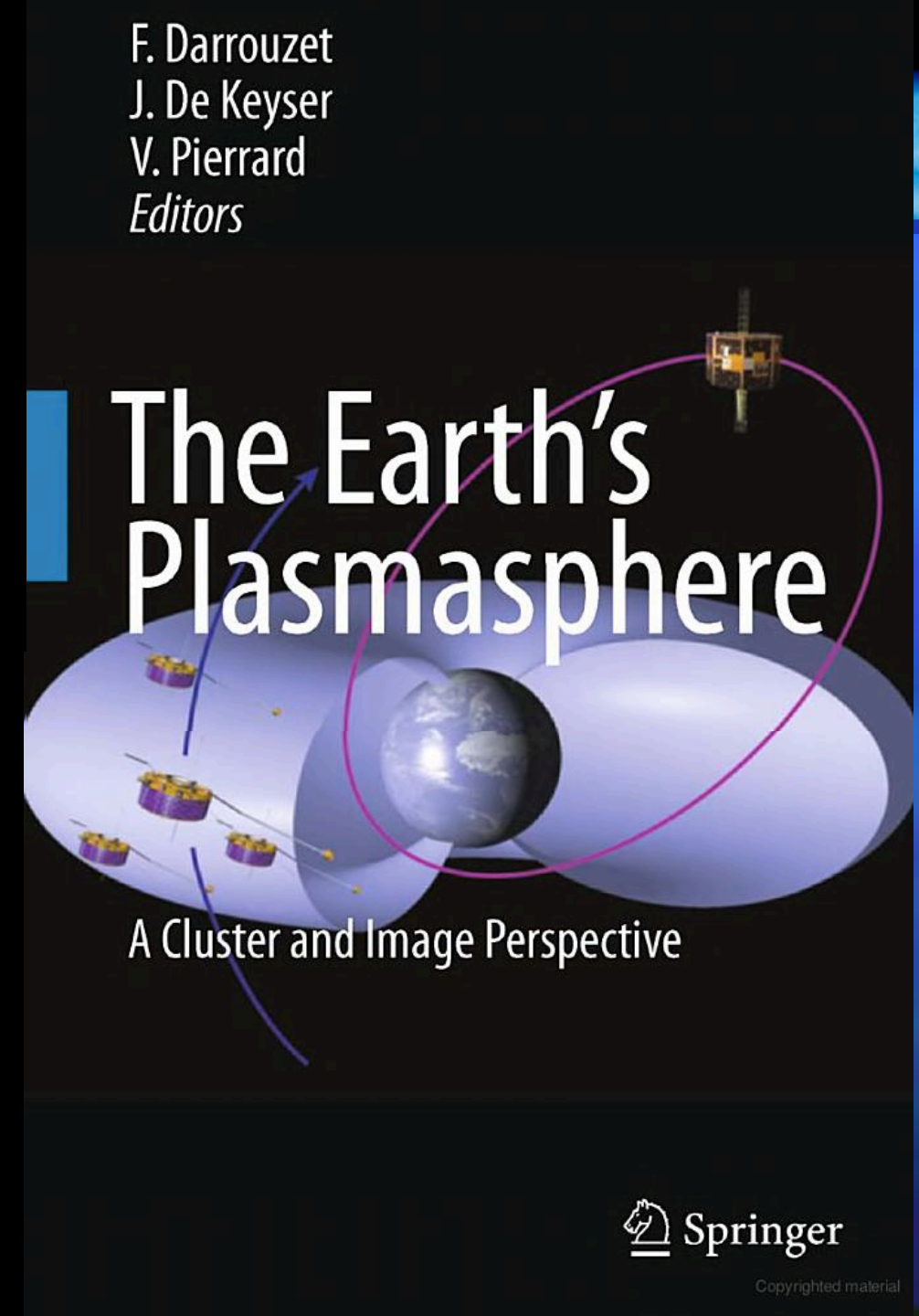


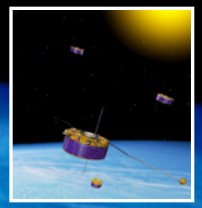
Decreau et al., Ann. Geophys., 2013



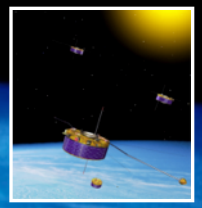
- The plasmasphere, innermost part of magnetosphere, constantly leaks out cold plasma (5×10^{26} ions s-1, 90 tons/day)
- Plasma interchange motion (Andre and Lemaire, 2006, Pierrard et al., 2009)

[Dandouras et al., 2013]





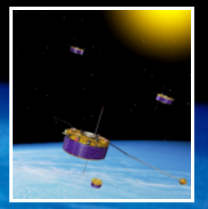
- Space Science Review, Vol 145, No 1-2,3-5, 2009
- Latest review on Cluster-IMAGE results and modeling



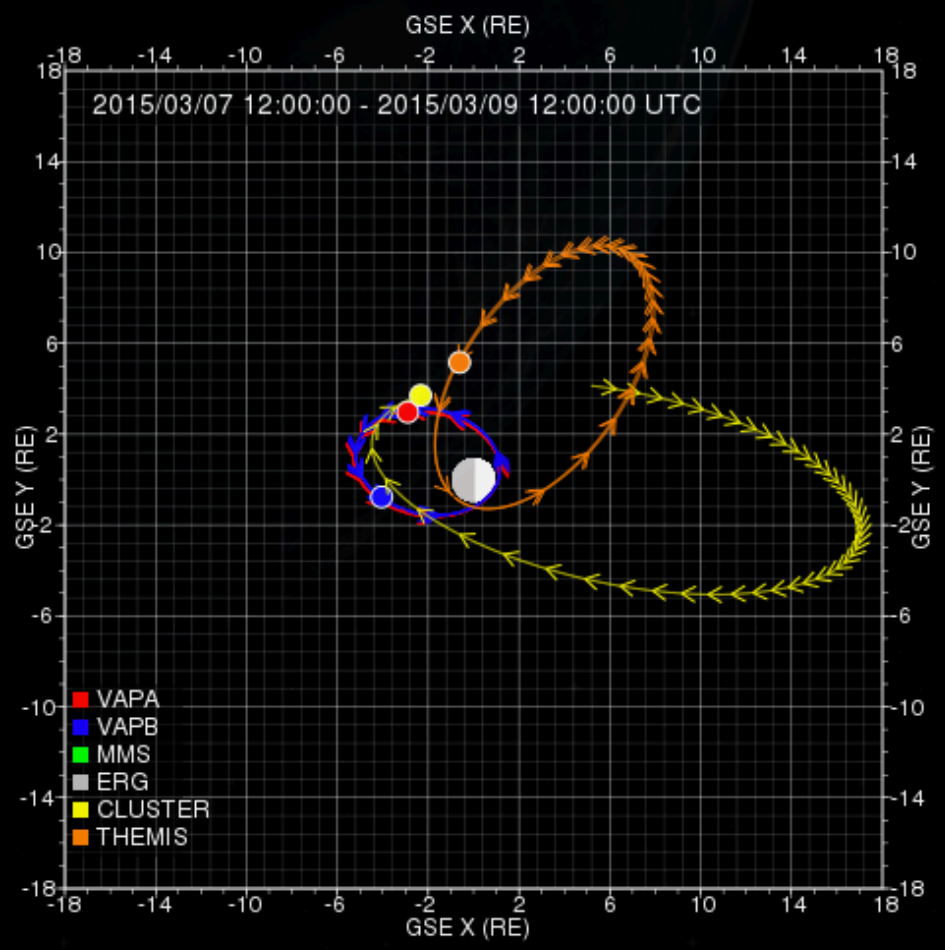
Future

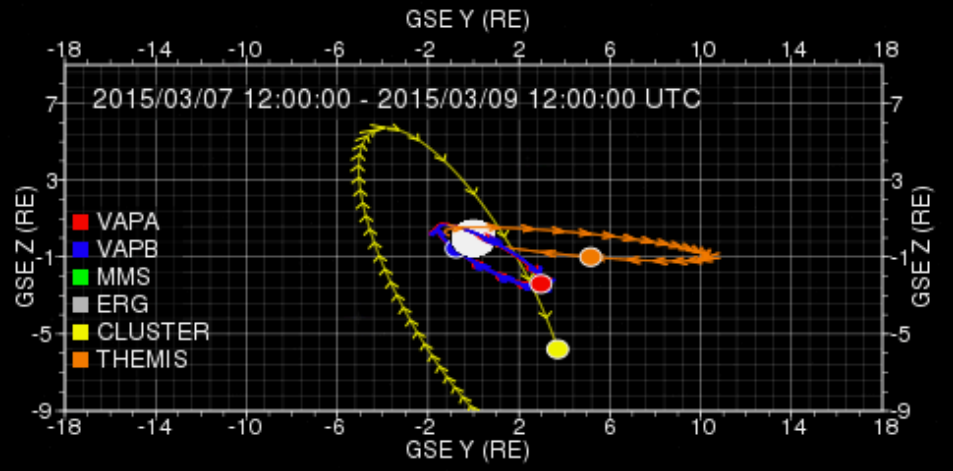
- Make new GI observations 2015-2016 (selection end 2014)
- Field aligned currents investigation with ESA SWARM (3 ionospheric spacecraft)
- Sample Earth's bow shock with two spacecraft at 5 km (10 times smaller than before) in January 2015
- Inner magnetosphere particle acceleration with THEMIS, Van Allen Probes and ERG (perigee 6-7 Re in 2017)
- Reconnection investigation with MMS: two tetrahedra at the magnetopause and in the tail at different latitude and MLT

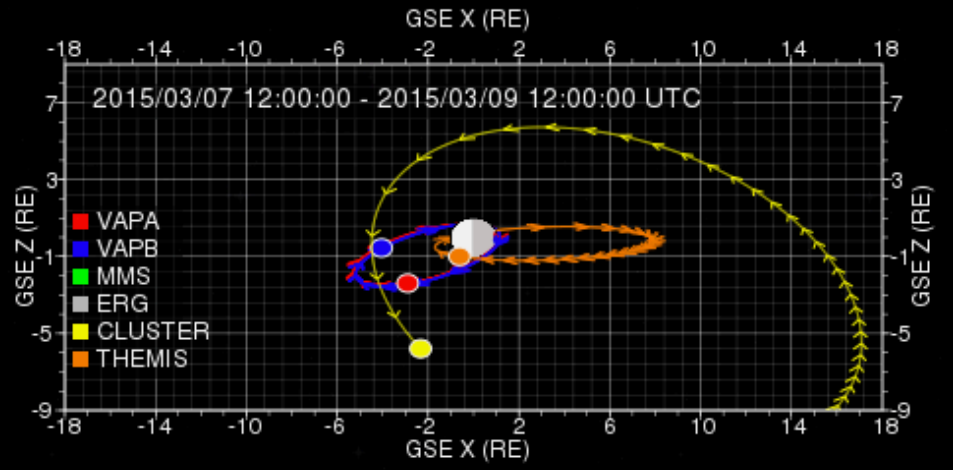
CLUSTER



2015 Mar: Multi spacecraft inner magnetosphere

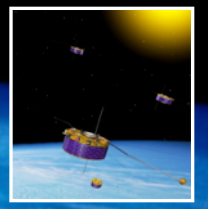




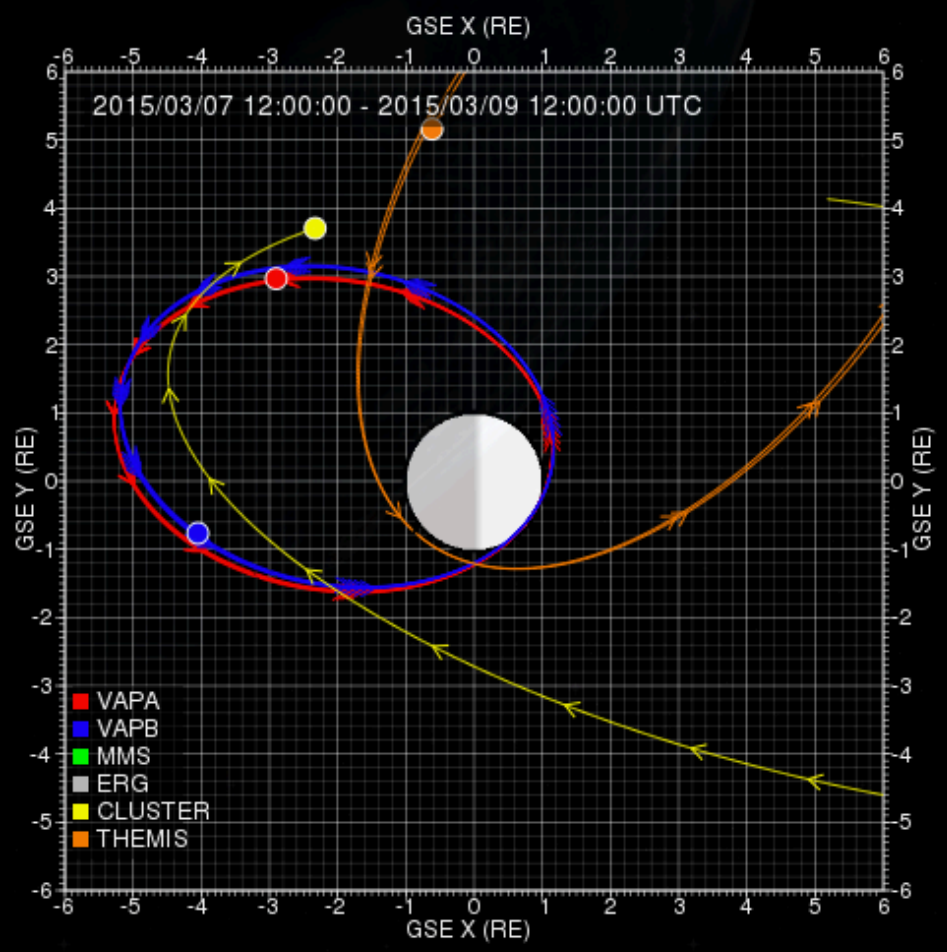


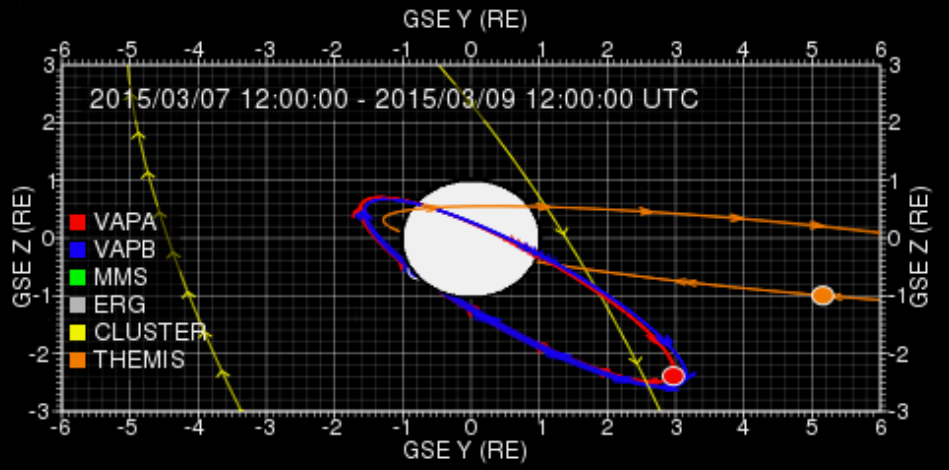
Van Allen Probe, JHU/APL

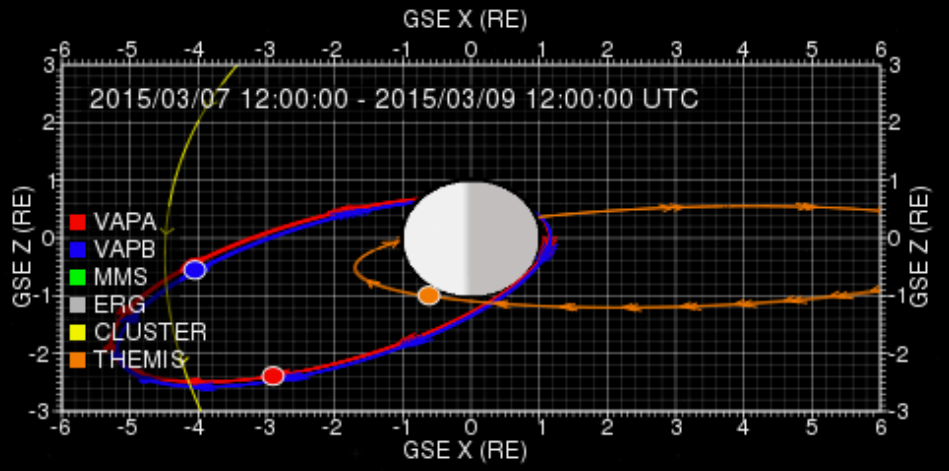
CLUSTER



2015 Mar: Multi spacecraft inner magnetosphere







Van Allen Probe, JHU/APL

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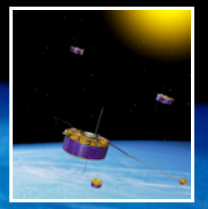
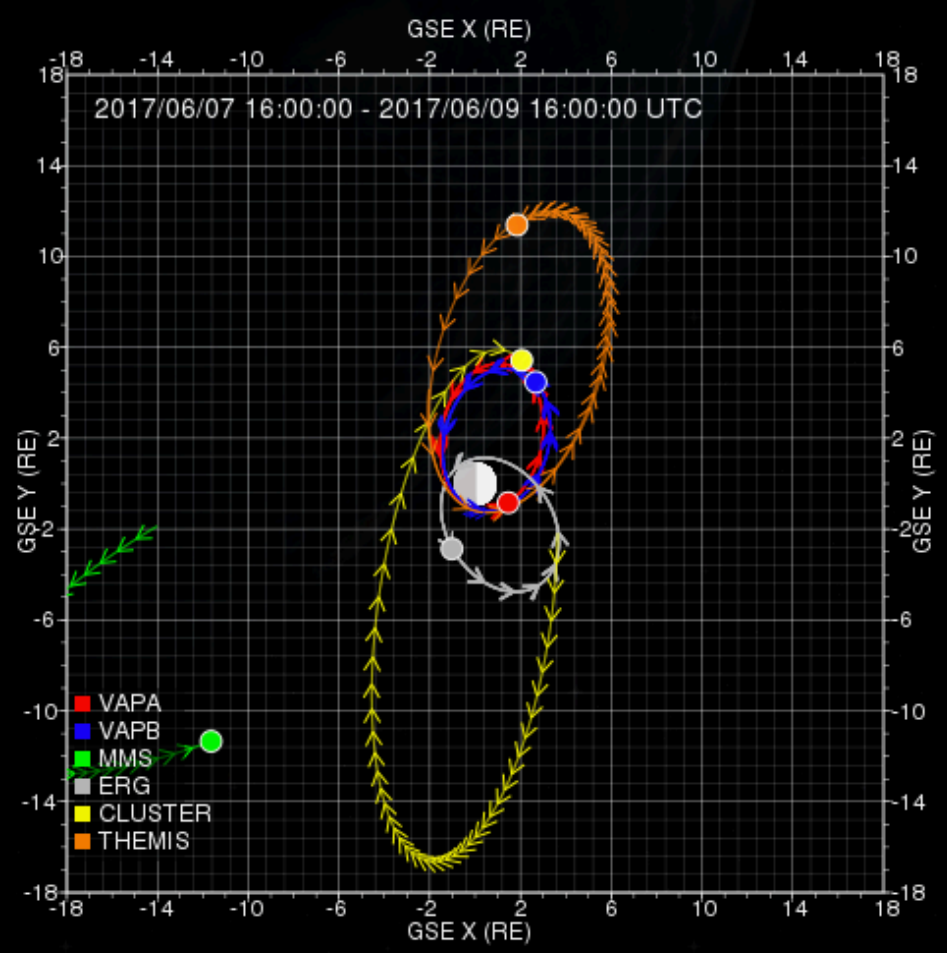
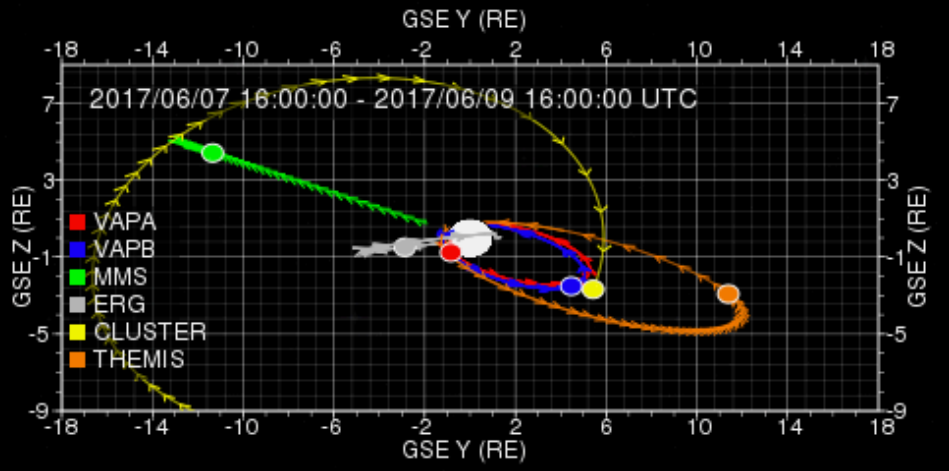
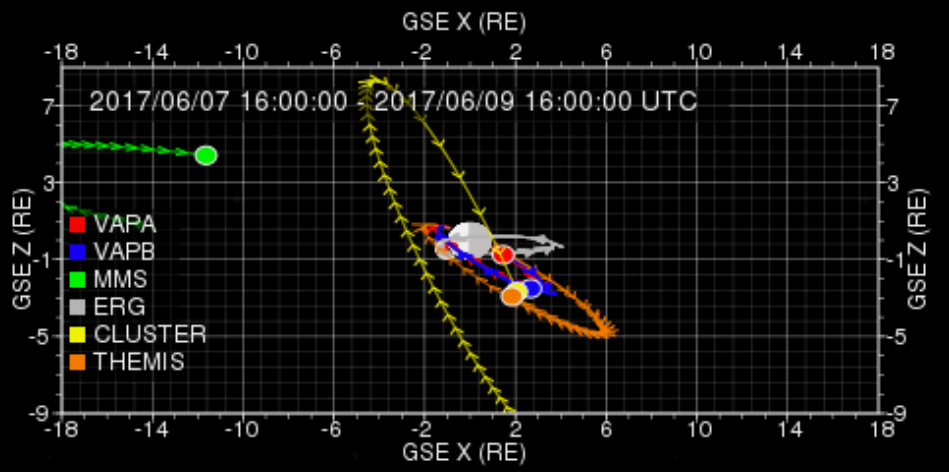


2017 June: Multi spacecraft inner magnetosphere

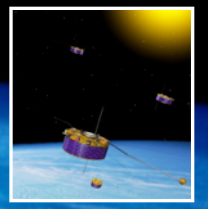




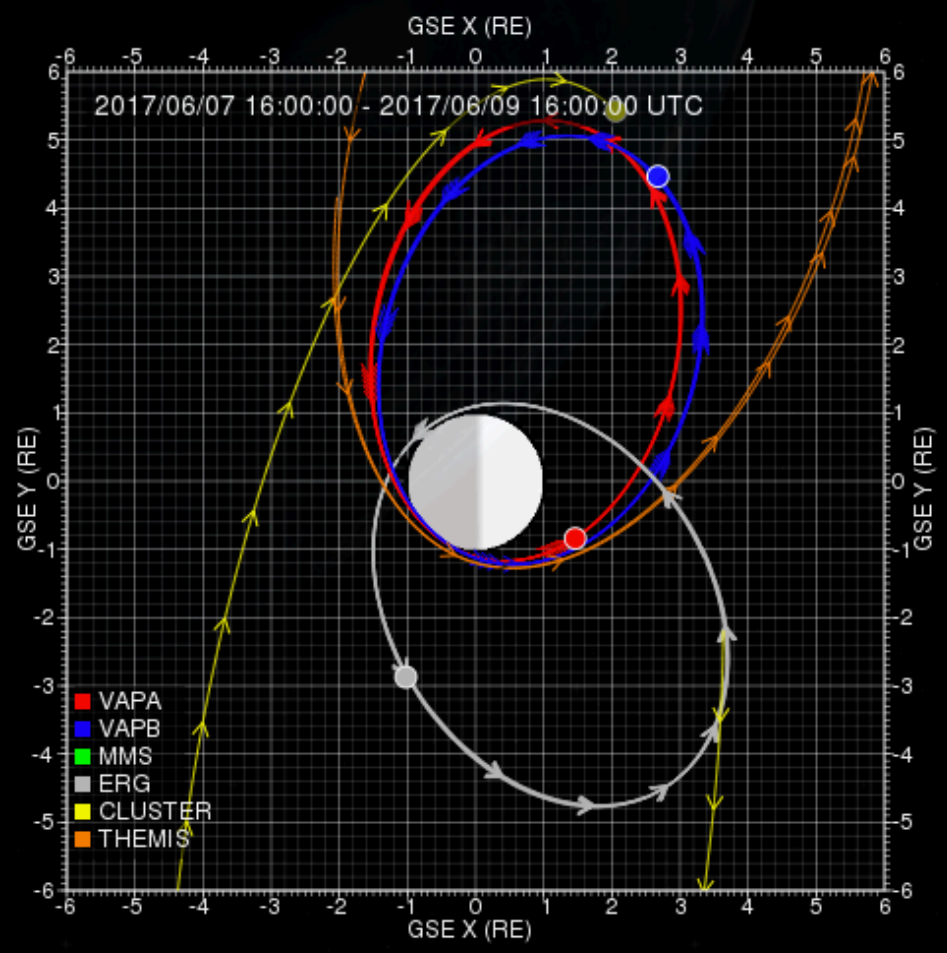


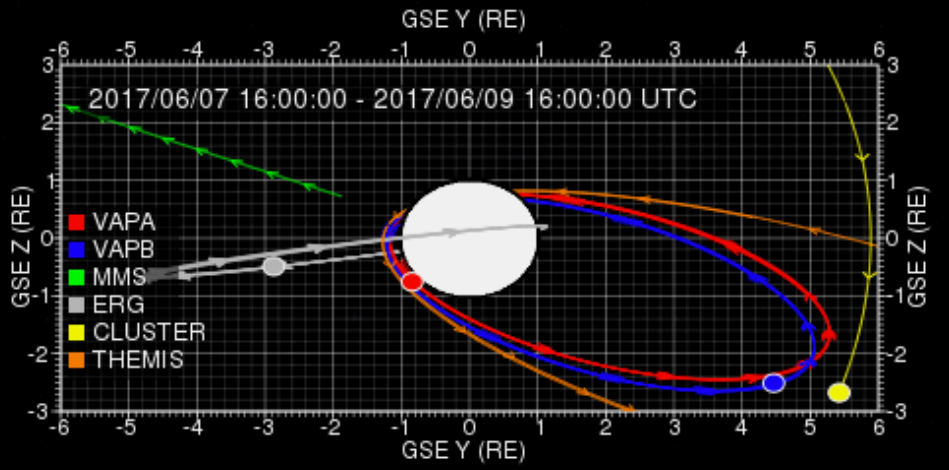
Van Allen Probe, JHU/APL

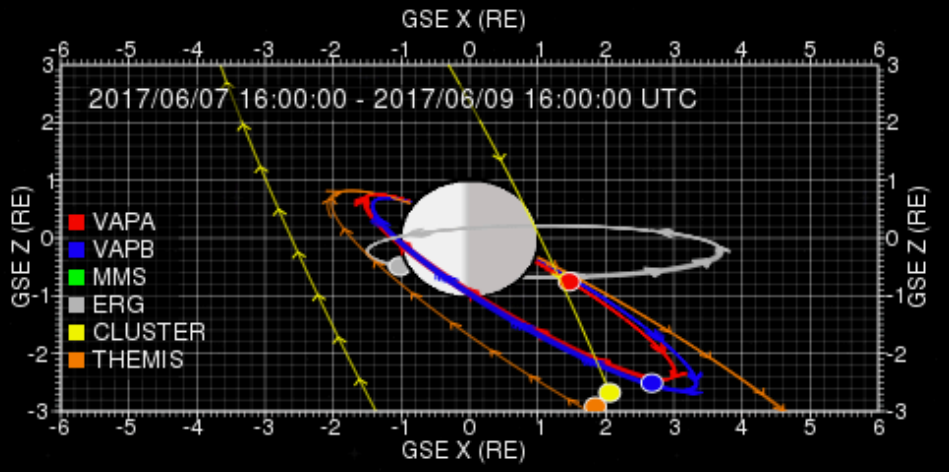
CLUSTER



2017 June: Multi spacecraft inner magnetosphere

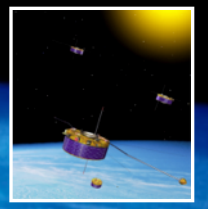




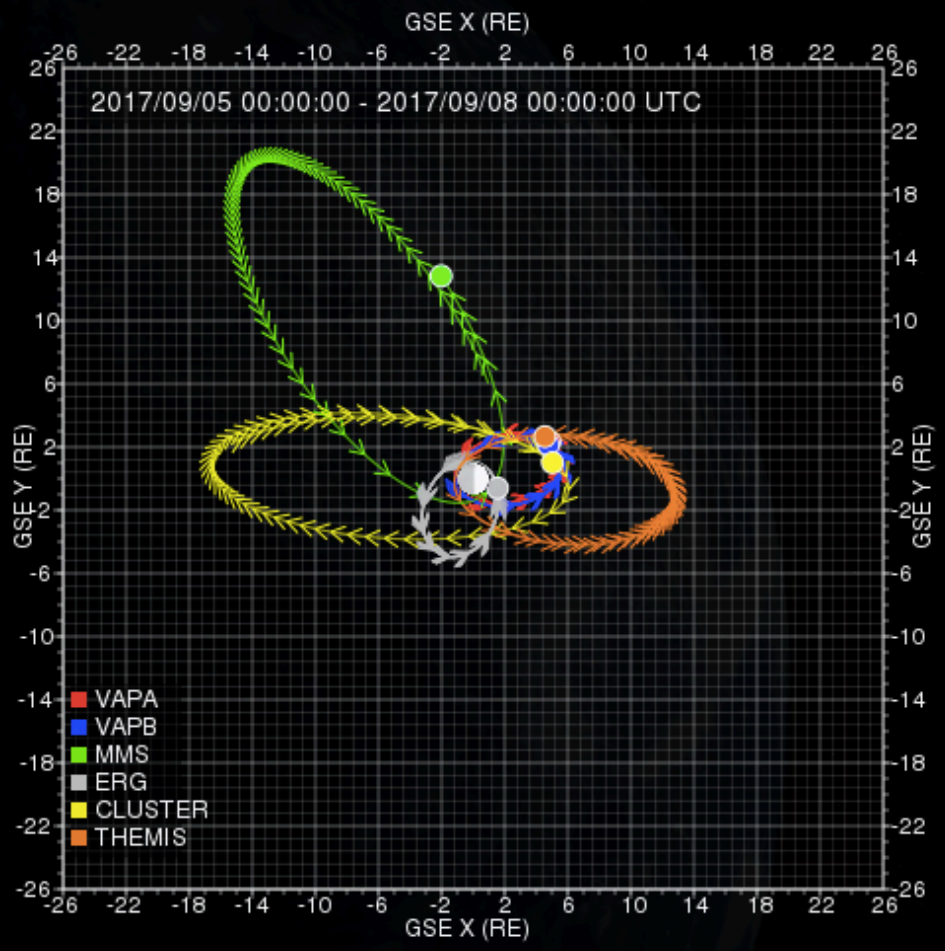


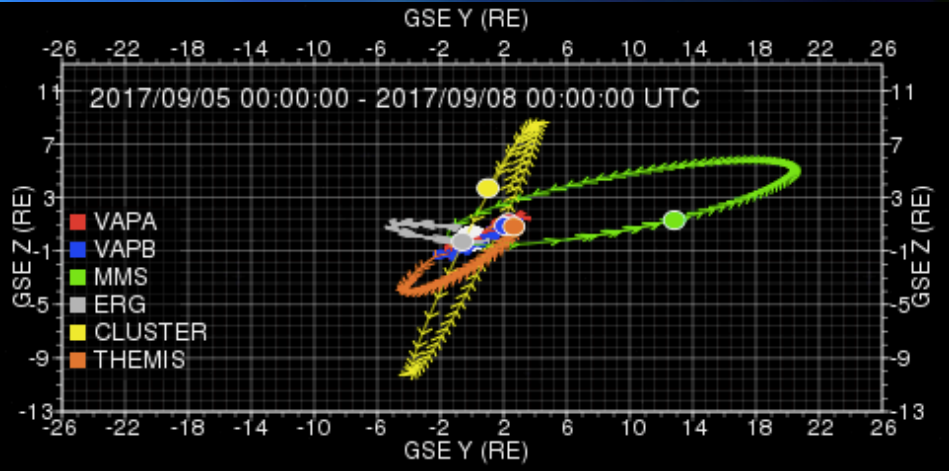
Van Allen Probe, JHU/APL

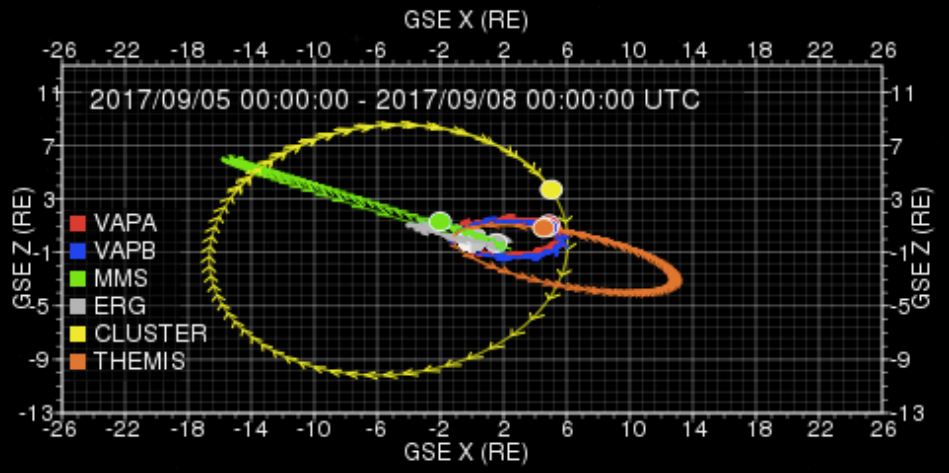
CLUSTER



2017 Sept: Multi spacecraft global magnetosphere







Van Allen Probe, JHU/APL

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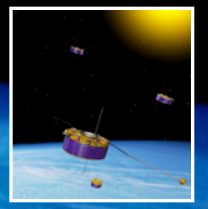
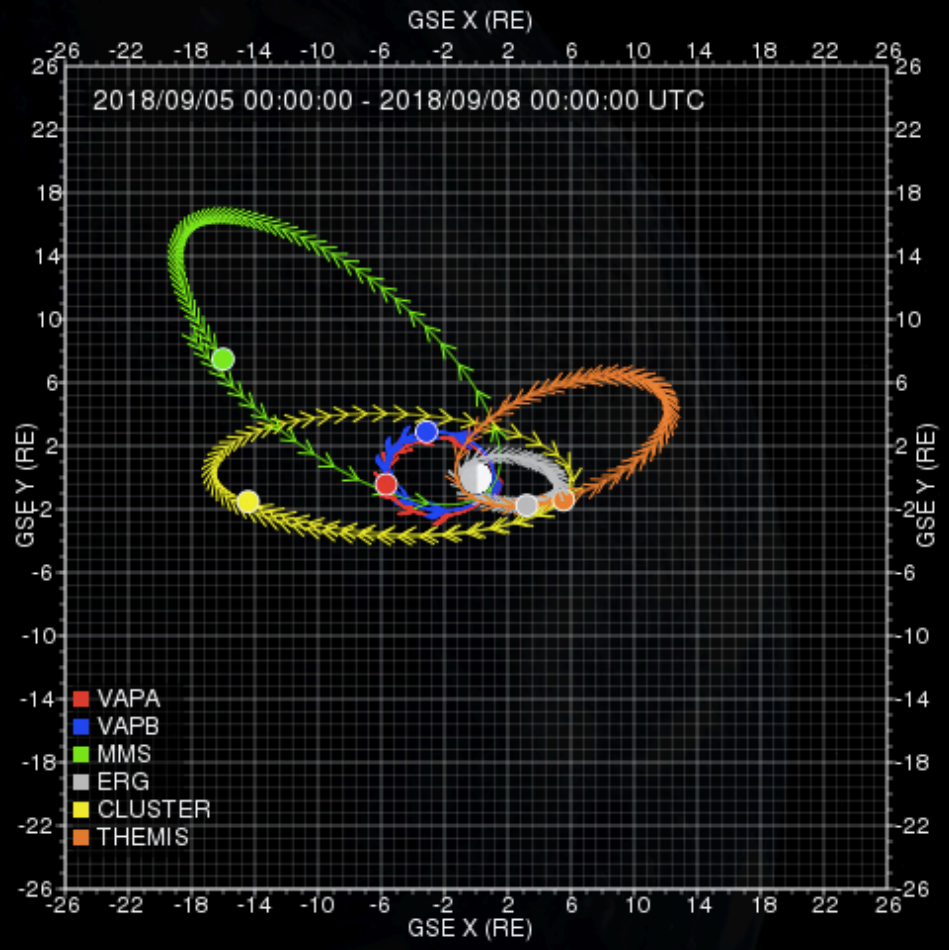
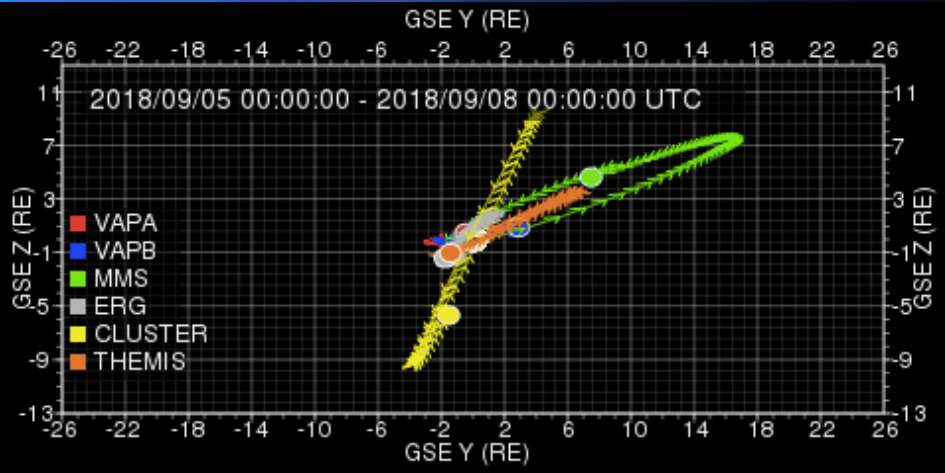
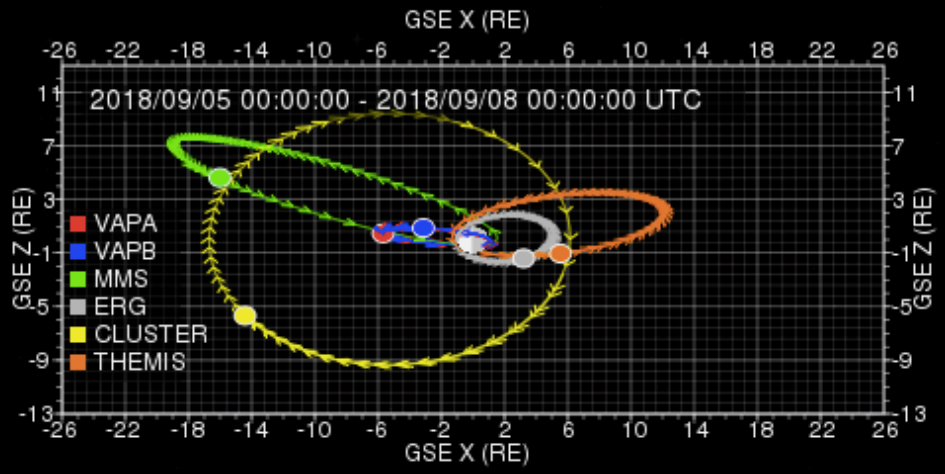


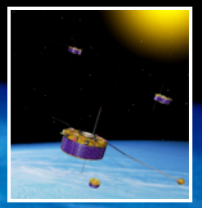
2018 Sept: Multi spacecraft global magnetosphere







Van Allen Probe, JHU/APL



Cluster payload status

Payload	C1 (FM5) "Rumba"	C2 "Salsa"	C3 "Samba"	C4 "Tango"
ASPOC	Failed in 2000	End of operations	End of operations	End of operations
CIS	HIA in magnet. mode (1hr/orbit)	Failed in 2000 (*)	Failed in 2009 (*)	CODIF fully operational
EDI	1 gun failed	EEPROM failed	Fully operational	Failed in 2000 (*)
	No use of gun beams (avoiding interference with Whisper)		Only one gun used (<-> Whisper)	
FGM				
PEACE				
RAPID electrons				
RAPID ions	Not working	Only heads 1 & 3	Not working	Only heads 1 & 3
WEC				
DWP				
EFW	Probes 2 & 3 OK	Probes 2, 3, 4 OK	Probes 2 & 4 OK	Probes 1, 2, 3 OK
STAFF				
WBD			max. 10 min/hour	
Whisper				

= fully operational

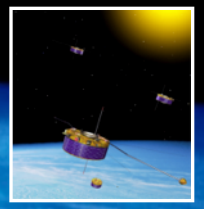
Not functioning since commissioning

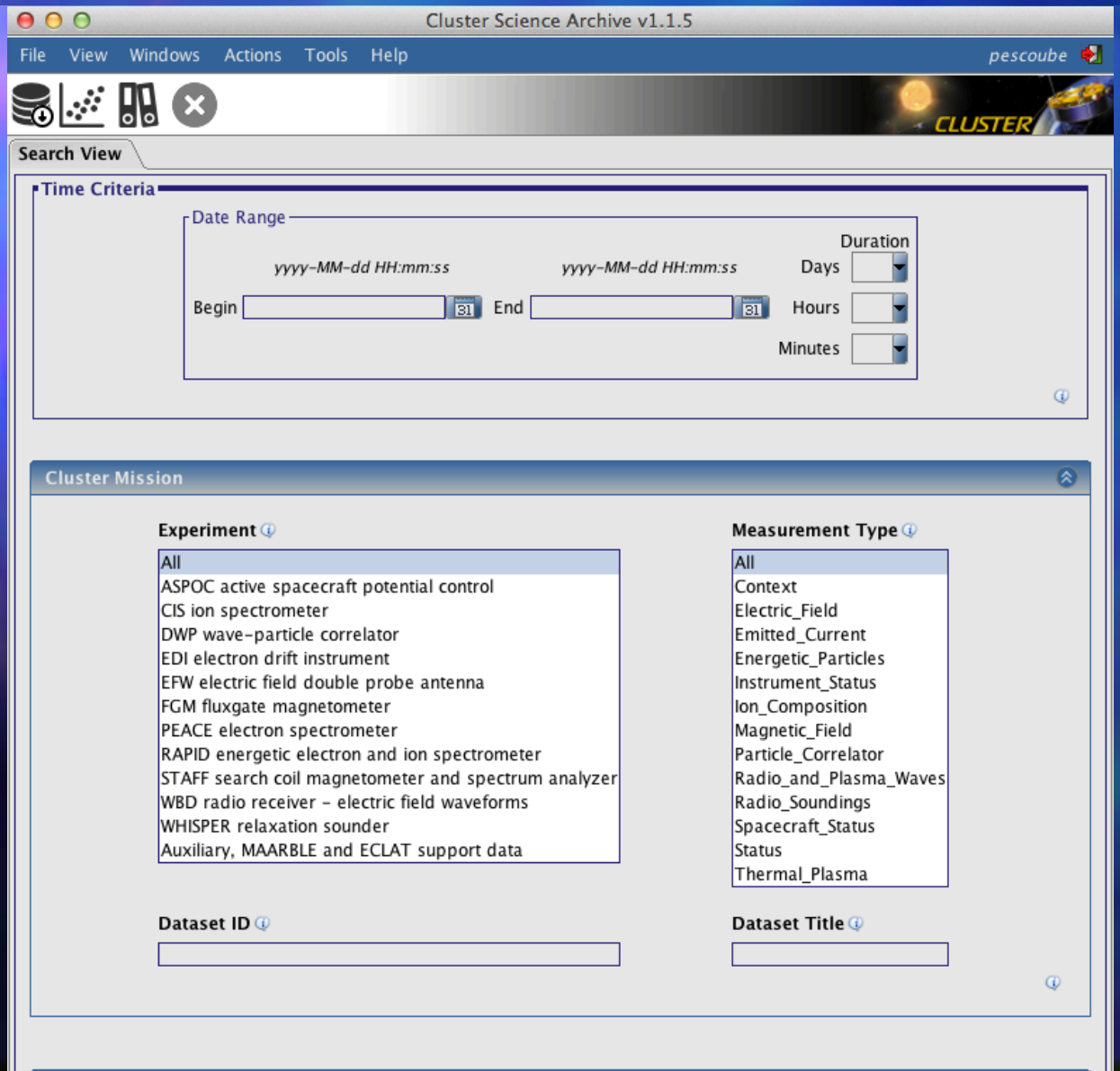
Status: May/2014

(*) Telemetry areas from CIS/EDI are used by PEACE and RAPID

Cluster Science Archive

CLUSTER





- New User interface (Java) and moved from NL to Spain
- CAA closure **31 October**
- High res. data open to public
- Special effort in calibration
- Data 2001-2013
- CDF or ASCII
- Good quality plots (spectro., 3D) in GIF or PS format
- Command line and streaming interface

http://cosmos.esa.int/csa

Cluster Science Archive v1.1.5

File View Windows Actions Tools Help pescoube

Search View | Key Graphical Products

yyyy-MM-dd HH:mm:ss

Begin 2003-10-31 00:00:00

End 2003-11-01 00:00:00

Duration

Days 1

Hours 0

Minutes 0

PEA1: ENERGY SPECTROGRAM (OMNI-DIRECTION
PEA2: ENERGY SPECTROGRAM (OMNI-DIRECTION
PEA3: ENERGY SPECTROGRAM (OMNI-DIRECTION
PEA4: ENERGY SPECTROGRAM (OMNI-DIRECTION
CIS4: ENERGY SPECTROGRAM (OMNI-DIR) - H+
CIS3: ENERGY SPECTROGRAM (OMNI-DIR) - IONS
CIS1: ENERGY SPECTROGRAM (OMNI-DIR) - IONS

Pregenerated 1 day | Plot Panel(s)

C1 C2 C3 C4 All Product Name

ASPOC

AUX

CIS

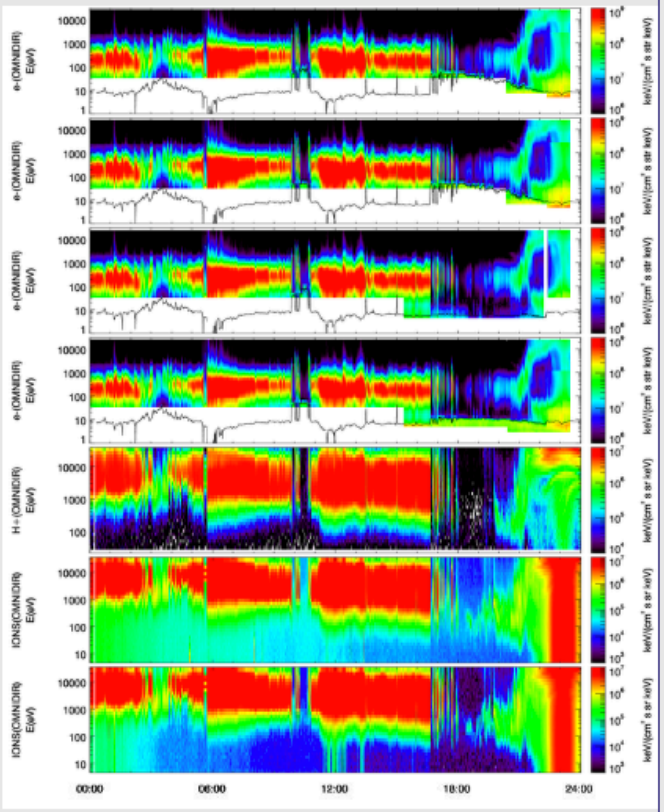
- DENSITY (H+)
- DENSITY (He+)
- DENSITY (O+)
- DENSITY (IONS)
- VELOCITY (IONS) - AZIMUTHAL COMPONENT IN GSE
- VELOCITY (IONS) - POLAR COMPONENT IN GSE
- VELOCITY (IONS) - TOTAL VELOCITY IN GSE
- VELOCITY (IONS) - X COMPONENT IN GSE
- VELOCITY (IONS) - Y COMPONENT IN GSE
- VELOCITY (IONS) - Z COMPONENT IN GSE
- VELOCITY (H+) - X COMPONENT IN GSE
- VELOCITY (H+) - Y COMPONENT IN GSE
- VELOCITY (H+) - Z COMPONENT IN GSE
- VELOCITY (H+) - AZIMUTHAL COMPONENT IN GSE
- VELOCITY (H+) - POLAR COMPONENT IN GSE
- VELOCITY (H+) - TOTAL VELOCITY
- ENERGY SPECTROGRAM (OMNI-DIR) - IONS (HIGH SENSITIVITY)
- ENERGY SPECTROGRAM (OMNI-DIR) - IONS (LOW SENSITIVITY)
- ENERGY SPECTROGRAM (OMNI-DIR) - H+

Plots

PS PNG

CSA_CG_PREGEN_1DAY_pescoube_20140908_140048__20031031000000.png

31 October 2003



Log Console

pescoube has logged in at 13:52:46

http://cosmos.esa.int/csa

esa

Cluster Science Archive v1.1.5

File View Windows Actions Tools Help pescoube

Search View | Key Graphical Products | Distribution Functions

Date Range

yyyy-MM-dd HH:mm:ss

Begin 2003-10-31 00:00:00 Duration Hours 1

End 2003-10-31 01:00:00 Minutes 0

#chanels (Sauvaud plots):

Varying scale (pa/nrj or angle/angle plots

Velocity plot (wheel plots):

Plot Panel(s)

C1 C2 C3 C4

CIS

- ANGLE-ANGLE DISTRIBUTION (HS MAG IONS)
- ANGLE-ANGLE DISTRIBUTION (HS SW IONS)
- ANGLE-ANGLE DISTRIBUTION (HS H+)
- ANGLE-ANGLE DISTRIBUTION (HS HE+)
- ANGLE-ANGLE DISTRIBUTION (HS O+)
- ANGLE-ANGLE DISTRIBUTION (LS SW IONS)
- ANGLE-ANGLE DISTRIBUTION (LS H+)
- ANGLE-ANGLE DISTRIBUTION (LS HE+)
- ANGLE-ANGLE DISTRIBUTION (LS O+)
- PITCH_ANGLE/ENERGY PLOT (IONS)
- PITCH_ANGLE/ENERGY PLOT (H+)
- PITCH_ANGLE/ENERGY PLOT (HE+)
- PITCH_ANGLE/ENERGY PLOT (O+)
- SAUVAUD PLOT (IONS)
- SAUVAUD PLOT (H+)
- SAUVAUD PLOT (HE+)
- SAUVAUD PLOT (O+)
- WHEEL PLOT (IONS)
- WHEEL PLOT (H+)
- WHEEL PLOT (HE+)
- WHEEL PLOT (O+)

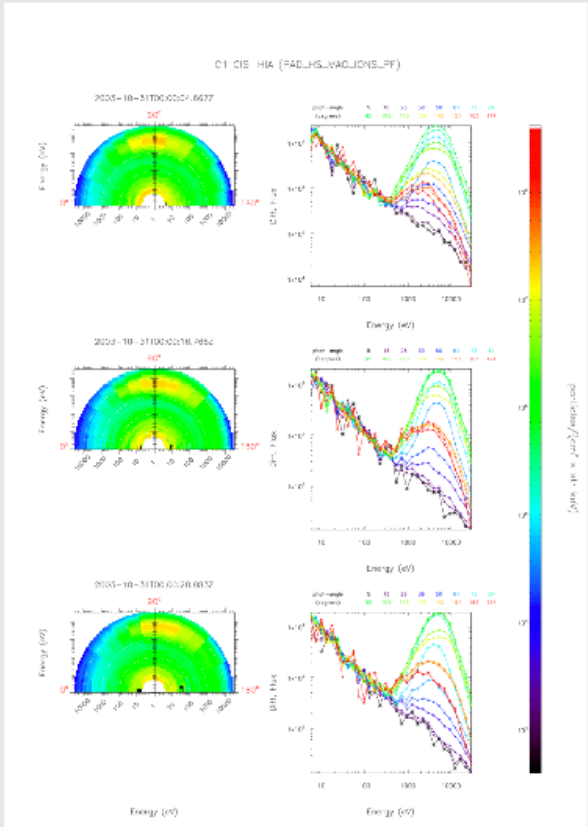
PEACE

RAPID

Plots

PS CEF

_PAD_HS_MAG_IONS_PF_CAA_WHEEL__20031031000000_20031031010000_201



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Cluster Science Archive v1.1.5

File View Windows Actions Tools Help pescoube

Search View | Key Graphical Products | Distribution Functions

Date Range

yyyy-MM-dd HH:mm:ss

Begin 2003-10-31 01:00:00 Duration Hours 1

End 2003-10-31 02:00:00 Minutes 0

#chanels (Sauvaud plots):

Varying scale (pa/nrj or angle/angle plots

Velocity plot (wheel plots):

Plot Panel(s)

C1 C2 C3 C4

CIS

- ANGLE-ANGLE DISTRIBUTION (HS MAG IONS)
- ANGLE-ANGLE DISTRIBUTION (HS SW IONS)
- ANGLE-ANGLE DISTRIBUTION (HS H+)
- ANGLE-ANGLE DISTRIBUTION (HS HE+)
- ANGLE-ANGLE DISTRIBUTION (HS O+)
- ANGLE-ANGLE DISTRIBUTION (LS SW IONS)
- ANGLE-ANGLE DISTRIBUTION (LS H+)
- ANGLE-ANGLE DISTRIBUTION (LS HE+)
- ANGLE-ANGLE DISTRIBUTION (LS O+)
- PITCH_ANGLE/ENERGY PLOT (IONS)
- PITCH_ANGLE/ENERGY PLOT (H+)
- PITCH_ANGLE/ENERGY PLOT (HE+)
- PITCH_ANGLE/ENERGY PLOT (O+)
- SAUVAUD PLOT (IONS)
- SAUVAUD PLOT (H+)
- SAUVAUD PLOT (HE+)
- SAUVAUD PLOT (O+)
- WHEEL PLOT (IONS)
- WHEEL PLOT (H+)
- WHEEL PLOT (HE+)
- WHEEL PLOT (O+)

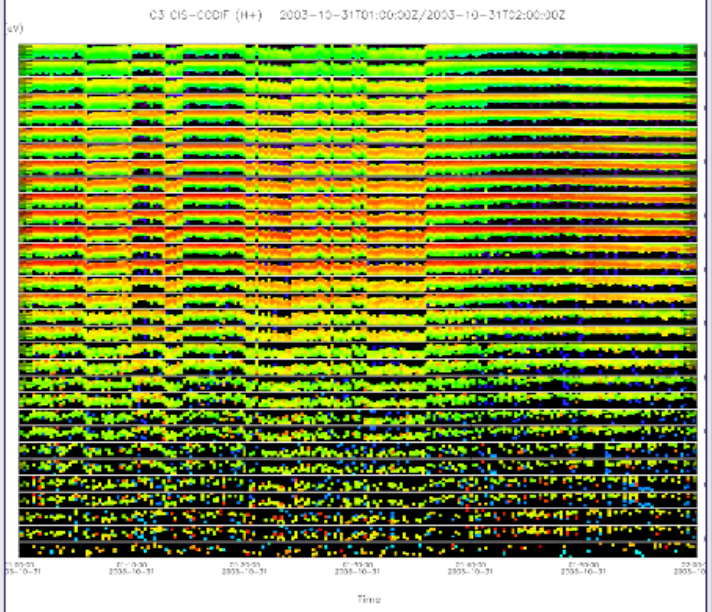
PEACE

RAPID

Plots

PS CEF

DIF_PAD_HS_H1_PF_CAA_TIME__20031031010000_20031031020000_20140908



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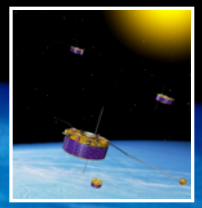

Summary and conclusions

- Cluster, first mission to observe plasma physics processes with four identical spacecraft
- Selected highlights in the inner magnetosphere
- Cluster Science Archive: public access to all high res. data
- Cluster extension up to end 2016 and preliminary extension up to end 2018 to be decided in Nov. 2014
- Looking forward to future opportunities with Van Allen Probes, THEMIS and in the future MMS, ERG