Plasmasphere Brainstorm Meeting
IASB, Brussels
24-25 February 2003
Minutes (F. Darrouzet)

Participants:

Arnaud Masson (AM) – ESTEC, Noordwijk, The Netherlands – amasson@so.estec.esa.nl
Fabien Darrouzet (FD) – IASB, Brussels, Belgium – Fabien.Darrouzet@oma.be
Gérard Chanteur (GC) – CETP, Vélizy, France – gerard.chanteur@cetp.ipsl.fr
Georg Gustafsson (GG) – IRFU, Uppsala, Sweden – gg@irfu.se
Harri Laakso (HL) – ESTEC, Noordwijk, The Netherlands – hlaakso@rssd.esa.int
Jean Gabriel Trotignon (JGT) – LPCE, Orléans, France – jgtrotig@cnrs-orleans.fr
Joseph Lemaire (JL) – IASB, Brussels, Belgium – Joseph.Lemaire@oma.be
Jean Louis Rauch (JLR) – LPCE, Orléans, France – jlrauch@cnrs-orleans.fr
Patrick Canu (PC) – CETP, Vélizy, France – Patrick.Canu@cetp.ipsl.fr
Pierrette Décréau (PD) – LPCE, Orléans, France – pdecreau@cnrs-orleans.fr
Viviane Pierrard (VP) – IASB, Brussels, Belgium – Viviane.Pierrard@oma.be

Agenda:

Presentations (24/02/2003):

- VP: Electric Field Models in the Plasmasphere
- FD: Plasmasphere Measurements from Spacecraft
- HL: Polar Results in the Plasmasphere
- AM: Density Determination from EFW and WHISPER
- JGT: Density Determination from WHISPER
- PD: AGU 2001 and COSPAR 2002 Talks
- HL: Cluster Results in the Plasmasphere
- GC: Barycentric Tools for Cluster
- JL: VHS-Video animation on plasmasphere

Discussions (25/02/2003):

- Events already studied
- Review of all plasmasphere crossings in 2001/2002
- List of new interesting events (small separation scale)
- Review physical mechanisms and models
- Tools available for plasmaspheric studies
- Papers in preparation
- Future conference/meeting
- Use of other instruments on Cluster (EDI, FGM, WBD, CIS, PEACE)
- Miscellaneous…

See also the file: Agenda_IASB_PLS_24_25FEB2003.doc

Presentations:

VP: Electric Field Models

cf.: PLS_24_25FEB2003_BXL_V.Pierrard_Plasmasphere.ppt
PLS_24_25FEB2003_BXL_V.Pierrard_Plasmasphere_Figures.zip

* 3 different electric field models:
  -Uniform dawn-dusk (Volland-Stern, 1973)
  - E3H (McIlwain, 1974)
    with data from ATS 5 and 6; OK for low Kp (<2)
  - E5D (McIlwain, 1986)
    dependent on Kp, LT ⇒ dawn-dusk and noon-midnight asymmetries

* Magnetic field model:
  - M2 (McIlwain)
    not dependent on Kp, but more complicated than a simple dipole

*Spacecraft Data-Simulation of the plasmapause formation by interchange motion:
  - 24/05/2000: IMAGE data: shoulder
    Simulation (with E5D and M2): shoulder and tail in the afternoon sector
  - 06/2001: Cluster and simulation: plasmapause like a circle (low Kp).

*Ground-Based Data-Simulation:
  - Position of plasmapause at different LT, comparison between Whistlers and simulation: good.

* Conclusion on simulation:
  - Advantages:
    Independent on plasmapause position
    Continuous dependence on Kp
    Dawn dusk and noon midnight asymmetries
  - Disadvantages:
    When Kp increases, E is disturbed and is non-stationary while E5D represented by stationary equipotential surfaces.
    B independent on Kp

FD: Plasmasphere Measurements from Spacecraft

cf.: PLS_24_25FEB2003_BXL_F.Darrouzet_Measurements_Spacecraft.ppt

* Particles and waves experiments; history divided in 3 parts (…-1970, 1970-1980, 1980-…).

* …-1970:
  - First ion density measurements with LUNIK 2: good agreement with whistlers results (Carpenter)
  - ELECTRON and OGO missions: size of plasmasphere decreases as Kp increases
    Plasmapause position from L=3 to 7
  - Temperature measurements: ion with LUNIK 2 and electron with IMP 2 and OGO 5
    → not very good measurements
  - OGO 3 and 5: helium and oxygen ions measured

* 1970-1980:
  - PROGNOZ 2: dawn-dusk asymmetry
  - GEOS 1 and 2: 3 different instruments measuring density (⇒ comparison)
  - ISEE 1: negative temperature gradient below L=3
    higher temperature in nightside than dayside for L>4
* 1980-…:
  - DE 1: lots of various categories of density profiles
  - DE 1: heated superthermal population in addition to the cold one seen only in the equatorial plane
  - EXOS-D: measurements of bulk velocities
  - ACTIVNY: observations of thermal O^{++} ions
  - CRRES: large frequency-time spectrograms (40 Hz - 400 kHz) ⇒ waves in the plasmasphere
  - INTERBALL: differences between nightside and dayside plasmapause (with 2 satellites)

HL: Polar observations in the plasmapause/trough region

cf.: PLS_24_25FEB2003_BXL_H.Laakso_Polar.ppt

* Polar orbit ⇒ 4 crossings per orbit ⇒ 10000 crossings !!
  - power law coefficients for the plasmasphere and trough densities
  - plasmapause location and thickness
  - as a function of MLT and Kp.
  - V_{sc} from EFI (04/1996-12/1999) → N_e

* Velocity measurements ⇒ convection and co-rotation regions

* Case 11-12/05/1999: evolution of plasmapause position with a substorm (L=12 → L=7)

* Power law to fit electron density in plasmasphere and trough (comparison with Carpenter curves), statistic on the parameter of the power law in the trough:
  - generally decreases with Kp
  - strongly asymmetric with MLT for all Kp

* Plasmapause location and thickness (MLT, Kp):
  - Kp increases ⇒ thickness decreases
  - Kp increases ⇒ L-position decreases
  - in MLT = 12-18, ΔL is ≈ constant for different Kp
  - dawn-dusk asymmetry for increasing Kp
  - PD: one should winter and summer data in the statistic
    for dayside, use average Kp, for nightside, use exact Kp
  - JL, VP: good agreement with simulation and whistlers data at 2 LT.
  - HL: V_x not used because calculated from ExB, and E_y poorly measured on POLAR.
  - cf. power point presentation for more conclusions

AM: Electron Density and Spacecraft Potential

cf.: PLS_24_25FEB2003_BXL_A.Masson.ppt

* V_{sc} every 0.2 seconds on Cluster, and working on all spacecraft with 100% coverage

* Old technique: 1 power law, without interference treated and on whole time interval
New technique: 2 power laws (for low and high density, separation around ΔV_{sc} = 2 Volts), with interference treated, estimation error, and chosen time intervals.
JL: Perhaps better to use Kappa function (= Maxwell at low energy and power law at high energy)

* Comparison with WBD data by extrapolation of fitting curve to validate the method:
good, but just a few cases.
* Future:
- More comparisons with data (electrons and ions measurements, systematic comparisons with WBD)
- Study the bias current and the satellite aging on the relation between N_e and V_{sc}.
- Study the influence of the magnetic field (Bouhram et al., 2002) on this relation.
- Study the influence of the geometry of the tetrahedron on this relation.

RQ: Not possible to derive electron temperature from WHISPER (too much electronic noise)

JGT: Determination of Fp from WHISPER

* Active case:
- valid for a Maxwellian plasma
- determination of fp done with fq: with the Hamelin diagram, the well aligned fp observed on the spectra give the fp.
- sometimes, all the fq are not well aligned: all the fq that can be aligned give the fp that corresponds to the cold plasma population, and the peak observed on the spectra corresponds to the total electron plasma frequency.
- the maximum of the spectral energy gives an upper limit for fp.
- in the plasmasphere, there are 95% of cold electrons, so all the fq are almost always aligned.

PD: AGU 2001: Outer plasmaspheric Structures, Topology and Dynamics: Views from the Whisper instrument on Cluster

cf.: PLS_24_25FEB2003_BXL_P.Decreau_OutPS_NdeT2.ppt

* General context:
- 1 pass in both hemispheres every 57 hours
- plasmasphere different with MLT and geophysical conditions

* 05/06/2001:
- s/c 1 and 4 on same LT, s/c 2 closest to the Earth
- irregularities: the large inbound one is seen on the 4 s/c ⇒ structure stagnant (in 1h00 at least)
the small ones are almost identical on s/c 1 and 4, but different on s/c 2 because s/c 2 is at different LT than 1 and 4)
the outbound structure is seen on 1 and 4 (problem in density data of s/c 4)
- 2D view: plan OXM (but this M point is not the same for the 4 s/c !!)

* Drift velocity and irregularities should be further studied.

PD: COSPAR 2002: Properties of density structures measured by the Whisper instrument on-board Cluster

cf.: PLS_24_25FEB2003_BXL_P.Decreau_WHI_COS_V3.ppt

* Large separation
  - density structures, generally field aligned
  - too dynamic on 24/06/2001 to be resolved by this large separation
  - remarkable similarity on the 4 s/c for the 13/06/2001.

* Small separation
  - 09/05/2002: IB structures superposed on the 4 s/c, and then not superposed → spatial effect
  - 08/02/2002: density gradient towards the Earth (OK), change in direction in the YZ plane, comparison between EDI velocity and velocity derived from time differences

* Problem with the magnetic field obtained with the models which is quite different from the FGM data
  - use FGM to improve models??

HL: Cluster Observations in the plasmapause region

cf.: PLS_24_25FEB2003_BXL_H.Laakso_Cluster_Plasmapause.ppt

* Short separation, 08/02/2002 (1-2 MLT):
  - lots of plasmapause crossings
  - 2 min waves on azimuthal electric field
  - larger radial inward drifts (due to waves)

  ⇒ 2 min waves on the plasmapause

* Large separation, 15/01/2002 (3 MLT):
  - crossings in 2.5 hours
  - plasmapause with a flow separatrix layer
  - radial flow speed is positive on both sides of plasmapause !!

  ⇒ narrow flow separatrix

* Large separation, 22/01/2002 (3 MLT):
  - again large outward flow

  ⇒ breathing plasmapause

* Large separation, 29/01/2002 (2 MLT):
  - large scale structure, the same in term of density on 4 s/c, not the same in term of radial velocity

  ⇒ plasma tail close to plasmapause

GC: Barycentric Tools for Cluster

cf.: PLS_24_25FEB2003_BXL_G.Chanteur_Tools.ps

* Tools based on the use of reciprocal vectors and reciprocal tensor

  ⇒ gradient of a field (scalar or vector)

* Covariance of the s/c positions

  ⇒ covariance of reciprocal vectors

* Example of a planar surface in uniform motion crossed by the 4 s/c
  - timing normal + normal velocity + covariance ⇒ cone of uncertainty

* Curvature of field lines
  - tangent and normal of a field, gradient of the field ⇒ curvature
  - GC: will develop a program in IDL to compute this new tool
  - FD: will create some files with spacecraft positions and magnetic field data from FGM, as input to test this new tool

[These 2 last items have been done the Wednesday 26th at IASB]

JL: VHS-Video Animation on Plasmasphere

"The plasmapause formation and deformation" (J. Lemaire, 1983).

Cluster plasmasphere crossings:

HL and PC: with EFW and WHISPER

* 4-L scale systematic plots of the plasmasphere crossings with
  - density from spacecraft potential
  - electric field
  - drift velocity

* Examples of crossings with small separation between spacecraft (after 01/02/2002):
  - 27/02/2002: small separation
  - 22/02/2002: differences between spacecraft, even with small separation
  - 20/02/2002: plasmapause at L=6.6
    perhaps SAID (Sub Auroral Ion Drift)
    PC: Whisper → very asymmetric
  - 17/02/2002: simple plasmapause
  - 08/02/2002: lots of irregularities

* Examples of crossings with large separation between spacecraft (in 2001):
  - 10/01/2002: PC: plasmapause not sharp
    electrostatic and electromagnetic emissions
    low density at perigee
  - 03/01/2002: large plasmapause
  - 27/12/2001: steep plasmapause
    radial flow??
    PC: burst emission just before the inbound crossing
  - 03/12/2001: disturbed in 1 hemisphere
    very different in the other hemisphere (double plateau)
    strong difference with s/c 3
    PC: waves on Whisper (3 type III bursts)
  - 26/11/2001: lots of structures
    strong electric field variations
  - 14/11/2001: similar pattern on 3 s/c
    PC: hole in the Whisper data for the outbound crossing

- 12/11/2001: structures inside plasmasphere
  PC: symmetric case
- 05/11/2001: structures
- 24/10/2001: large structure, perhaps shoulder
- 07/10/2001: plasmapause not seen
- 30/09/2001: ULF waves in trough
- 15/09/2001: lots of variations in electric field
  PC: wave activity
  low density at perigee
  electrostatic emission in plasmasphere
- 09/09/2001: steep plasmapause
- 25/08/2001: low frequency waves
- 09/08/2001: plasmapause seen in southern hemisphere, but not in northern
- 04/08/2001: high density outside plasmasphere (20 part at L=8)
- 21/07/2001: lots of structures
- 18/07/2001: very high density
- 27/06/2001: large density structure
- 13/06/2001: flow separatrix at plasmapause
- 29/05/2001: density structures
- 13/05/2001: strange case !!!
- 08/05/2001: structure in plasmasphere and then strange density profile
- 26/04/2001: very sharp plasmapause
- 14/04/2001: very sharp plasmapause
- 07/04/2001: very sharp plasmapause

* Remarks on Harri's plots:
  - JL: Add geomagnetic index on the Harri's plots
  - HL: Change drift velocity into eastward and westward velocity
  - JL: Add fitting curves (with power law) on the density plots for the plasmasphere and the trough

* Remarks:
  - AM: PEACE data at perigee since 08/01/2003
  - JL: AE or/and Dst index perhaps better than Kp (just every 3 hours)
  - JL: Better to use R_m than L (R_m= radial distance, where the magnetic field intensity has a minimum along the magnetic field lines passing through the position of the spacecraft)

FD: Cluster-IMAGE-Kp orbit plots

* Plots with Kp index and radial distance of the orbits of Cluster and IMAGE (on the same plot), with time intervals of available IMAGE-EUV data and Cluster plasmasphere crossings, in order to select the plasmasphere crossings with Cluster-IMAGE conjugations. The LT_{GSE} of the first Cluster plasmasphere crossing of each plot is also indicated.

FD and PC: with WHISPER and EDI

* List of a selection of plasmasphere crossings with EDI data available and small separation:
  - 11/03/2002: irregularities
  - 11/04/2002: 2 tails, continuum radiation trapped between the tail and the plasmapause
  - 25/04/2002: asymmetry
  - 30/04/2002: sharp gradient, smooth transition, small tail (substorm onset near the inbound crossing)

- 07/05/2002: plume in the inbound crossing
- 09/05/2002: differences between satellites, densities irregularities
- 31/05/2002: sharp gradient and then smooth plasmapause on both hemispheres
- 02/06/2002: large irregularities, trapped continuum radiation
- 07/06/2002: asymmetric plasmapause, detached elements in both hemispheres
- 09/06/2002:
- 12/06/2002: tail, irregularities and $3/2f_{ce}$ emission
- 14/06/2002: irregularities at the outbound crossing

* Other plasmasphere crossings in 2001:
- 17/05/2001: asymmetry, tail on s/c 3
- 27/06/2001: large irregularities

HL: Other Cluster plasmasphere crossings

- 13/03/2002: plumes on both hemisphere, eclipse data gap
- 18/03/2002: steep density gradients at plasmapause, bite-out and irregularities during the outbound crossing
- 23/03/2002: strong irregularities
- 30/03/2002: SAID ??, quick plasmapause encounter
- 08/04/2002: differences in drift velocities between four satellites?
- 18/04/2002: no plasmapause crossing
- 20/04/2002: no plasmapause encounter but plumes on both hemispheres

Possible papers:

* 13/06/2001:
- Topics:
  - narrow shear flow
  - curvature of plasmapause
  - motion of the plasmapause
  - irregularities along **B**
  - density variation along field line
- Data:
  - EDI: contact Matias Förster
  - EFW
  - CIS available?

* 05/06/2001:
- Topics:
  - detached regions
  - irregularities
  - time versus space issues
  - velocity of irregularities with error bars
- Data:
  - IMAGE data available (but not exactly at the time of the crossing by Cluster)

* 08/02/2002:
  - Topics:
    irregularities: significant differences between the satellites even during short separations
    low-frequency waves in **E** and **B**
    density hole at equator
    where is Roche limit?
    density gradients
    flow patterns near & within the irregularities
  - Data:
    IMAGE data available!

Conclusions (input from HL taken during the meeting):

1) Wave activity on the plasmapause:
  - 08/02/2002 case
  - EFW-FGM 2-minute waves on the plasmapause, Poynting flux?
  - density irregularities, detached plasma elements

2) Detached regions, plasmaspheric tails, and shoulders
  - vs. MLT, Kp, AE
  - comparison with IMAGE:
  - June 5, 2001: detached, plumes, irregularities etc
  - July 2, 2001
  - July 16, 2001
  - July 21, 2001
  - August 8, 2001: drifting patches
  - August, 21, 2001
  - August 25, 2001
  - September 9, 2001
  - September 25, 2001: detached elements
  - October 24, 2001: shoulder
  - December 15, 2001: morning side detached element
  - January 29, 2002: flows within the tail
  - February 8, 2002

3) Small-scale irregularities at the plasmapause
  - statistics [vs. MLT, Kp, AE]
  - distribution: size, amplitude
  - surface curvature – local characterization
  - interchange motion
  - Roche-limit surface: erosion
  - parallel-E events? – use Polar data

4) Radial flow across the plasmapause, from trough into plasmasphere
  - during substorms at different MLT
  - EFW-EDI comparison useful for EFW calibration
  - Feb 8, 2002 & Jan 15, 2002: net flow inward and outward, respectively

5) Velocity shear near the PP
  - June 13, 2001: clear shear
  - January 15, 2002: thin flow separatrix

6) Breathing PP - radial motion of the plasmapause
- January 22, 2002

7) SAID (sub-auroral ion drifts)
- relationship to SAR
- relationship to plasmapause location
- February 20, 2002

8) sub-auroral arcs (SAR)
- precipitation data from low-altitude red auroral arcs needed

9) Particle distributions near the plasmapause (cf. case 21/07/2001)
- PEACE data available since 08/01/2003

10) Density distribution along field lines
- flux tube refilling

11) Lunar effects on plasmasphere – plasmaspheric tides
- superposed epoch analysis of Polar data

12) Quality of symmetry of the Cluster orbit

13) Summary plots on the web
- EFW: density, azimuthal drift, geomagnetic index
- Whisper: daily plots from Pierrette; detailed plots from Patrick
- Cluster-IMAGE orbit plots from Fabien

14) fq cold-hot population, Maxwell-Kappa functions

Miscellaneous:

* Web site for Polar data: ftp://pwgdata.gsfc.nasa.gov/pub/00readme.html
- EFI, MFE and Orbit/Attitude