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Motivation

Plasmasphere and plumes studied with single satellites (CRRES), with ground-based data (GPS), with imagers (IMAGE) \Rightarrow Global and local view Plume Narrowing Plume Rotating





[Foster et al., 2002] With Cluster, constellation of 4 satellites

- Various perigee altitudes (from 4 to 1.5 Re and now around 5,5 Re)
- Different configurations (string of pearls, tetrahedron, 2 close satellites, ...) and different spacecraft separations (~10 to 100 000 km)
- But not many ion density and temperature data (except RPA) mode by CIS instrument)
 - Old mission **Dynamics Explorer 1** detects H⁺, He⁺, He⁺⁺, O⁺, O⁺⁺ ions
- Active mission, Van Allen Probes (RBSP)
 - Similar instrument than WHISPER but higher upper density limit (3000 cm⁻³) shorter orbital period (3 plasmasphere crossings per day), 2 satellites



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Outline

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Motivation

Cluster

- Plasmapause study
- Plume study

Dynamics Explorer - 1

- Data
- First results

Van Allen Probes

- Data
- First results
- Summary Future







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Cluster – Plasmapause / Radiation Belt 04/2007-03/2009: Low perigee (2 R_E) for Cluster satellites Correlation between PP position obtained from WHISPER (black) and boundary position of the RB obtained from CIS (blue - green) and RAPID (red - magenta) during 2 years (April 2007 – March 2009):

- Quite low activity during those months: plasmasphere very extended at L>5 R_E
- Plasmapause position very variable due to different conditions and strong interaction with geomagnetic activity
- Plasmapause coincides with outer boundary at larger L (low activity) and to inner boundary at smaller L (high activity)

Jan-2008

Day

[Darrouzet et al., 2013]

Apr-2009





Cluster – Plumes / Waves

2001-2006: Perigee ~4 R_E and separation 100 to 10000 km

- Survey of plumes in 2001-2006 identified from WHISPER + search of EMIC waves in magnetic field data from FGM
 - Observation of EMIC waves during only 11% of the time when Cluster observed plumes along its orbit (7% inside the plume and 4% inside and outside the plume)
 - Enhanced EMIC probability observed in the noon sector beyond the GEO orbit (not at plume)

EMIC occurrence significantly increases with solar wind dynamic pressure (up to ~40%)



[Usanova et al., 2013]

Dynamics Explorer - 1 / RIMS Data

- DE 1 launched 3 August 1981
 - Polar orbit: 567 x 23289 km, 409 min, 89° inclination
- RIMS (Retarding Ion Mass Spectrometer) data
 - More than 3 years of data (Oct 1981-Dec 1984 ; 218 692 times of data)
 - Valid plasmapause crossings ($N_{max} > 20 \text{ cm}^{-3}$, increase of N of min factor 3 in a distance of min L=0,5 R_E):



- Not many events (cm⁻³)
 with Kp>5 during this time period (decreasing phase of solar cycle) Kp
- All MLT covered but MLT-statistical analysis possible only for H⁺ and He⁺





[Chappell et al., 1981]



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DE-1 / RIMS – First Results

Analysis of density during plasmapause (and/or PBL) crossings

- Not very often plasmapause crossings data for all 5 ions (mostly only before Feb 1982)
- Higher density for H⁺ and lower density for O⁺ (not O⁺⁺ !!)
- Higher density ratio with respect to H⁺ at low L
 - L~2: 90% H⁺ 9% He⁺ 0.2% He⁺⁺ 0.1% O⁺ 0.1% O⁺⁺
- Similar distribution for H⁺, He⁺ and He⁺⁺
- Higher O⁺ and O⁺⁺ density at L = 3 4.5
- Should separate this data by latitude ranges (polar orbit)





- 600 x 32 000 km, inclination 10°, period 9h
- 5 instrument suites dedicated to study the radiation belts
- 19 July 2019: end of satellite RBSP-B

EMFISIS/Waves onboard Van Allen Probes

- Single electric field component of waves (10-500 kHz) \rightarrow upper hybrid resonance frequency Fuh \rightarrow electron plasma frequency Fpe \rightarrow electron density Ne (similar as WHISPER); Ne up to 3000 cm⁻³, resolution of 6 s, precision ultimately 3% after density smoothing





[Kletzing et al., 2013]





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RBSP / EMFISIS – First Results

- Plasmapause (or plasmasphere boundary layer, PBL) not easy to determine automatically
 - Very different density profiles, large or short PBL in terms of L-scale (E-F)
 - Many density irregularities and plumes observed (C-H)
 - Density values outside the plasmapause (plasmatrough) variable (B-D)
 - Simply no plasmapause boundary (G)

 \Rightarrow The usual condition "Location closest to the Earth where Ne increases by a factor of 5 within 0,5 L" does not work !!



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Summary - Future

- 19 years of plasmasphere crossings by Cluster with different configurations, perigee altitudes and spacecraft separations
 - Low perigee: Comparison of plasmapause with radiation belts positions
 - Close and similar spacecraft separation: Wave analysis between all s/c
 - Very close distance between 2 satellites: Event analysis of plume crossing (+ data from other mission and numerical simulation)
 - And many more studies not presented here...
- And new data from old mission: Dynamics Explorer 1 / RIMS
 - Many possibilities of new analysis with data of 5 different ions
- And data from actual mission: Van Allen Probes / EMFISIS
 - Full crossing of plasmapause (PBL) with various structures of boundary
- Future
 - Analyse plasmasphere by Cluster with higher perigee altitude (5-6 R_E now)
 - Multi-mission study of the plasmasphere (ERG satellite, BARREL balloons, VLF whistlers ground-based instruments, ...)
 - Continue analysis of old DE-1/RIMS data and actual RBSP/EMFISIS data



Some References

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