From Science To Double Star Program (DSP)

(Part 2)

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Chapter 3

Double Star operation

Outline

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1. Double Star Program system
2. Science operation
3. The science data system

1. Double Star Program system

S/C and PLs system

Launch vehicle system

DSP

Launch site system

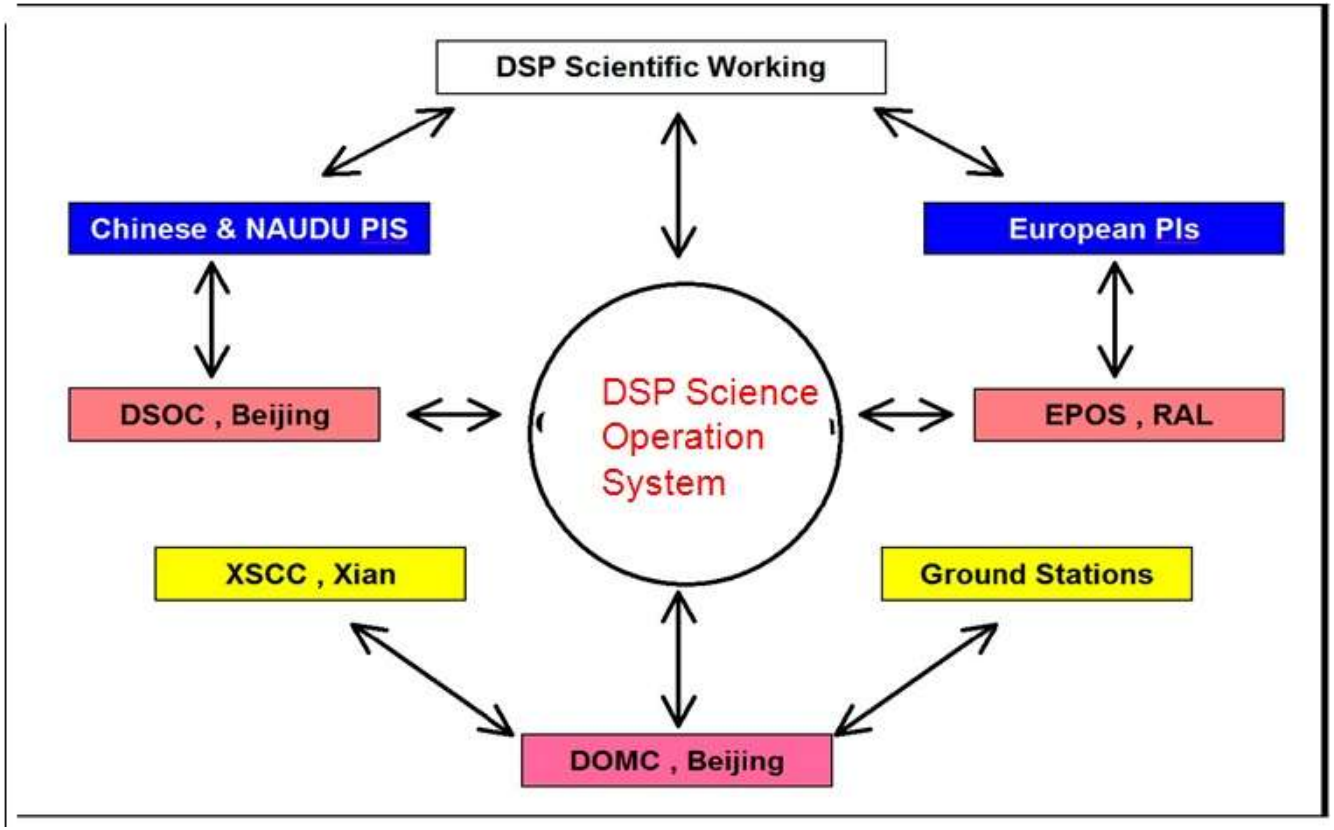
Telemetry system

Ground receive system

- TC-1
  - -- Launched on 31 Dec. 2003
  - -- Planned running 18 months
  - -- Real running 45 months
- TC-2
  - -- Launched on 25 July 2004
  - -- Planned running 12 months
  - -- Real running 47 months
- 500 Gb data obtained for Scientific research
- Both the TC-1 and TC-2 operation were extended

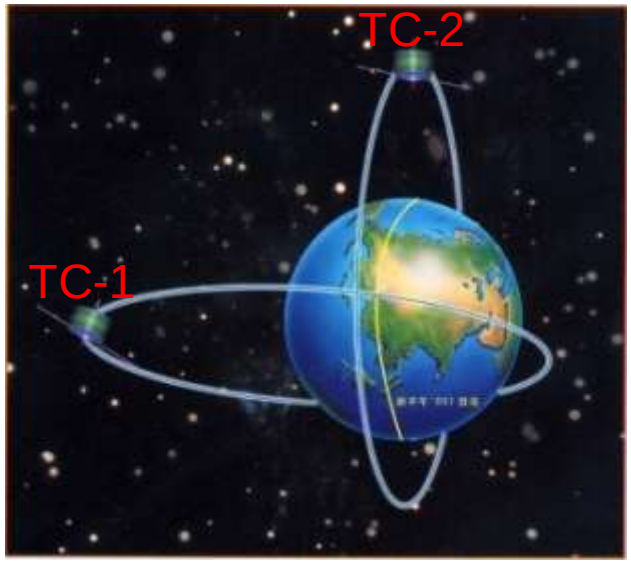
2. Science operation

- There was a DSP Science Operation Center (DSOC) in charge of the DSP science operation in China.
- There was an European Payload Operation Service (EPOS) to help DSOC collect European payload requirement for DSP science operation plan in UK



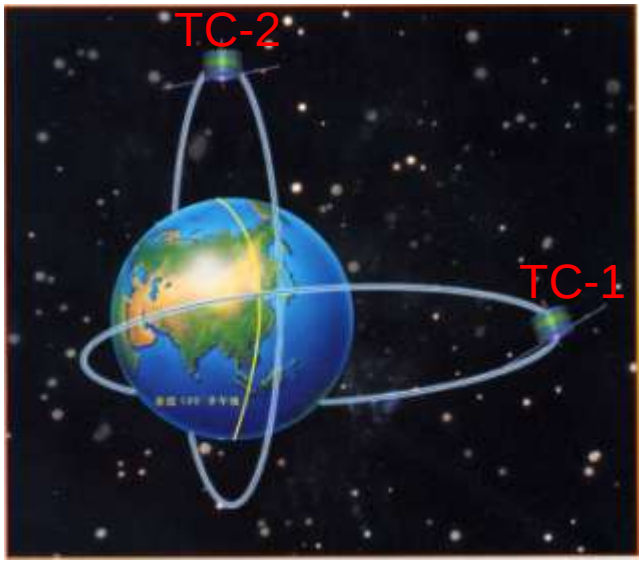
DSP is an independent space science mission, the data can be used to do research in many aspects.

Dayside



TC-1 apogee in dayside

- The TC-1 can observe the
  - --- Solar wind
  - --- Bow shock
  - --- Magnetosheath
  - --- Magnetopause
- The TC-1 Mainly monitors the magnetopause and magnetotail



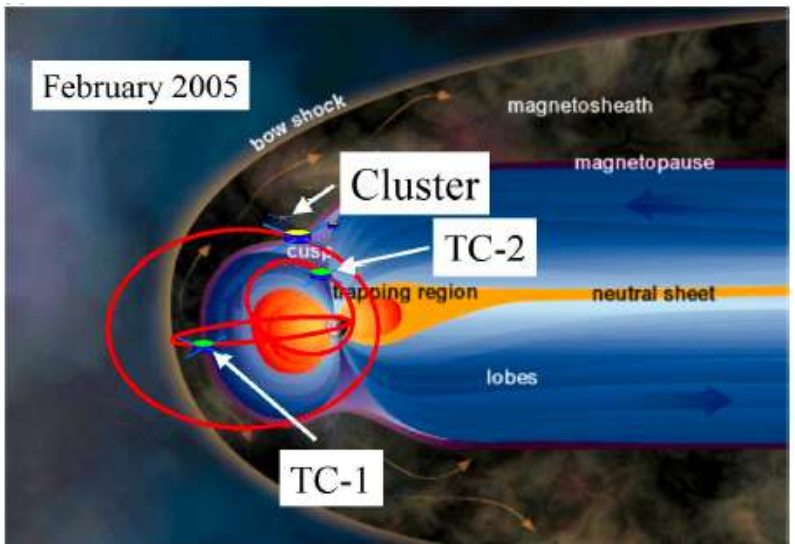
Nightside

TC-1 apogee in nightside

- The TC-1 can observe the
  - --- Plasmasphere
  - --- Plasmasheet with its
  - --- Boundary layers
  - --- The magnetic neutral sheet
- The TC-2 Mainly monitors the polar space

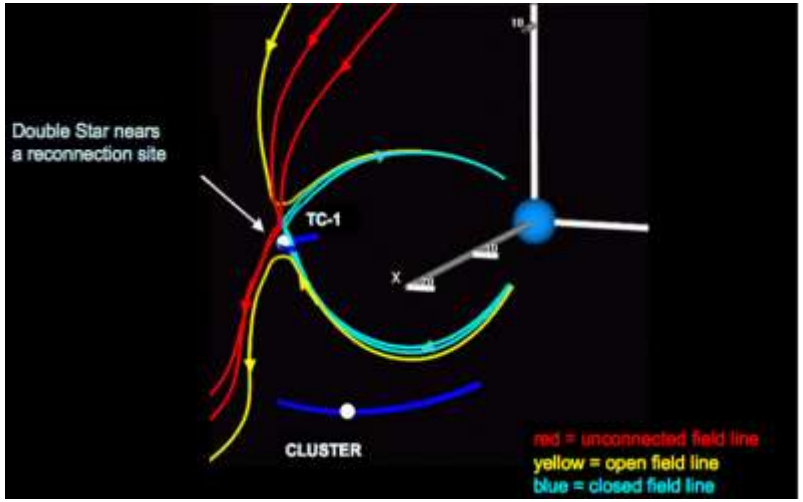
The apogees of TC-1 and Cluster in dayside

With DSP and Cluster coordinated observation: we can perform



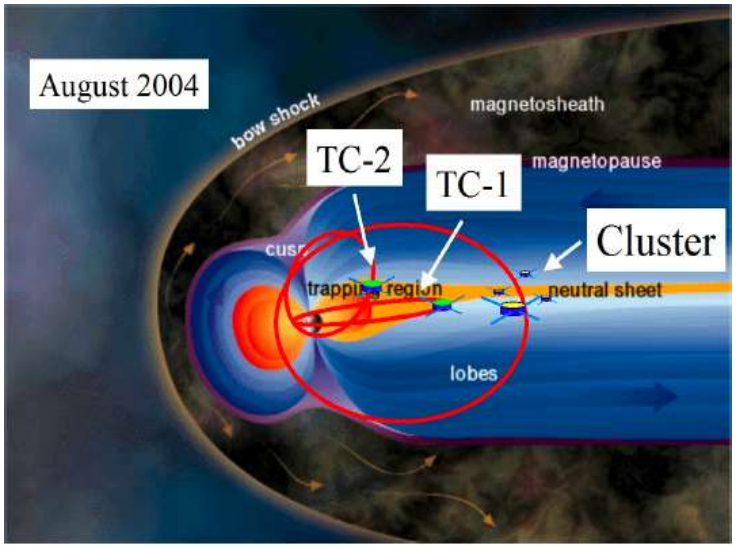
- Investigation on the solar wind structures
- Study on the magnetic reconnection and large scale FTEs in the magnetopause
- Study on the solar wind entry into magnetosphere

- Study on the cusp/cleft structures and the particle dynamics
- Study on precipitation electrons and up-flowing ionospheric ions
- To understand the solar wind - magnetosphere-ionosphere coupling process



The apogees of TC-1 and Cluster in nightside

With DSP and Cluster coordinated observation, we can perform



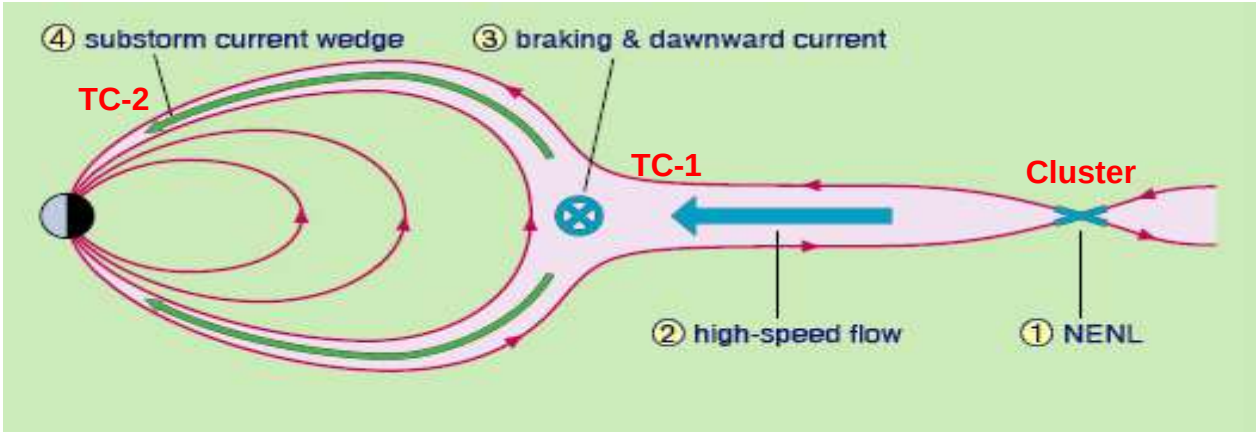
- Study on the large, medium and small scale physics process

  --- the position of the X-point

  --- FAC in the plasmasheet boundary layers

  --- the waves in the plasmasheet

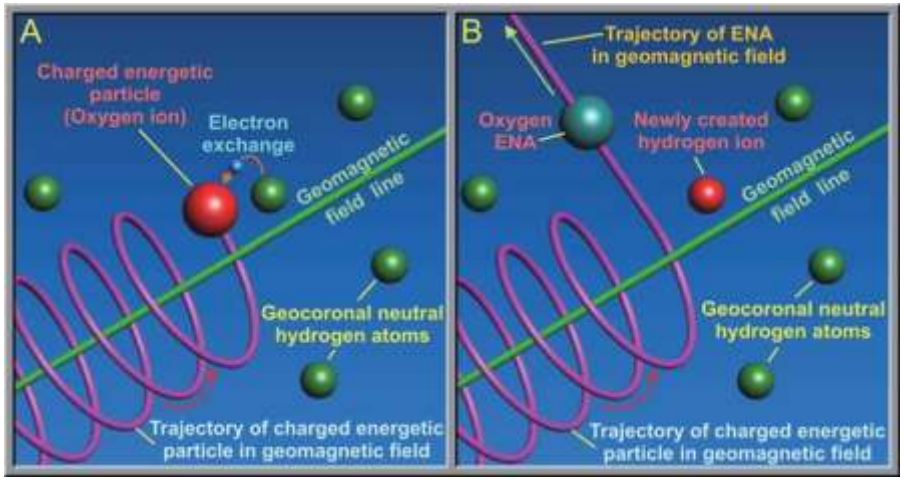
  --- the burst block fast flow (BBF)

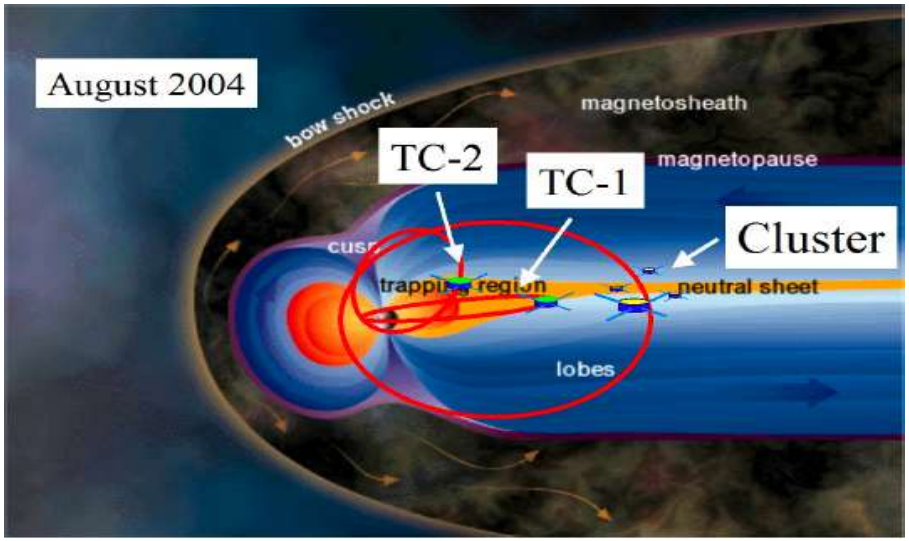


- Study on the diplarization and the particles dynamics

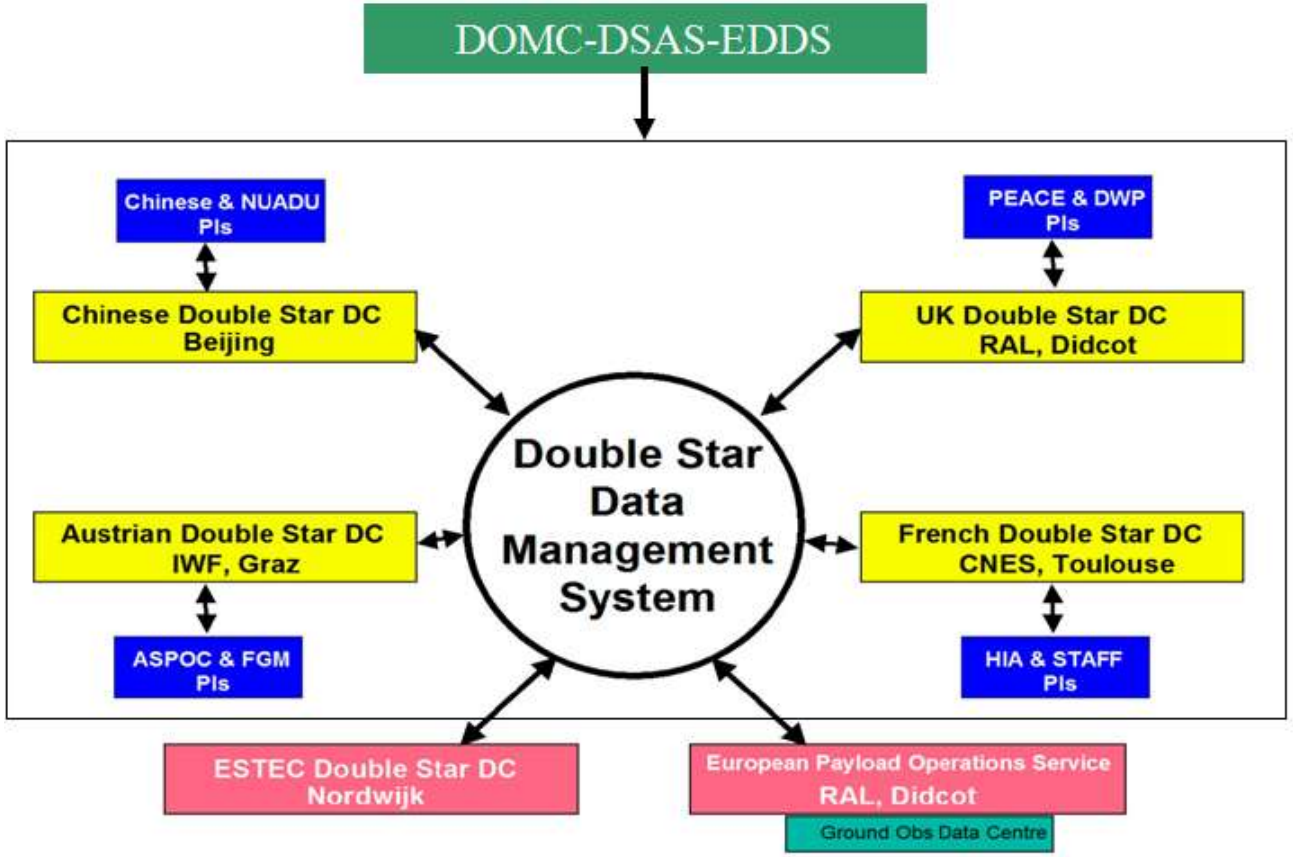
- Study on physics process in the field line from magnetotail to polar region to understand the time series of the phenomenon in the substorm.

The NUADU onboard TC-2 observe the ring current, radiation belt and auroral particles with Eenergetic Neutral Atom Imager





3. The DSP science data system



Double Star Science Data System

(1) The DSP downlink data receive in three ground stations

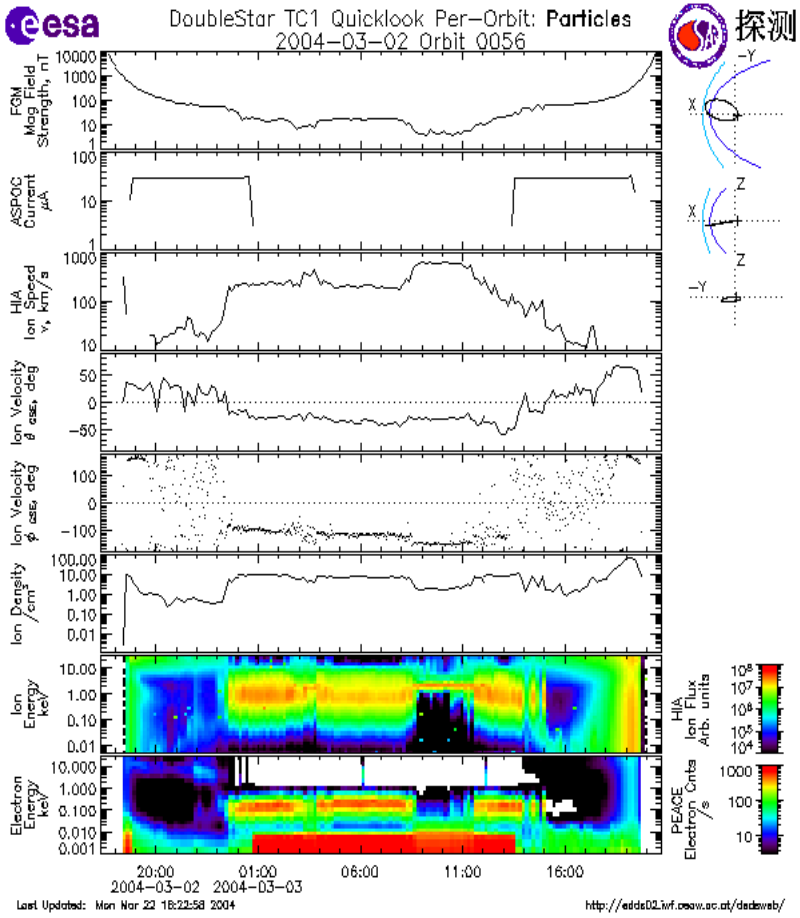
- There are three Ground Stations to receive the DSP science data:
  --- Vilspa Station, ESA's ground station in Vilafranca, Span
  --- Miyun Station, China's ground station in Beijing, China
  --- Shanghai Station, China's ground station in Shanghai, China

(2) Science Data Levels

- The are 4 data levels defined in the DSP data system:
  --- Level 0 (L0): the downlink data
  --- Level 1p (L1p): 20 minutes of each obit, for each instrument and each S/C. for payload health checking, available in one day
  --- Level 1 (L1): raw data, 1 file per day for each payload and each S/C, available in 2 days,
  --- Level 2 (L2): calibrated data, available in 2 months,
  --- Level 3 (L3): Data products, Including PP, SP and auxiliary data, available in 3 months.

(3) Double Star QuickLook web page (DSDSweb)

- It displays the latest data from each instruments in each DSP S/C.
- It is available in each DC for Scientific user to quick look the latest data.
- It is not calibrated data.
- It is available in 2 days after downlink.



(4) DSP data products

- The DSP science data product means the Level 3 data
  --- Prime Parameters, spin average, about 4 seconds time resolution, also called “PP data ”.
  --- Summary Parameters, 1 minutes average, also called “SP data”.
- The are also auxiliary data available together with the PP and SP data for science user, they are:
  --- LTOF: Long Term Orbit File
  --- STOF: Short Term Orbit File
  --- LTEF: Long Term Event File
  --- STEF: Short Term Orbit File
  --- CMD: CoMmand Definition file
  --- CMH: CoMmand History file
  --- SATT: Spin and Attitude file
  --- TCAL: Time CAlibration file
- In general, the scientific user needs the auxiliary data with the science data together to do data analysis.

(5) DSP science data distribution

- All the data are available in the website of each data center's (CDDC, ADDC, FDDC, UKDC and ESTEC DC)
- At present, all the DSP data is available together with Cluster data in the website http://www.cosmos.esa.int/web/csa/access

Chapter 4

DSP main science achievements

Outline

1.DSP main science achievements

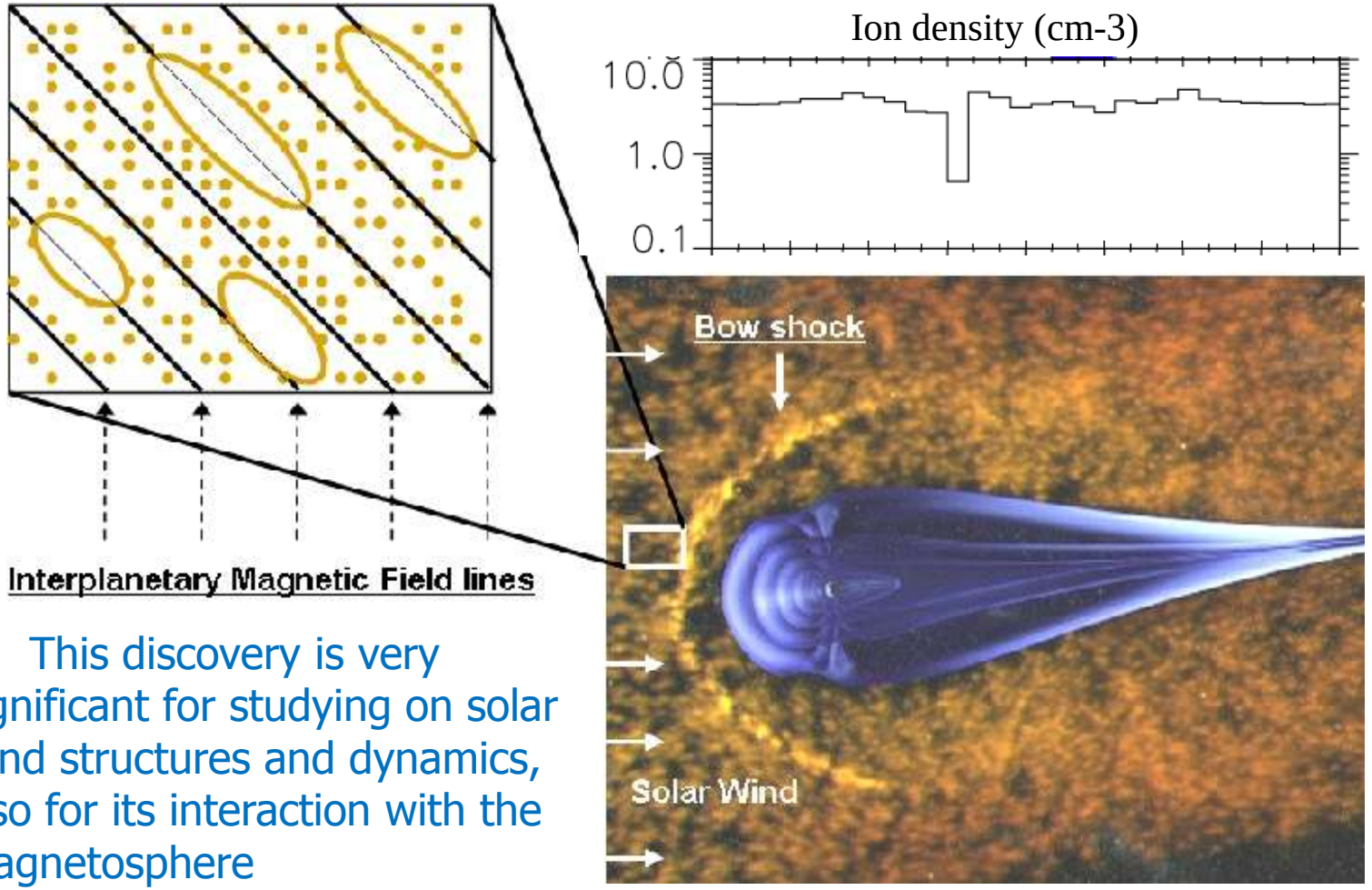
(1) Solar wind structure
(2) MR and FTEs at low latitude magnetopause
(3) Polar space particles
(4) Dynamics in the magnetotail
--- BBF
--- Large-scale waves
--- FACs
--- Particle distributions
(5) Substorm model
(6) Wave-particle interactive in Radiation Belt
(7) Others

2. Awards for the DSP

1. DSP main science achievements

(1) Solar wind structure

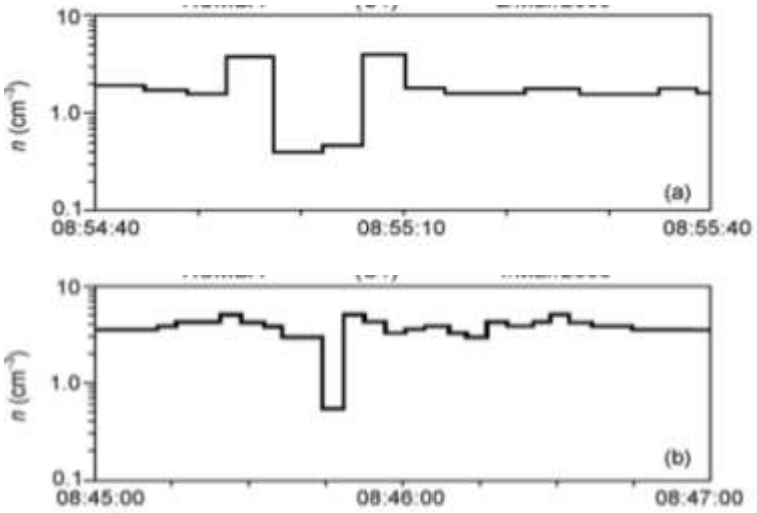
★ Cluster and Double Star, the first ever, discovered density holes in the solar wind in front of the bow shock. [Parks et al., 2006 and Schwartz et al., 2006]



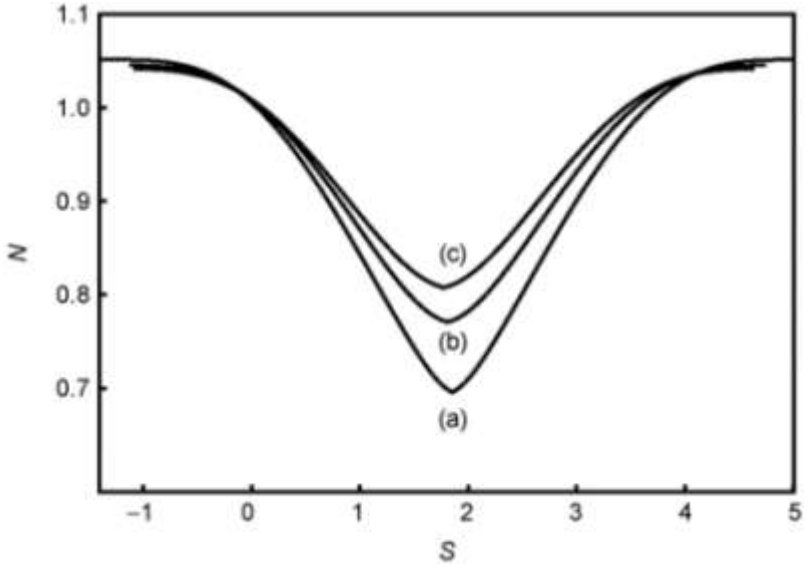
- This discovery is very significant for studying on solar wind structures and dynamics, also for its interaction with the magnetosphere

- TC-1 and Cluster observed ion density holes can be ~3700 km.
- The size of the hole edges is ~1300 km Earthward and 2300 km Sunward, making the overall size of the structure more than 7000 km.

(Parks et al., 2006 and Schwartz et al., 2006)



Solar wind Ion density (cm-3) observed by DSP and Cluster



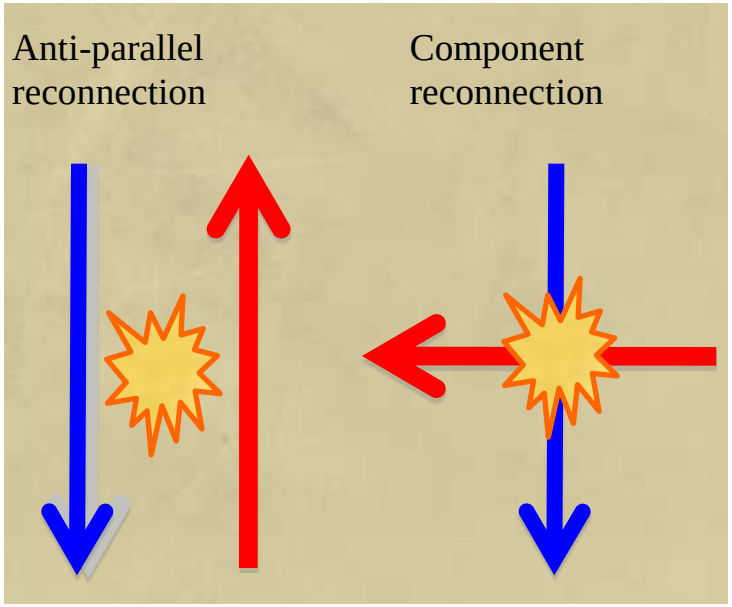
- An electrostatic ion fluid model proposed to interpret density holes in the solar wind observed by DSP and Cluster.
- The model results are good consistence with the observations.

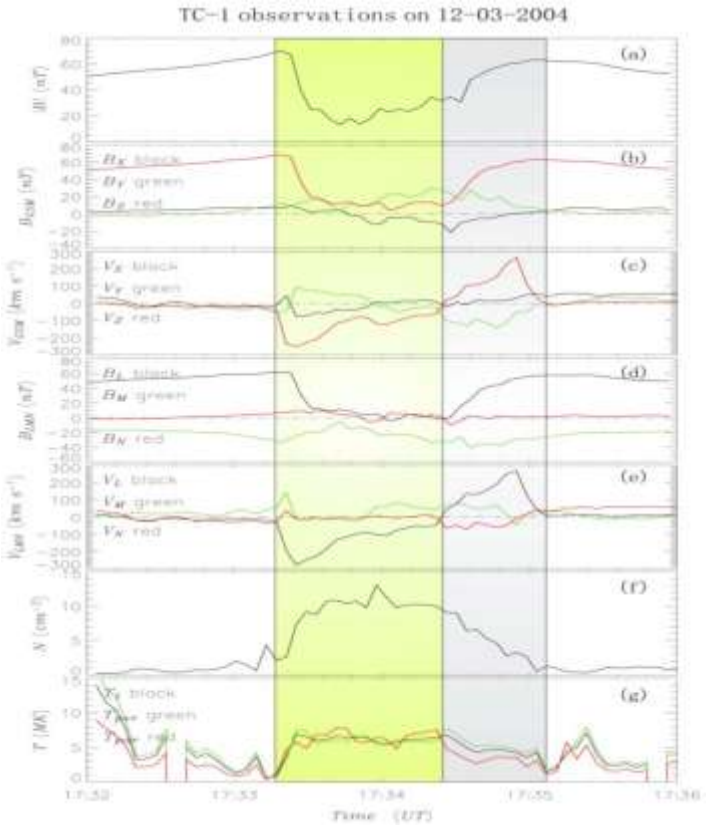
(Qureshi and Shi, et al., 2006)

(2) MR and FTE at low latitude magnetopause

★ DSP observed component reconnection at low latitude M-pause

It is the first ever to give an observation evidence for component reconnection **(Pu et al., 2005)**

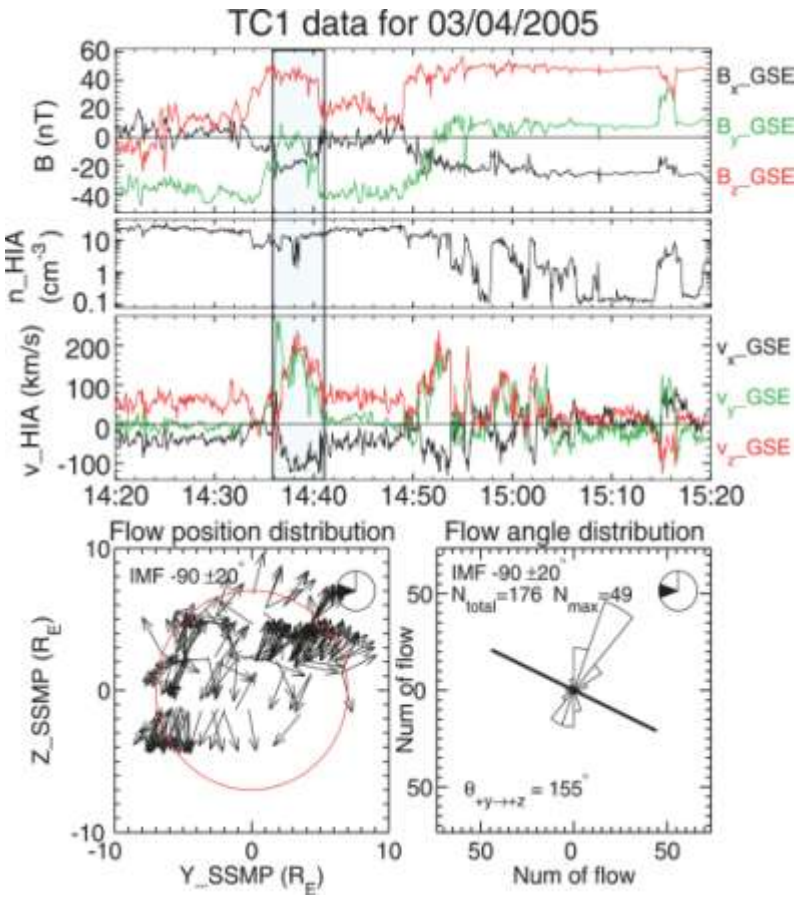




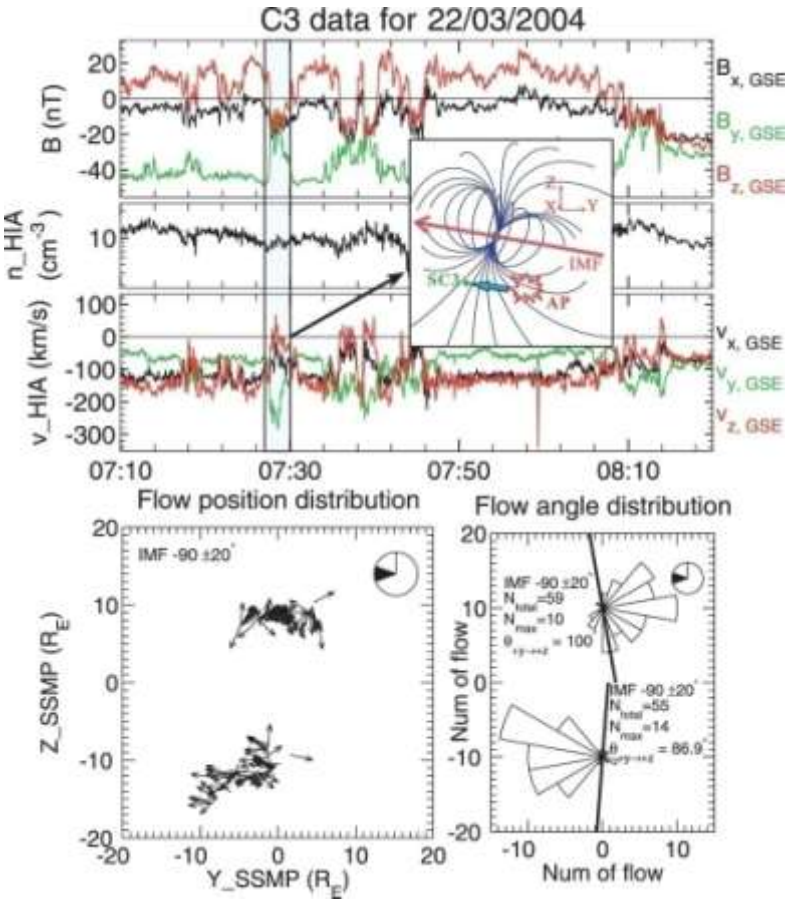
(12 March 2004): TC-1 observed the M-spheric part of the quadrupolar field, together with a consistent flow reversal.

★ FTE: A possible S-shaped configuration of the reconnection X-line under dawnward dominated IMF orientation, the first ever detection.

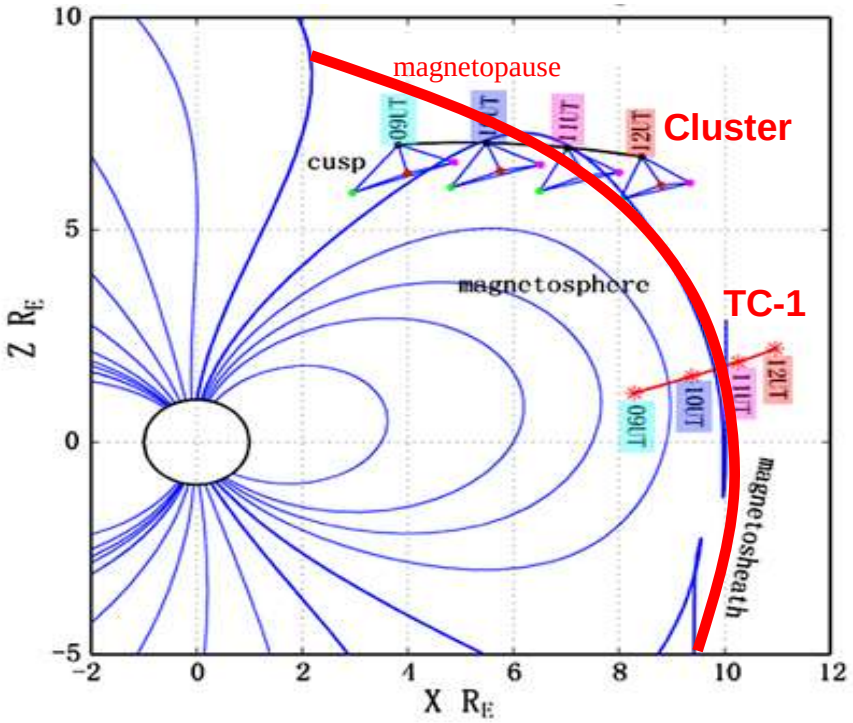
(Pu et al., 2005, Dunlop et al., 2009)



(Top) TC-1 observations during 1420~1520 UT, Apr. 3, 2005, and (Bottom) statistical results of fast flows in/near the subsolar MP region.

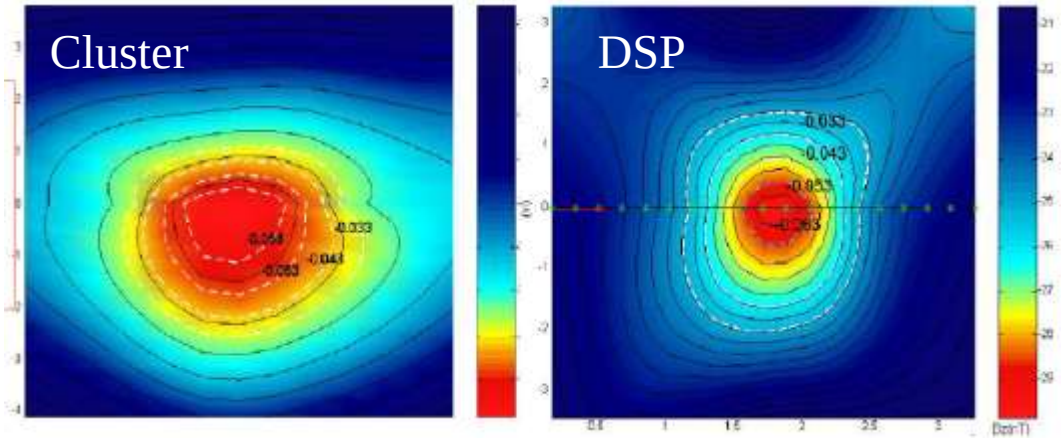


(Top) Cluster/C3 observations during 0710~0820 UT, Mar. 22, 2005, and C3 position in T96 magnetosphere model, and (Bottom) the statistical results of fast flows at high latitude MP.

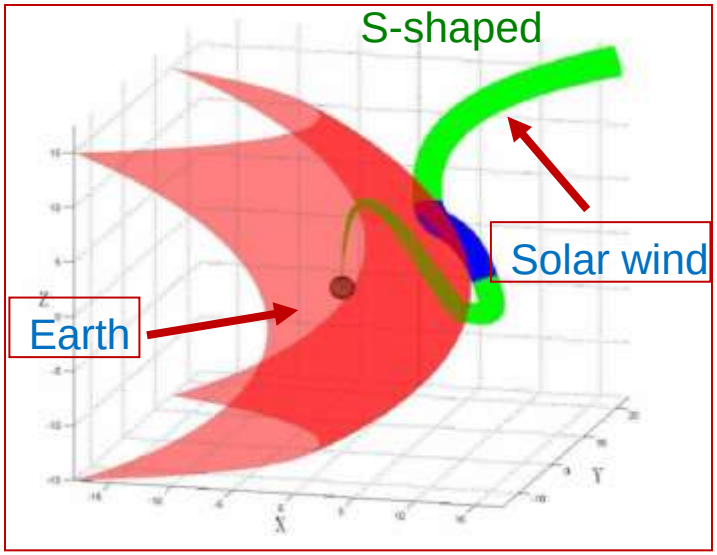


- TC-1 and Cluster data show both component and anti-parallel reconnection at the m-opause when IMF is predominantly dawnward.
- According to statistics of 290 fast flows in both the low and high latitude magnetopause, a possible S-shaped configuration of the X-line was drawn

(Pu et al., 2005)

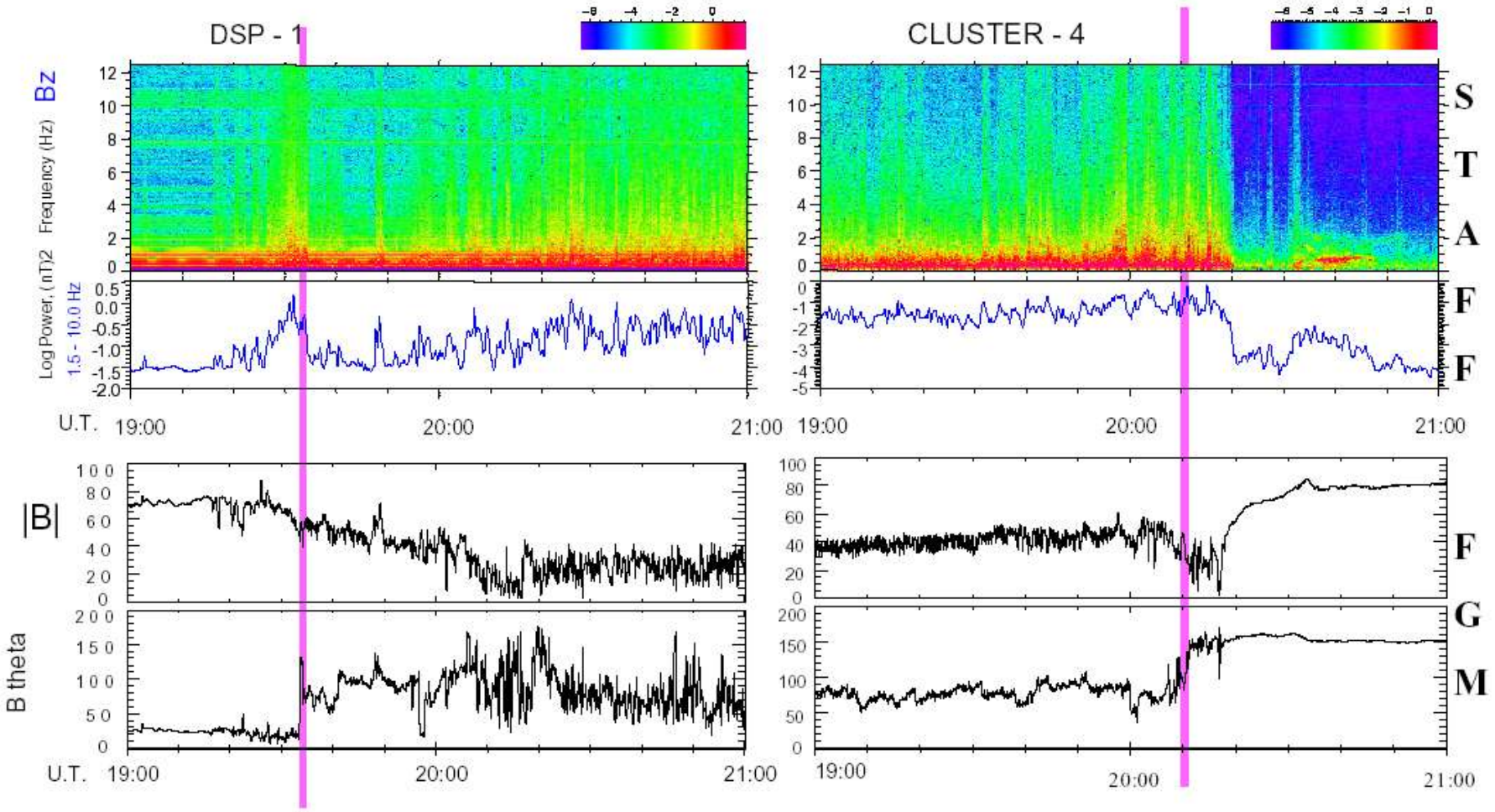


FTE Cross-section

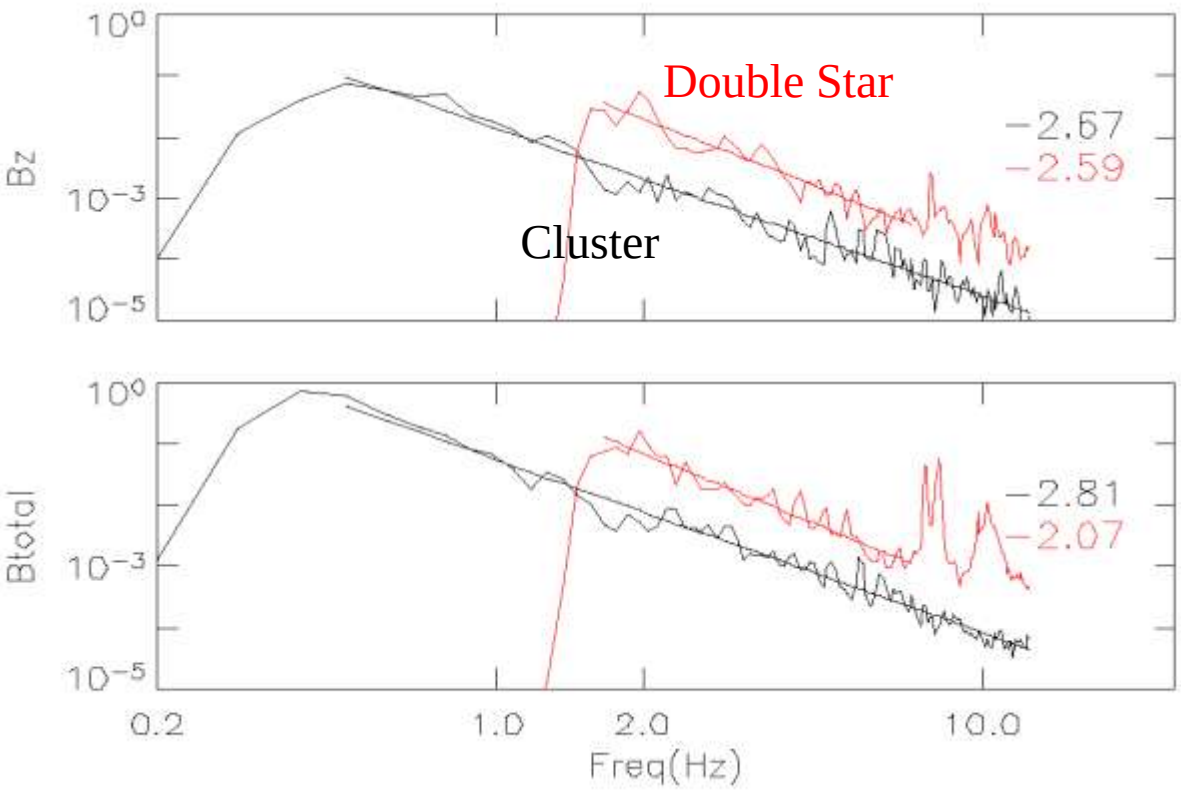


★ Magnetic fluctuations at the magnetopause were concurrently observed by DSP and Cluster at the same time, the first ever.

From Cornilleau et al., 2005



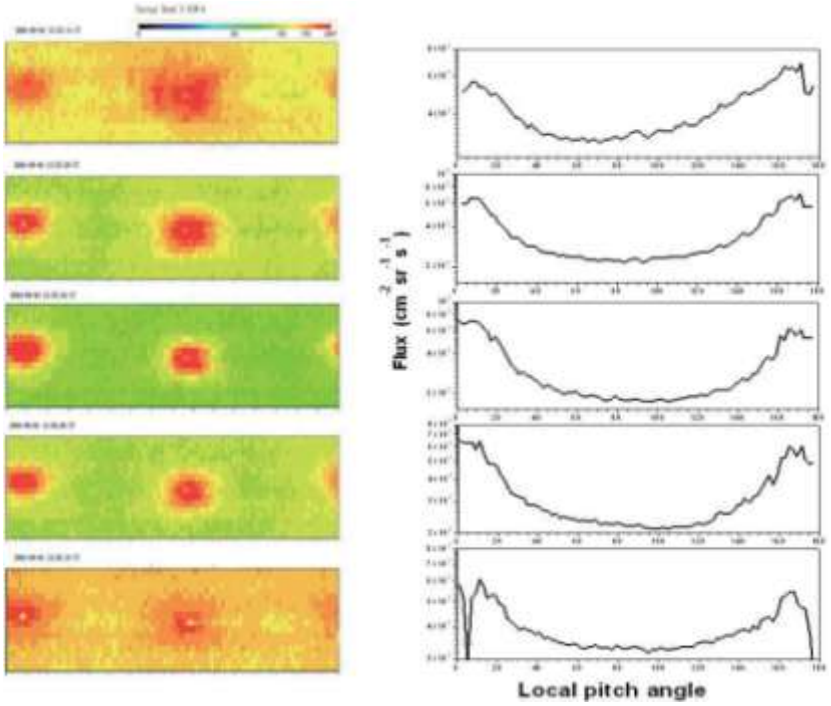
- The DSP and Cluster found that the Magnetic fluctuations increased at Equator
- 10 times wave power at subsolar (Double Star) than high latitude (Cluster)



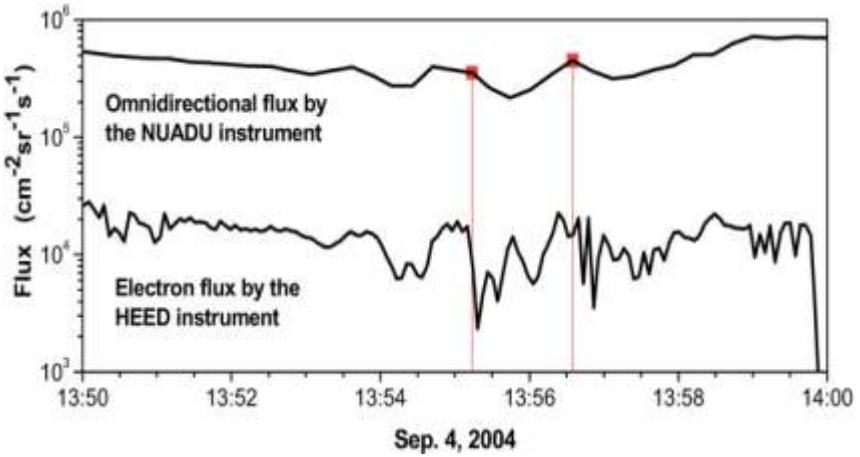
From Cornilleau et al., 2005

(3) Polar space particles

★ TC-2 data discovered the Up-flowing electron beams with “ring-like” pitch angle distributions at polar space (Lu et al., 2005)



NUADU (NeUtral Atom Detector Unit) data frames (left side) and local PAD plots (right side)

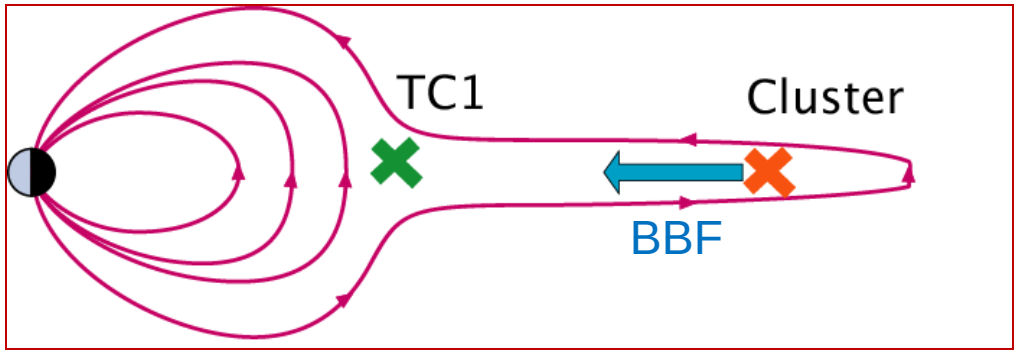


The omnidirectional electron flux (top line) recorded by NUADU, and the high energy (0.2–0.4MeV), omnidirectional, electron flux (bottom line) observed by the HEED instrument.
The vertical red lines indicate the period of the observations under study.

Changes in these pitch angle distributions due to transient magnetic variations are suggested to have been associated with electron acceleration along the geomagnetic field lines.

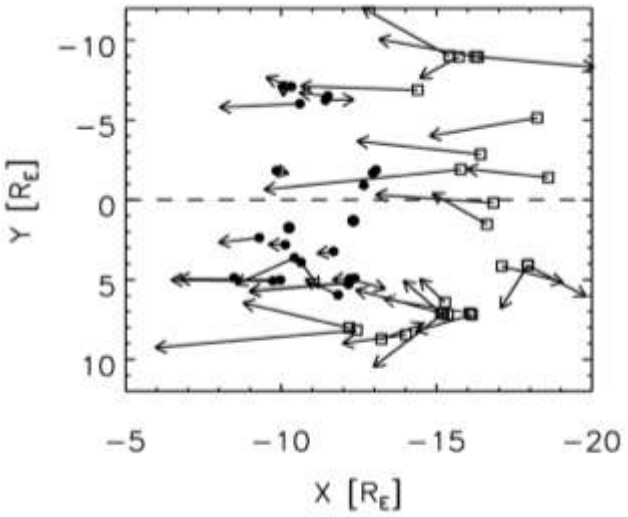
(4) Dynamics in the magnetotail

★ Both BBF with and without dipolarization observed by DSP and Cluster at plasmasheet

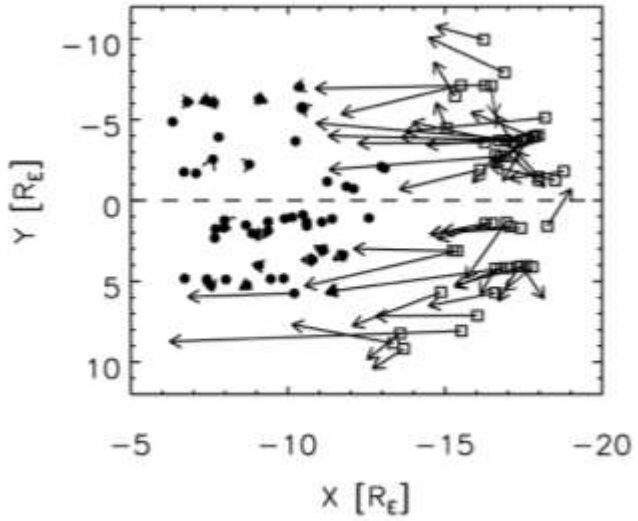


- BBF in the plasmasheet is a very important transport phenomenon to the substorm process.
- The TC-1 and Cluster concurrently observed the BBF can occur both with and without the dipolarization
- The magnetic topology in the inner magnetosphere can control the earthward penetration of BBFs

dipolarization and BBF

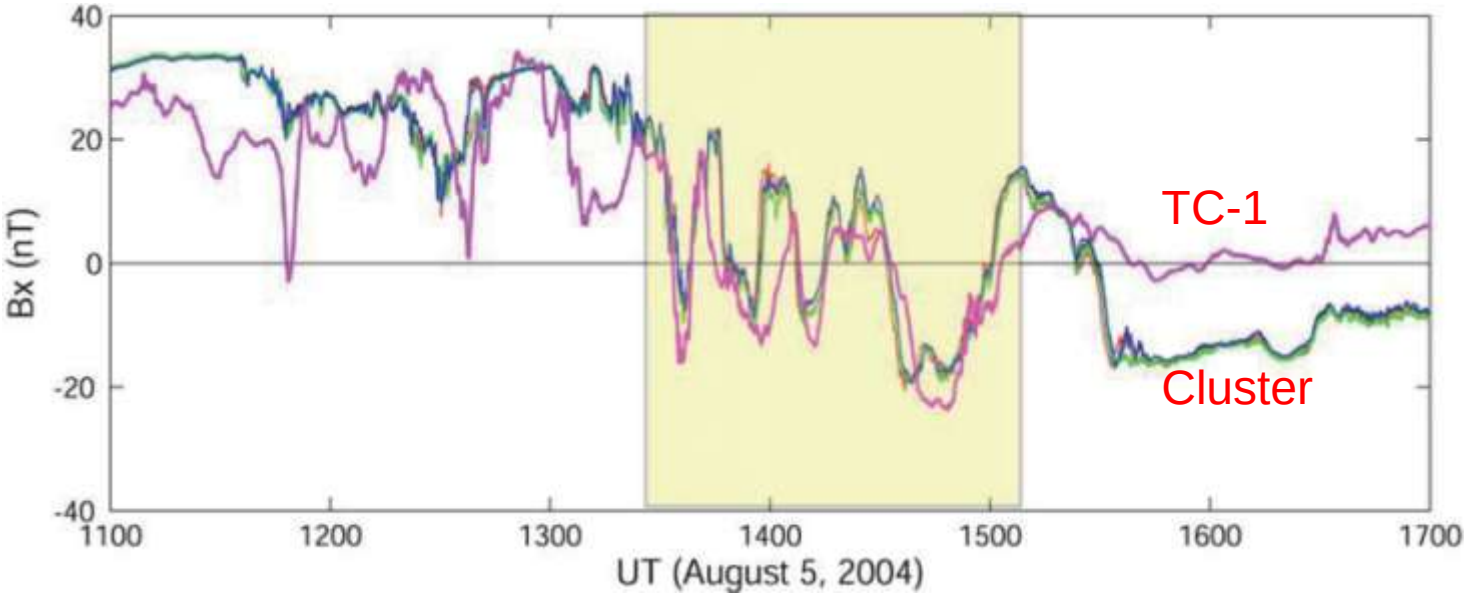


no dipolarization and BBF



[Takada et al., GRL, 2006]

★ The large scale neutral sheet oscillations were discovered by the DSP and Cluster in the magnetotail

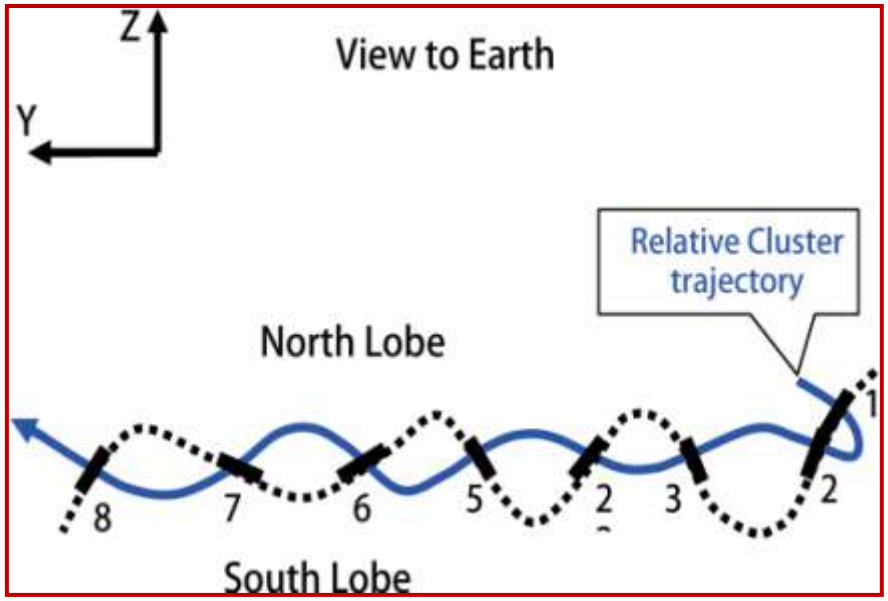


Bx components of the magnetic field observed by Cluster and TC-1. The shaded region indicates the eight neutral crossings to be studied in detail.

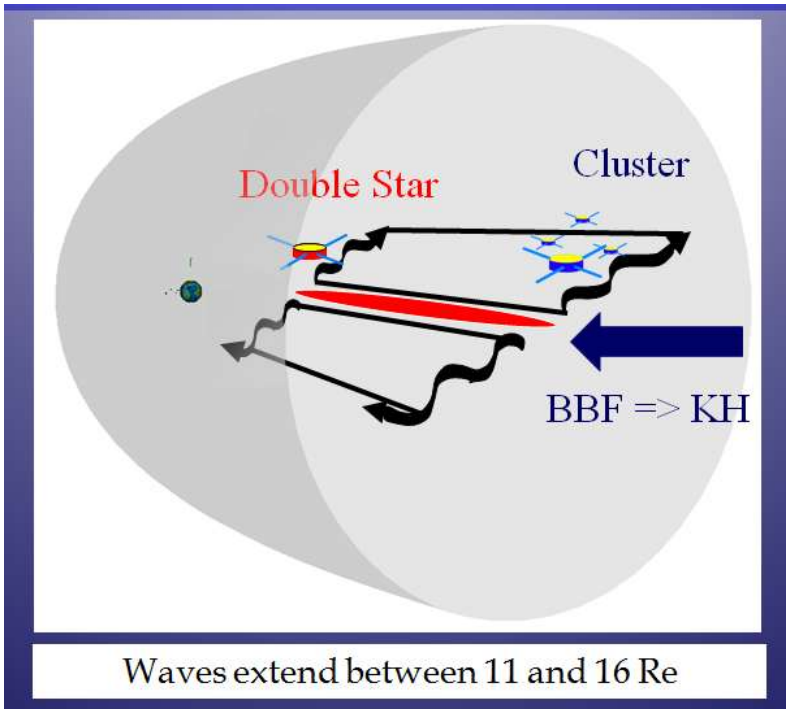
Eight crossings both for TC-1 and Cluster were identified, as shown in the figure, by shaded area. These multiple crossings are due to the dawn-dusk wave propagating across the neutral sheet.

[Zhang et. Al., 2005]

- The DSP and Cluster observed kink-like wave from the central of the magnetotail propagates toward the tail flanks.



Schematic illustration of the motion of the neutral sheet determined from each individual crossing in the plane.

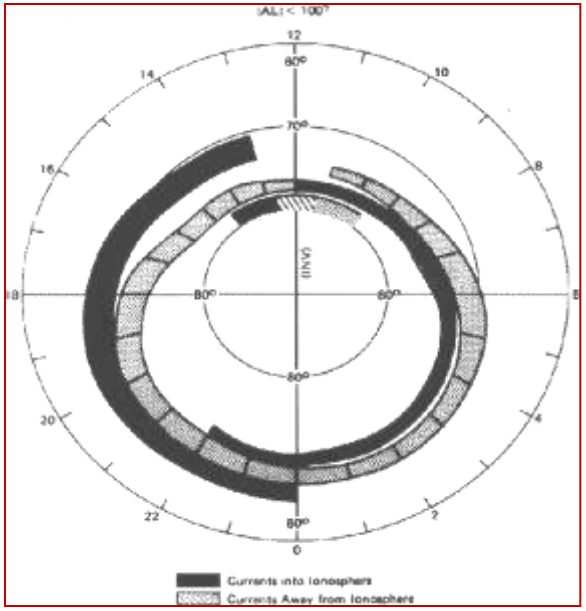


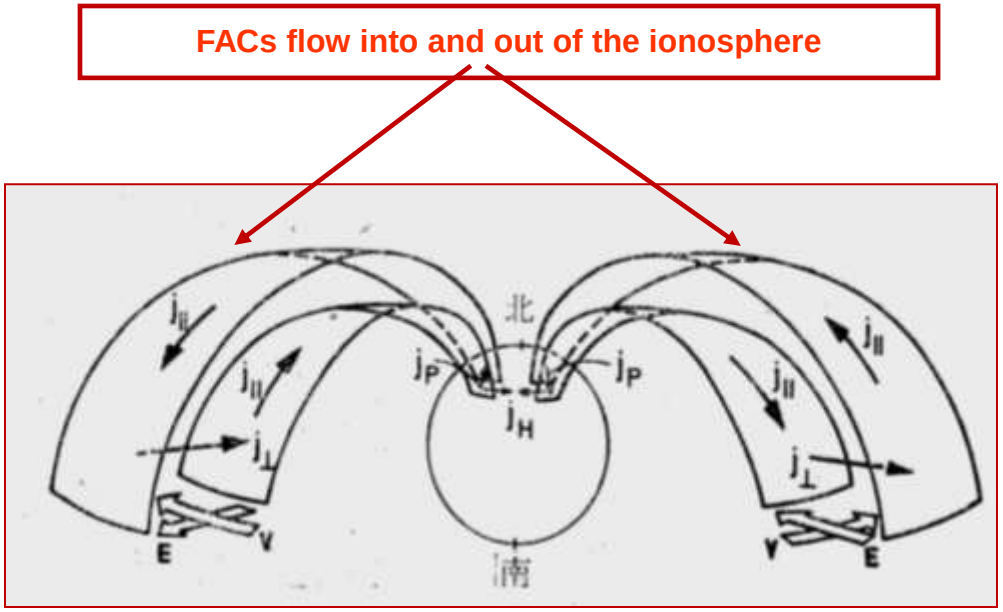
- The waves extend 5 Re in the X-direction, from TC-1 location (11 Re) to Cluster location 16 Re)

[Zhang et al, 2005; Volwerk et al, 2007]

★ TC-1, TC-2, and Cluster observed large-scale FACs simultaneously in the Ionosphere-magnetosphere coupling system, the first ever

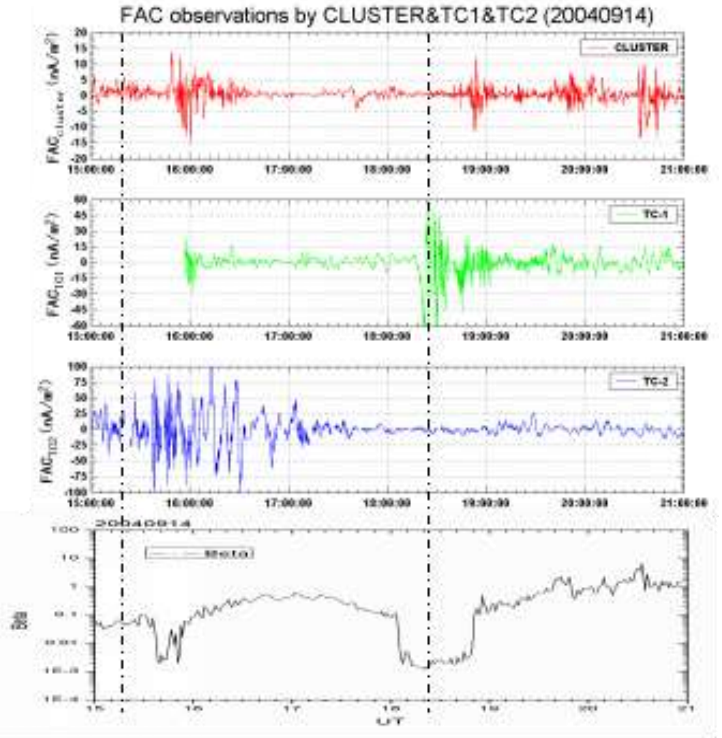
- We know the R1 and R2 FAC in the polar region which is concerning the particles dynamics

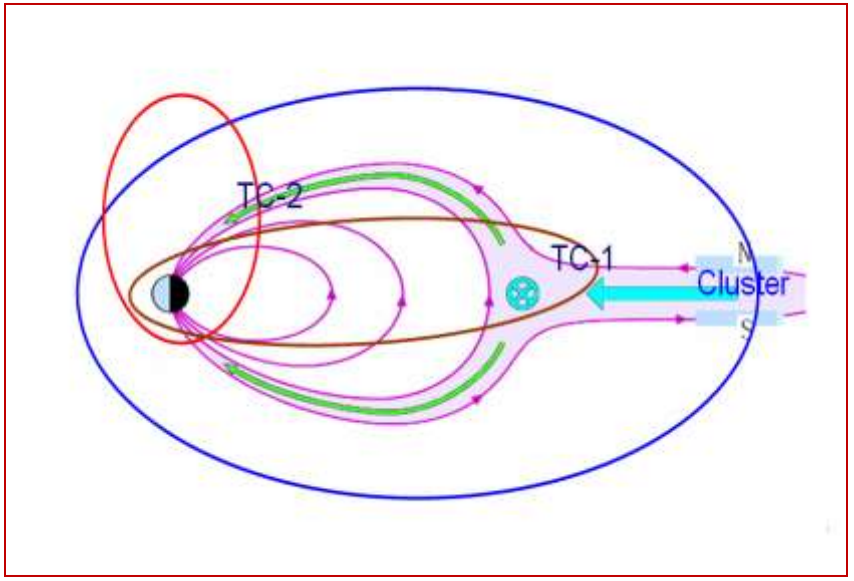




- The R1 and R2 FAC in the polar region was considered along the field line and connecting the magnetotail
- However, there was no observation to show that.

- The TC-1, TC-2 and Cluster observed FACs simultaneously



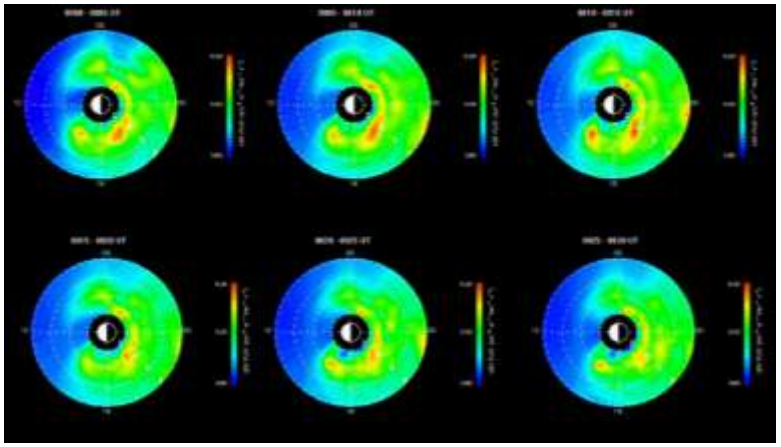


- It is in three substorm times, the TC-2 just in the polar space TC-2, TC-1 in the near Earth Plasma Sheet Boundary Layers and the Cluster in the further magnetotail ,
- It is the first time to give an observation evidence for the large scale FAC simultaneously appearing along the field line from polar region to magnetotail.

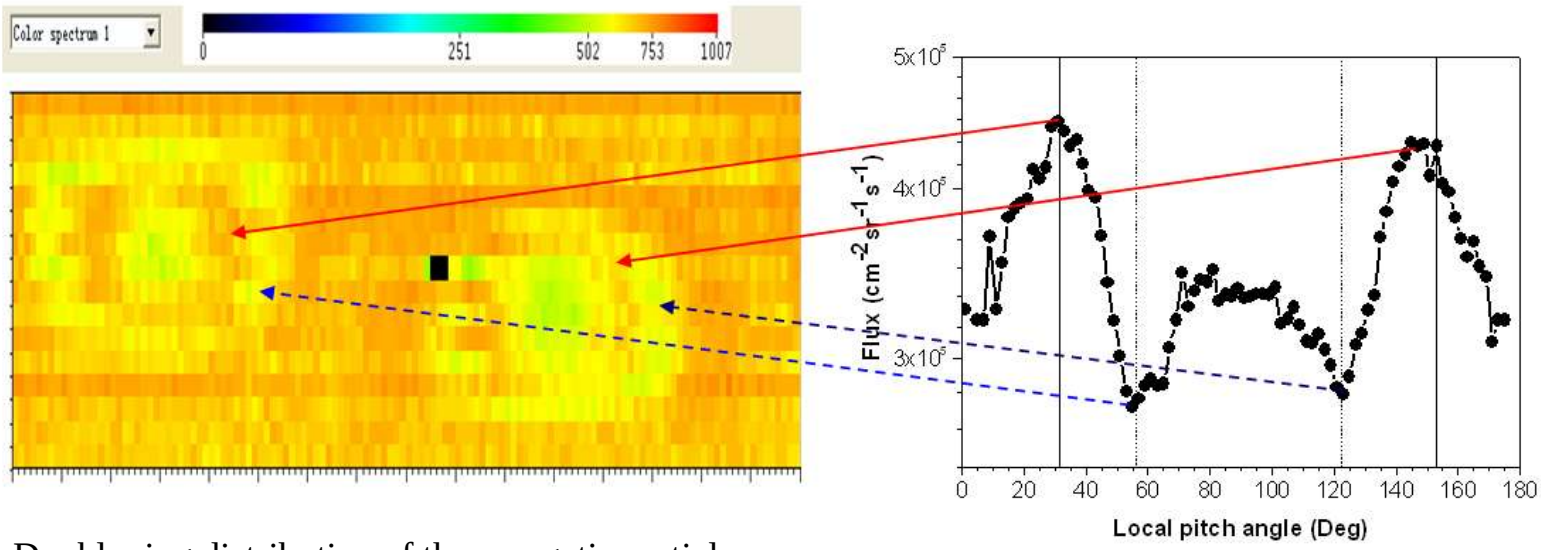
(Shi et al., 2013)

★ DSP discovered double ring distribution of the energetic particles in the ring current region (Lu et al., 2005)

- The NUADU (neutral atom imager) onboard TC-2, obtained ions flux distribution and variation in the equatorial plane of the ring current
- It discovered the ion distribution was with a double ring structure
- This is important to study the particle dynamics in the ring current



The ions flux distribution and variation in the equatorial plane of the ring current

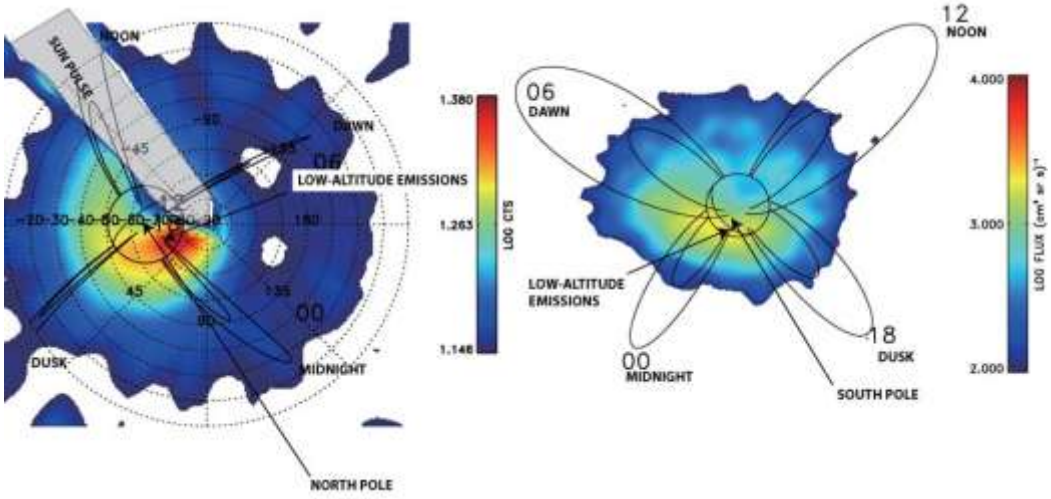


Double ring distribution of the energetic particles

★ DSP / NUADU and IMAGE / HENA simultaneously observed the ions injection into inner magnetosphere in the nightside

(McKenna-Lawlor et al., 2005)

NUADU/ DSP, North HENA/IMAGE, South

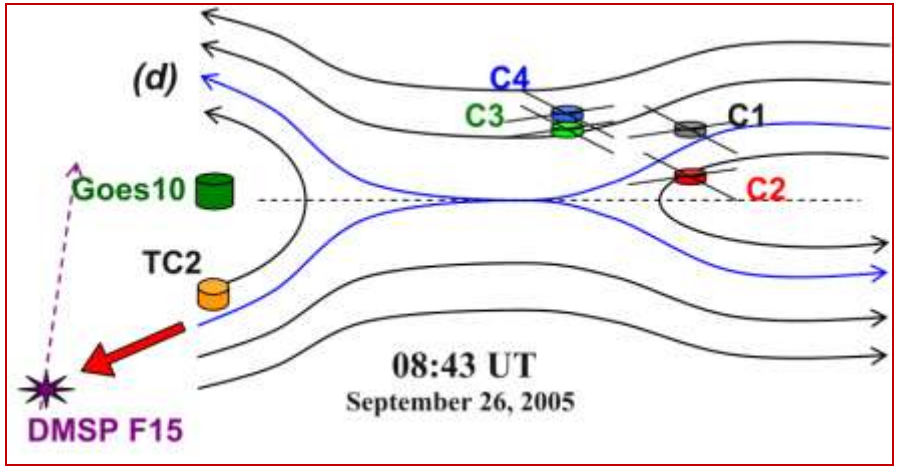


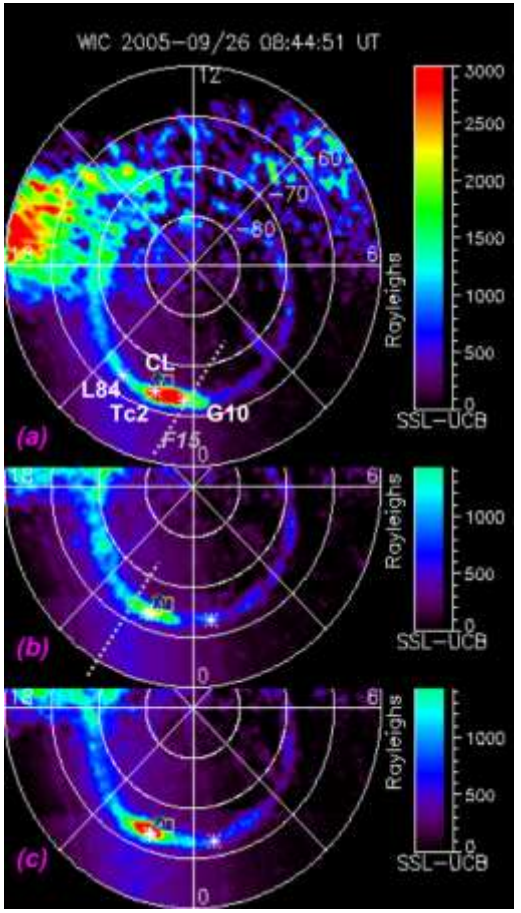
- ENA image obtained by NUADU in the 81–158 keV range in the North pole and obtained simultaneously by HENA/IMAGE in the 60–119 keV range in the South pole on Nov. 8, 2004.
- From the both hemispheres, the ring current can be seen extending from local midnight through dusk.
- This shows that enhanced emissions in the local midnight through the dusk sector, indicating that ions were injected on the nightside into the inner magnetosphere

(5) Substorm model

★ TC-2, Cluster and other S/C observed the current disruption process and MR are coincidence in space and time in substorms

- Three consecutive substorm onsets on Sep. 26, 005 were analyzed with DSP, Cluster, Goes an DMSP data.





- The data indicate the current disruption and M-R coincide in space and time showing the same process in the two sides.
- Also, M-R occurred closer to the Earth than usual, almost co-located with the current disruption process, 60,000 –90,000 km.

(Sergeev et al., GRL 2007)

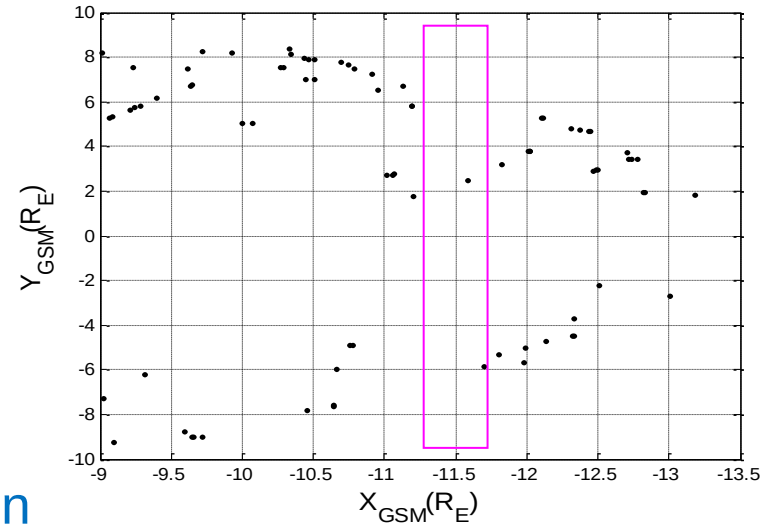
★ TC-2 observed the lost of the earthward flow at 11.5 Re magnetotail

- Plasma flow is a very important process in the magnetosphere, especially in the storm and substorm times

- The flow were both earthward and tailward

- According to statistics, DSP shows lost of the Earthward flow at 11.5 Re magnetotail

- This is provides an observation to understand the substorm mechanism



The Earthward flow in the magnetotail observed by TC-1

(Zhang et al, JGR, 2009)

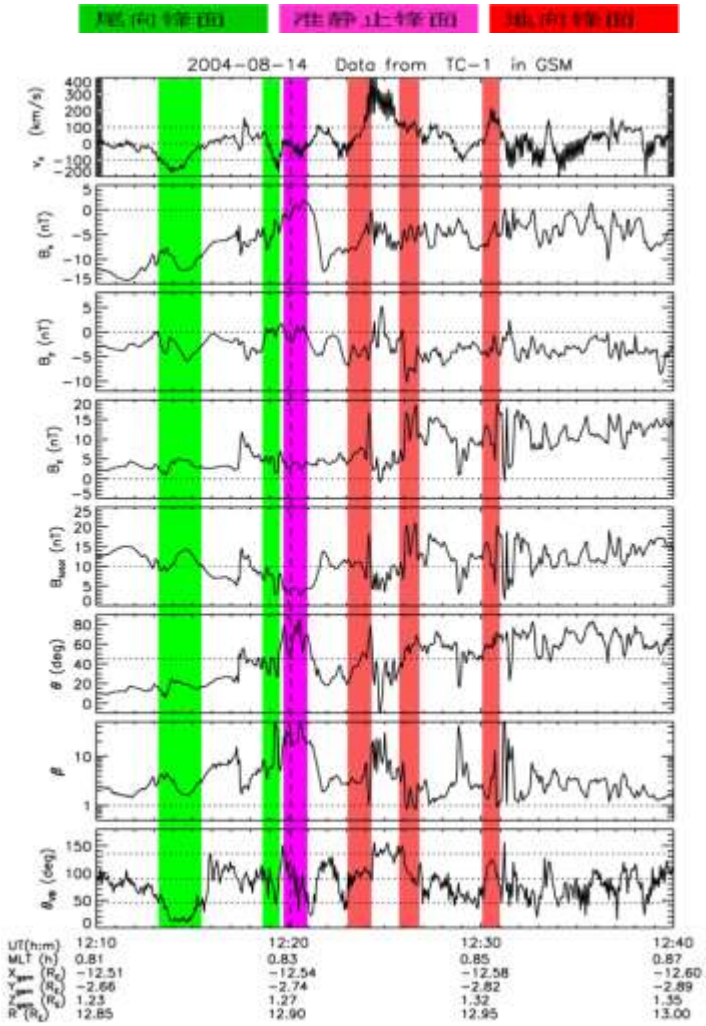
Based on the observation and the lost of the earthward flow, Prof. Liu proposed a new substorm model: Front Interaction Model

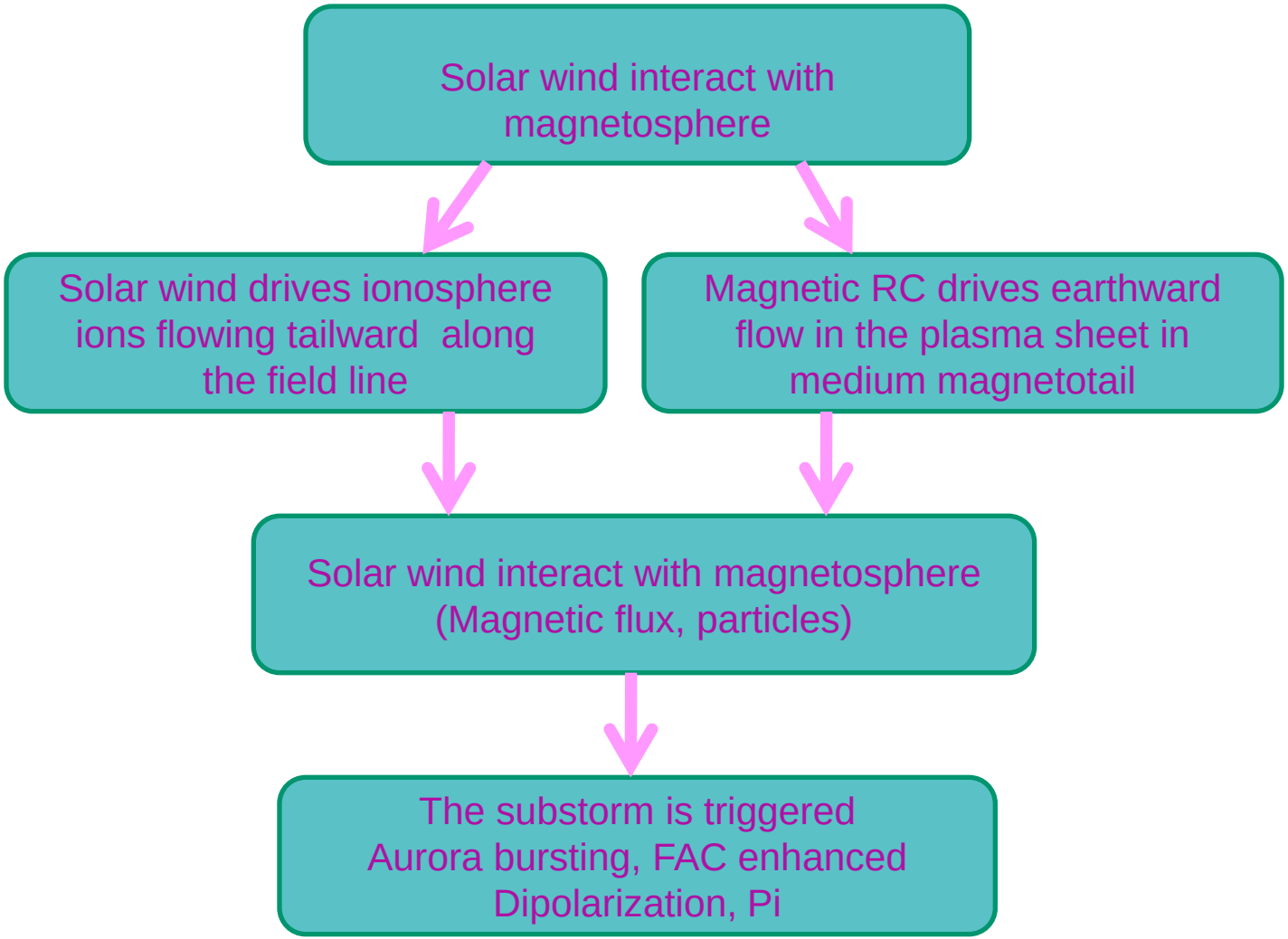
★ Proposed a substorm onset model: Bidirectional Flow Front Interaction model (BFFI) (Liu et al, 2006)

The BFFI model is based on the dada analysis of the DSP, Cluster and other satellite observation, considering that:

- Two plasma flows in the nightside magnetosphere: Tailward flow from the ionosphere, Earthward flow from the magnetotail.
- TC-2 observed the lost of the earthward flow at 11.5 Re magnetotail
- According to DSP and Cluster observation of 6 substorms, it is found that the substorm onset process have the time series:

-- Tailward flow front (Energy storage)
-- Quasi stable flow front
-- Earthward flow front (Energy release)

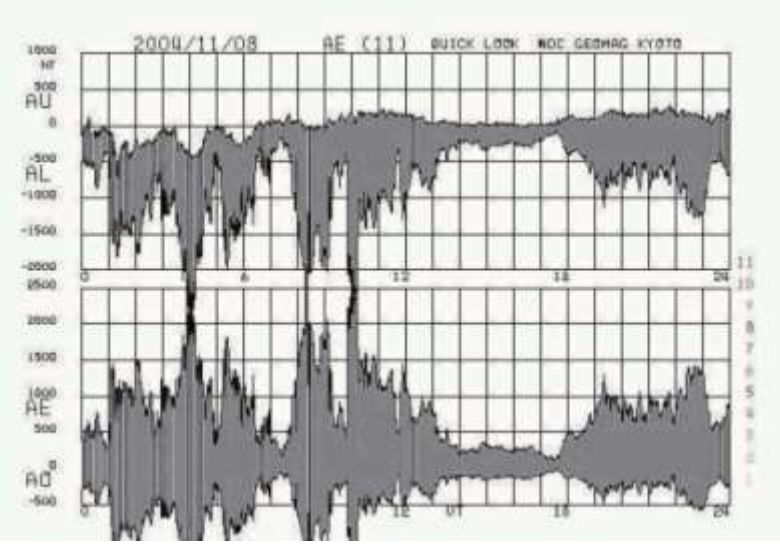




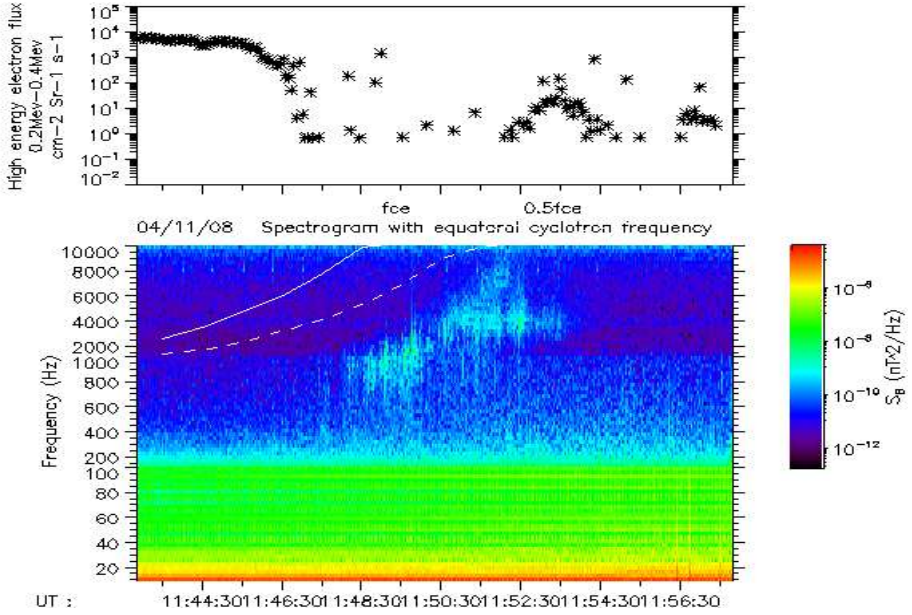
Substorm Bidirectional Flow Front Interact (BDFFI) model illustration

(6) Wave-particle interaction in radiation belt

★ LFEW and HEED onboard TC-2 observed the wave-particle interaction in the radiation belt, It is the first ever.



the AE index on Nov. 8th 2004

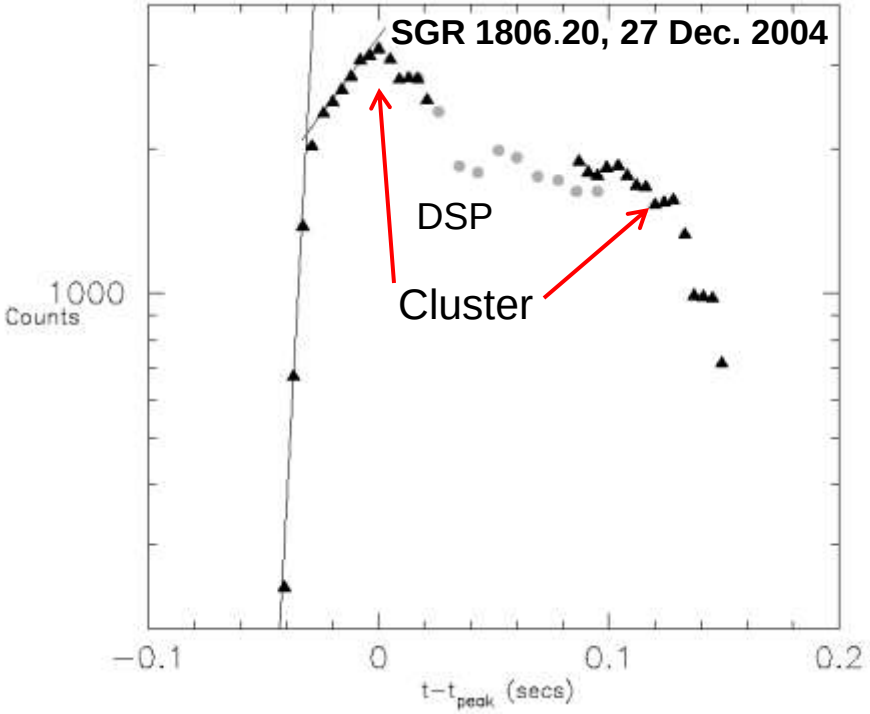


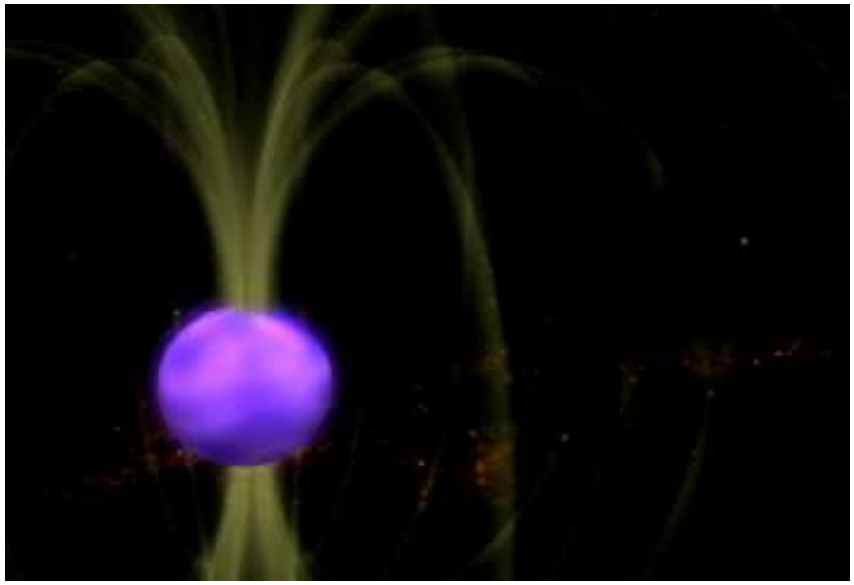
The high energy electron flux from HEED and the power spectral density of waves from LFEW on Nov. 8th 2004.

- During the large geomagnetic storm on Nov. 8th 2004, the LFEW and HEED of TC-2 observed relativistic electrons and whistler mode waves concurrently.
- The wave power enhanced and the electron flux reduced indicated the wave-particles interaction.
- This is the first time to give an observation evidence for the wave-particle interaction in the radiation belt. (Cao et al., 2007)

(7) DSP and Cluster observed on other star crust cracks

★ On 27 Dec.2004, TC-2 and Cluster observed a cracks in the neutron star crust in the universe (Schwartz et al., ApJ, 2005)





Kouveliotou, Duncan, Thompson, 2003

- Cluster and DSP PEACE detected electron peak intensity was hundreds of times stronger than any other observed so far.
- For the first 200 ms, it saturated almost all satellites instruments to observe γ-rays. Cluster and DSP detected the electrons.
- It is the first time observational evidence of cracks in the neutron star crust, during the initial phase of the starquake.

2. Awards for the DSP

Laurels Team Achievement Awards

DSP/Cluster obtained IAA 2010 “Laurels Team Achievement Awards”

International Academy of Astronautics

Laurels for Team Achievement

DOUBLE STAR and CLUSTER TEAM

Representing both the first Chinese space science mission and the first Sino-European space program cooperation, the team of scientists, engineers and managers of the Double Star and Cluster missions have made the extraordinary achievement of the first ever coordinated six-point multiple-satellite measurements, which have advanced our understanding of the dynamic properties of the Earth's magnetosphere, in both macro and micro scales.

China:

Zhenxing Liu, Ji Wu, Yongwei Zhang, Shigong Yuan, Qiang Liu, Kaixiang Zeng, Yanxong Xu, Hongliang Xu, Zuyin Pu, Jiankui Shi, Jinbin Cao, Chao Shen, Li Lu, Shoulan Dai, Jinrong Cai, Fengyu Liao, Fengmei Bian, Guangwu Zhu, Xiaomin Chen, Xin Meng, Xuzhi Li

Europe

Philippe Escoubet, Bodo Grankyn, Karl Bergquist, Henri Rème, Susan McKenna-Lawlor, Andrew Fazakerley, Christopher Carr, Yulong Zhang, Nicole Cornilleau-Wehrlin, Hugo Alleyne, Klaus Torkar, Trevor Dimbylow, Roland Nord, Stephane Ostpenco, Gunter Laky, Eric Sorensen

Awarded this day of September 26 2010
Prague, Czech Republic

The President

IAA Awards Ceremony 2010 in Prague

Representing both the first Chinese space science mission and the first Sino-European space program cooperation, the team of scientists, engineers and managers of the Double Star and Cluster missions have made the extraordinary achievement of the first ever coordinated six-point multiple-satellite measurements, which have advanced our understanding of the dynamic properties of the Earth's magnetosphere, in both macro and micro scales.

The Laurels for Team Achievement Award

(History)

2010 - Double Star and Cluster Team
2009 - Sea Launch Space Rocket System Team
2008 - International Team
2007 - Spirit and Opportunity Missions Team
2006 - Cassini - Huygens Program Team
2005 - VLBI Space Observatory Program Team
2004 - Hubble Space Telescope Team
2003 - SOHO Team
2002 - US Space Shuttle Team
2001 - Russian Mir Space Station Team

(From IAA Website)

The first level China national price for great contribution to Science and Technology Progress

(国家科学技术进步一等奖（2010）)

Chapter 5

What we learned from the DSP

Outline

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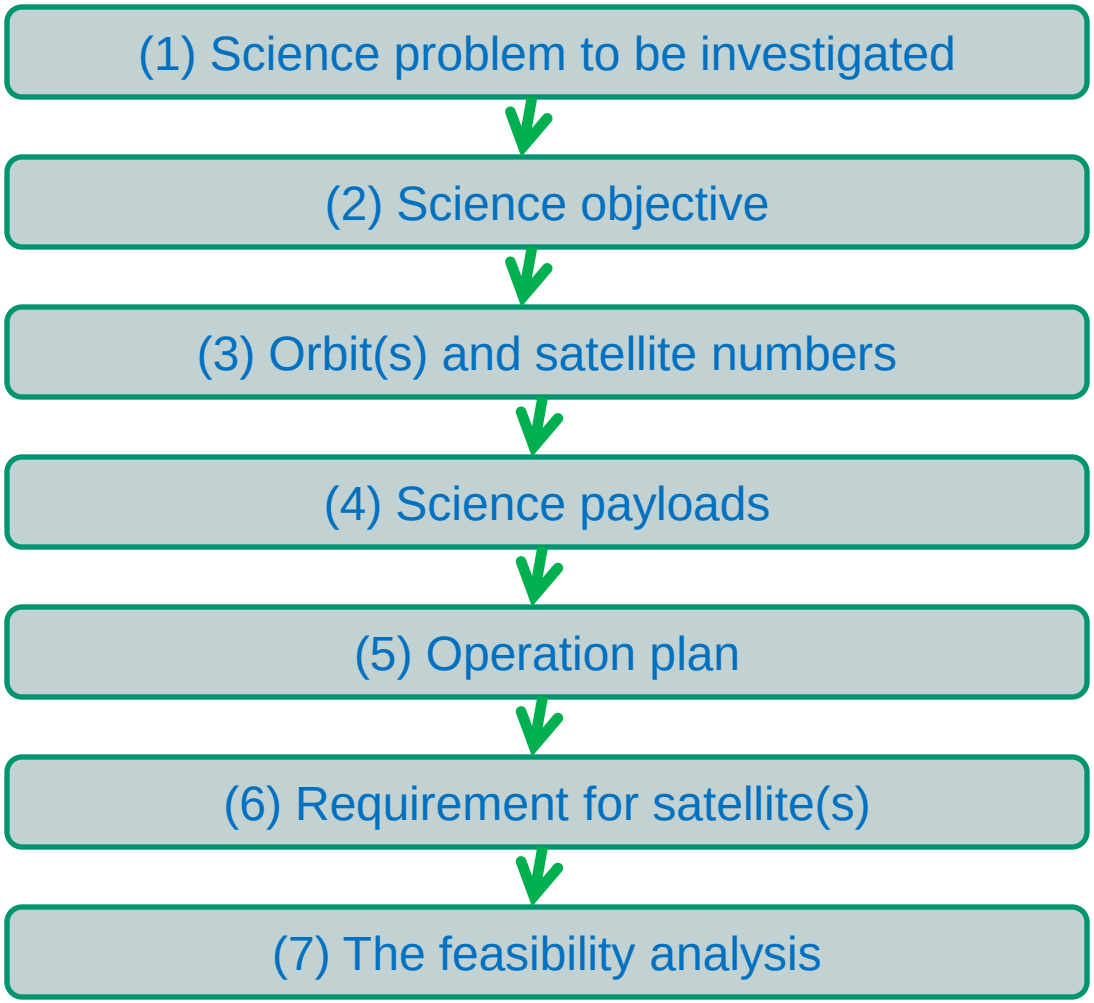
1. Main content of a proposal for a space science mission
2. What should be done for a space science mission proposal
3. Last words

1. Main content of a space science mission proposal



2. What should to done for a space science mission proposal

(1) The concerning science problems to be investigated

- This is based on the scientific research situation.
- In general, there are many science problems to be studied or further studied.
- The proposal person or group should choose that they are interesting or that is the key one to the scientific research.

For example:

--- Cluster: aiming to the small-scale plasma structures in space and time in the key plasma regions

--- DSP: aiming to the storms and substorm

(2) Science objective

The science objective means the main scientific goals of the proposed space science mission.

For example:

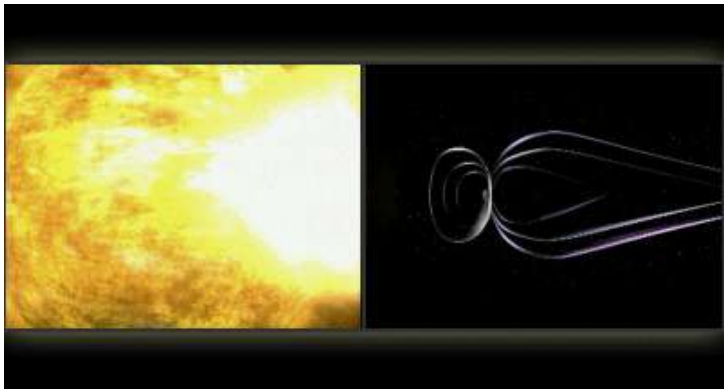
--- Cluster: Studying how the solar wind affects the Earth, making the most detailed investigation on the Sun and Earth interaction.

--- DSP: to understand the transfer of solar wind energy through the various boundaries, to study the MC process at the magnetopause and in the magnetotail, to study the particles acceleration in the geospace, ….

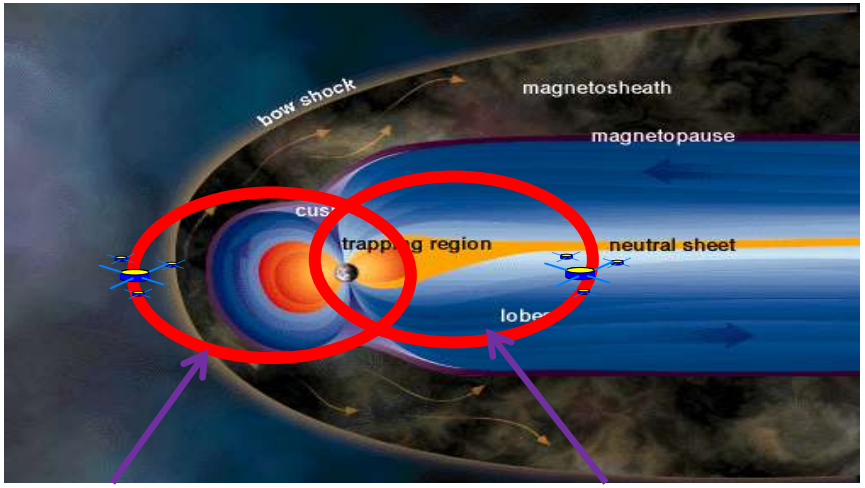
3. Orbit(s) and satellite(s)

The orbit(s) is(are) also basing on the aimed science problem and objective.
For example:

- Cluster: Studying how the solar wind affects the Earth, according to the process:

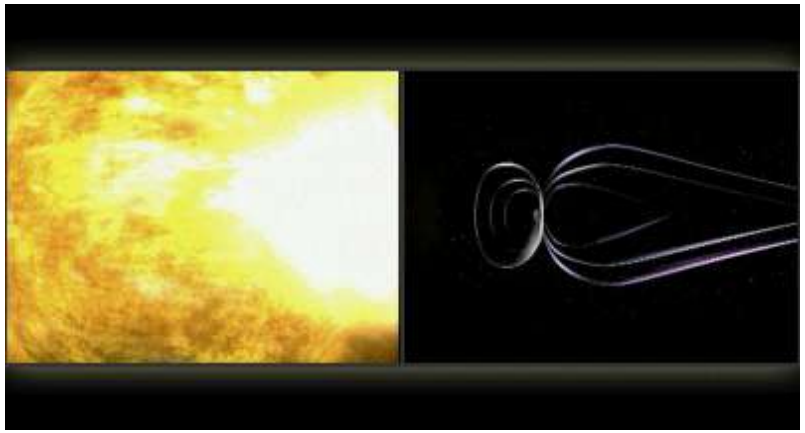


The Cluster orbit takes as:

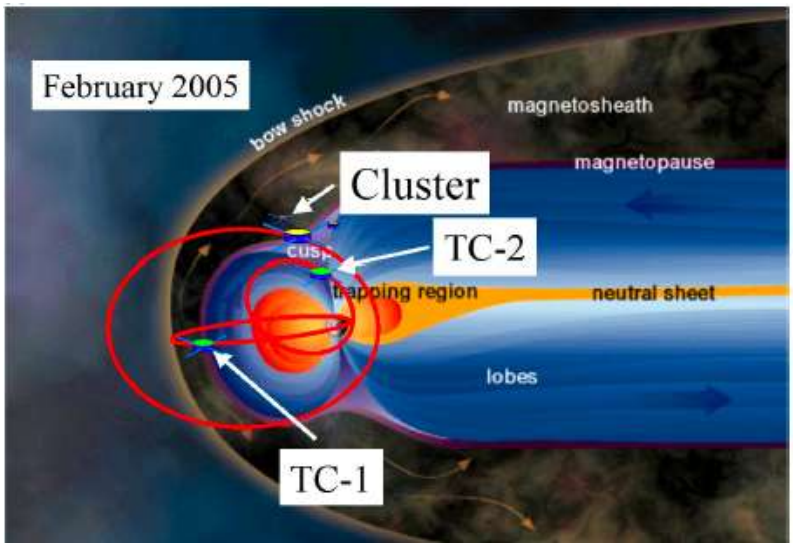


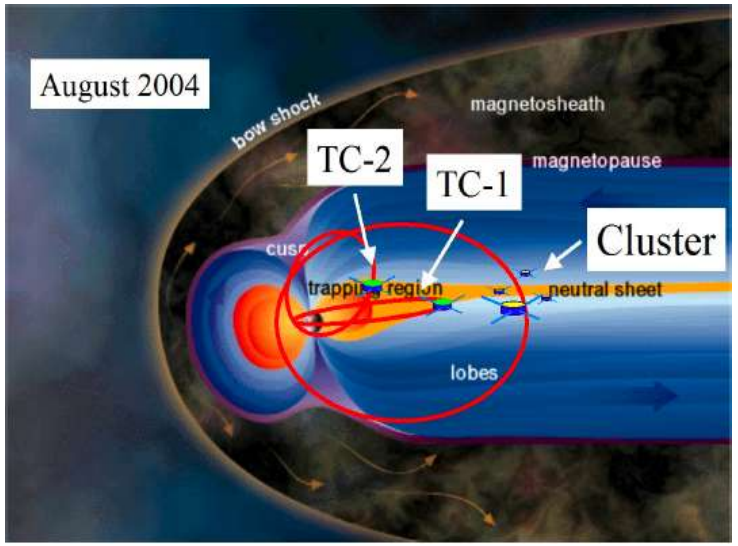
Dayside season orbit Nightside season orbit

- DSP: also considers the process:



The orbit designed as:

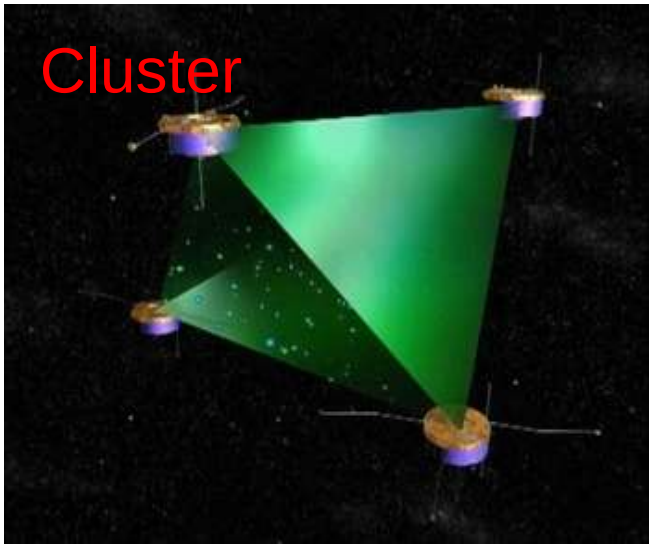




The satellite number is basing on the science problems, the objective. And the orbit. For example:

- Cluster, aiming to small scales, to study the detail of the process, the four S/Cs are used, forms an tetrahedron
  --- to observe 3-D and time-varying phenomena
  --- to distinguish the spatial and temporal variations

- DSP, aiming to the storm and substorm, to study the different scales, the Two S/Cs were used,
  --- TC-2 mainly to monitor the polar space, TC-1 mainly to monitor the magnetopause or magnetotail, the two ware coordinated.



(4) The science payloads

The science payloads are also based on the science problem and the objective. including:

--- The parameters to be measured,
--- The dimensions of the parameters
--- The quantity range of the parameters
--- The accuracy of the parameters measured
--- The temporal and spatial resolution
--- ……

--- Imager: View width, resolution, accuracy, …

The payload capacity and function are depend on the technology development.

(5) The operation plan

- What years the mission will be
  - --- high, low, or medium solar activity year?
  - --- some special years,
  - --- or any.
- How many years the mission will be running.

(6) Requirements for satellite

- S/C attitude: spin stable or 3-axises stable, axis direction,
- The position of each payload onboard the S/C and others……,
- If the stretch pole is needed,
- E-M background inside the S/C,
- Data onboard process, transfer rate, ground station(s)
- Power supply, and others…...

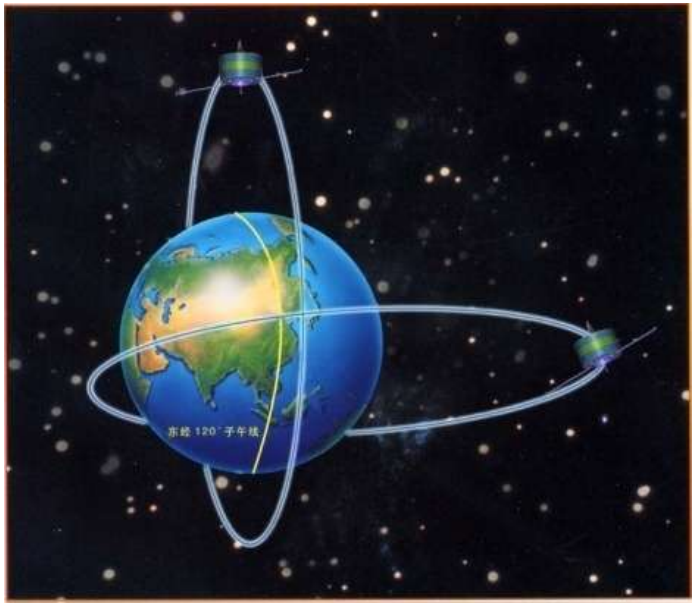
(7) The feasibility analysis

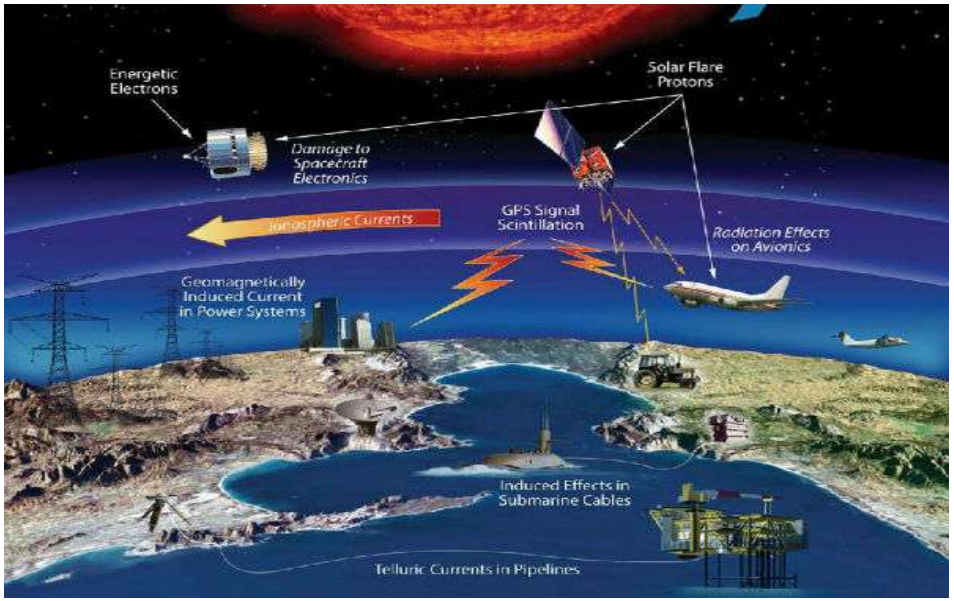
- --- Science objective
- --- Techniques
- --- The ground segment
- --- Financial support
- --- and, others

3. Last words

- DSP is the first space science mission in China.
- It is a China-ESA joint space science mission.
- It is an independent mission, and made an coordinated operation with ESA's Cluster, realized the first ever coordinated six-point multiple-satellite measurements.
- It is a very successful space science mission.

I hope and believe you, young scientists, will propose more successful space science missions in the near future.





That's all for this lecture

Thanks for attention!