Space Weather Payloads Onboard BDS

13th Meeting of the International Committee on Global Navigation Satellite Systems

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2018-11-06

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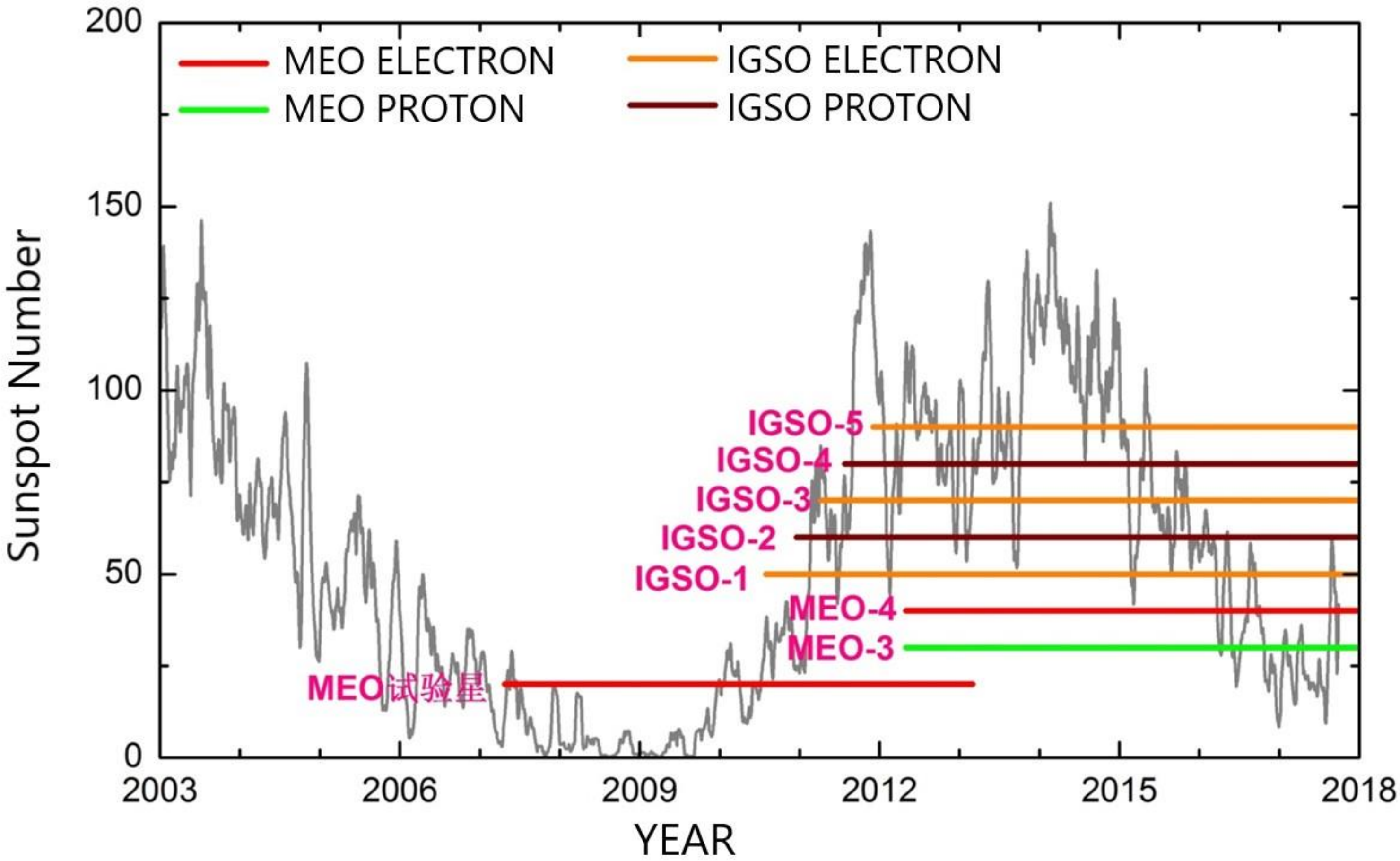
Space Weather Payloads Onboard BDS-2 Satellites



In MEO orbit, data of the high energy electrons covered a solar cycle, data of the high energy proton covered the time from solar maximum to solar minimum.

In IGSO orbit, data of the high energy electrons and protons both covered the time from solar maximum to solar minimum.

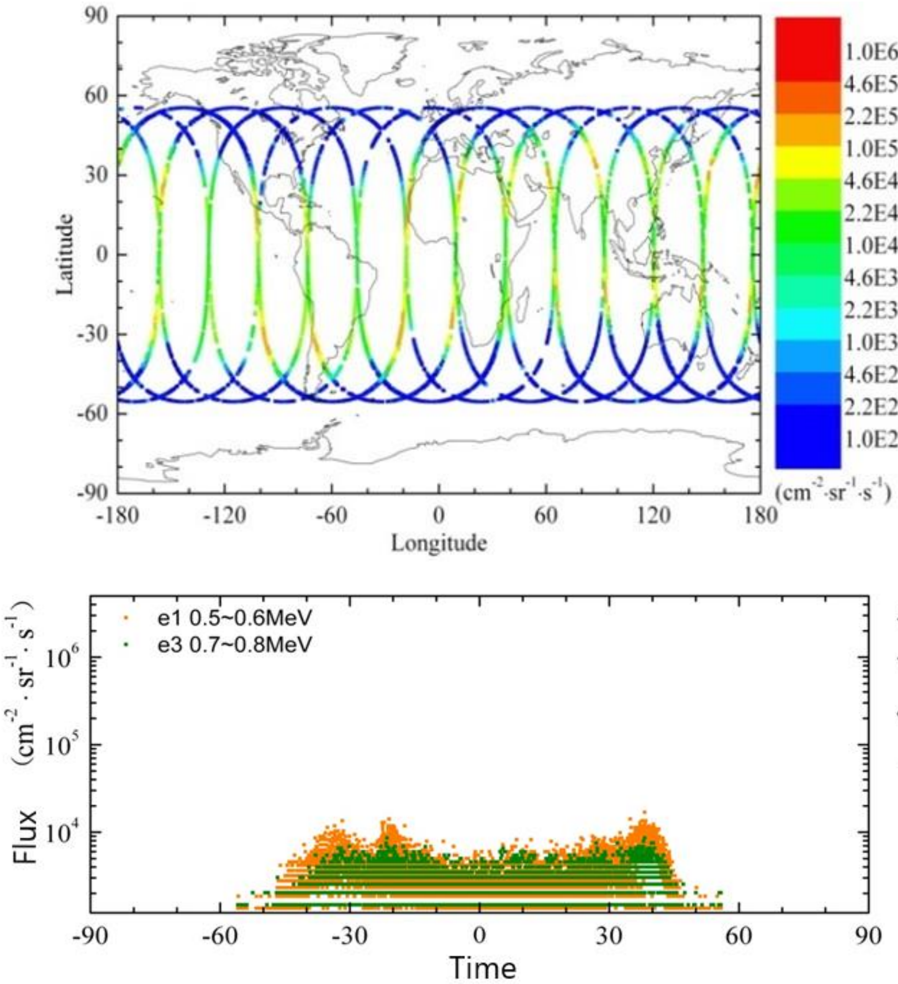
Space Weather Payloads Onboard BD Satellites

Satellite	Payload	Characteristic Parameter	Launch Time
MEO TEST	High energy electron detector, radiation dosimeter, Surface potential detector	8 channels of electron: 0.5~0.6, 0.6~0.7, 0.7~0.8, ≥0.8, 1.2~1.4, 1.4~1.6, 1.6~1.8, ≥1.8 (MeV) Radiation dosage: 0 ~ 10^7rad Surface potential : - 6500V ~ +500V	2007-4-25
MEO-3	High energy proton detector, radiation dosimeter, Surface potential detector	8 channels of proton: 2.0~3.0, 3.0~5.0, 5.0~10.0, 10.0~20.0, 20.0~30.0, 30.0~50.0, 50.0~100.0, 100.0~200.0 (MeV) Radiation dosage: 0 ~ 10^7rad Surface potential: - 6500V ~ +500V	2012-4-30
MEO-4	High energy electron detector, radiation dosimeter, Surface potential detector	8 channels of electron: 0.5~0.6, 0.6~0.7, 0.7~0.8, ≥0.8, 1.2~1.4, 1.4~1.6, 1.6~1.8, ≥1.8 (MeV) Radiation dosage: 0 ~ 10^7rad Surface potential : - 6500V ~ +500V	2012-4-30

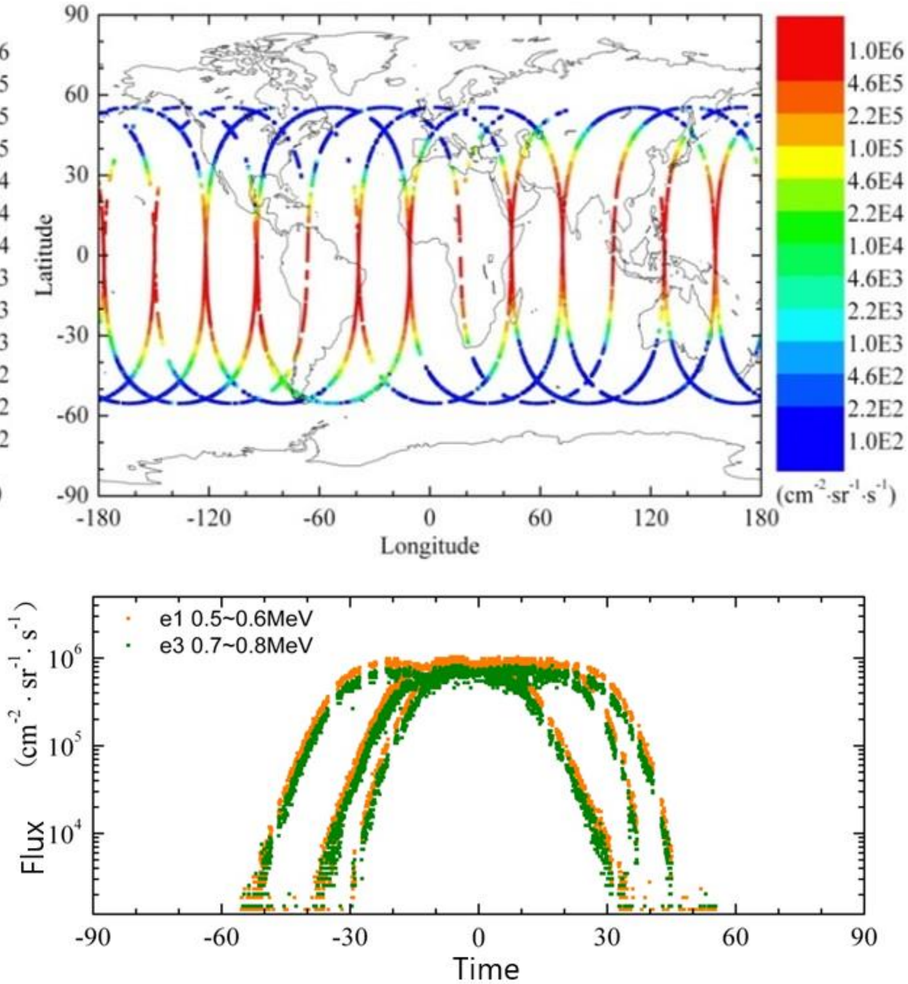
Space Weather Payloads Onboard BD Satellites

Satellite	Payload	Characteristic Parameter	Launch Time
IGSO-1	High energy electron detector, radiation dosimeter, Surface potential detector	8 channels of electron：0.5~0.6, 0.6~0.7, 0.7~0.8, ≥0.8, 1.2~1.4, 1.4~1.6, 1.6~1.8, ≥1.8（MeV） Radiation dosage：0 ~ 10^7rad Surface potential ：- 6500V ~ +500V	2010-8-1
IGSO-2	High energy proton detector, radiation dosimeter, Surface potential detector	8 channels of proton：2.0~3.0, 3.0~5.0, 5.0~10.0, 10.0~20.0, 20.0~30.0, 30.0~50.0, 50.0~100.0, 100.0~200.0（MeV） Radiation dosage：0 ~ 10^7rad Surface potential ：- 6500V ~ +500V	2010-12-17
IGSO-3	High energy electron detector, radiation dosimeter, Surface potential detector	8 channels of electron：0.5~0.6, 0.6~0.7, 0.7~0.8, ≥0.8, 1.2~1.4, 1.4~1.6, 1.6~1.8, ≥1.8（MeV） Radiation dosage：0 ~ 10^7rad Surface potential ：- 6500V ~ +500V	2011-4-10
IGSO-4	High energy proton detector, radiation dosimeter, Surface potential detector	8 channels of proton：2.0~3.0, 3.0~5.0, 5.0~10.0, 10.0~20.0, 20.0~30.0, 30.0~50.0, 50.0~100.0, 100.0~200.0（MeV） Radiation dosage：0 ~ 10^7rad Surface potential ：- 6500V ~ +500V	2011-7-27
IGSO-5	High energy electron detector, radiation dosimeter, Surface potential detector	8 channels of electron：0.5~0.6, 0.6~0.7, 0.7~0.8, ≥0.8, 1.2~1.4, 1.4~1.6, 1.6~1.8, ≥1.8（MeV） Radiation dosage：0 ~ 10^7rad Surface potential ：- 6500V ~ +500V	2011-12-2

Observation of the high energy electron detectors in MEO orbits

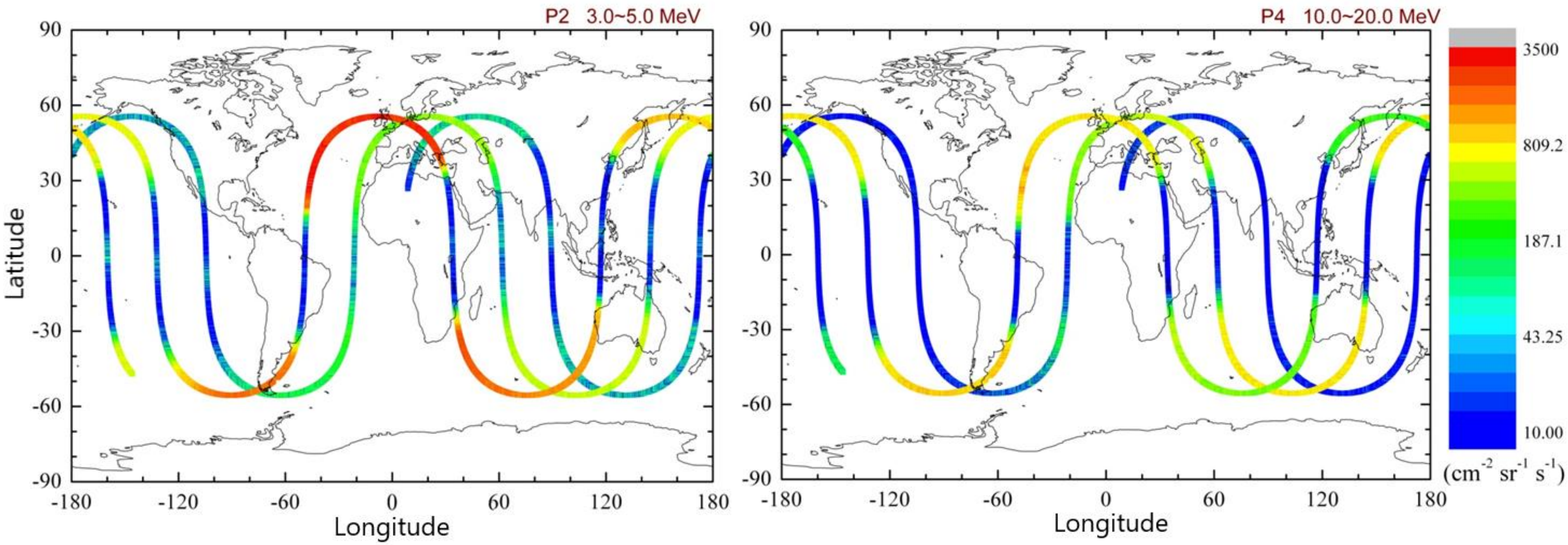


High energy electron distribution in quiet space environment.



High energy electron distribution during magnetic storm.

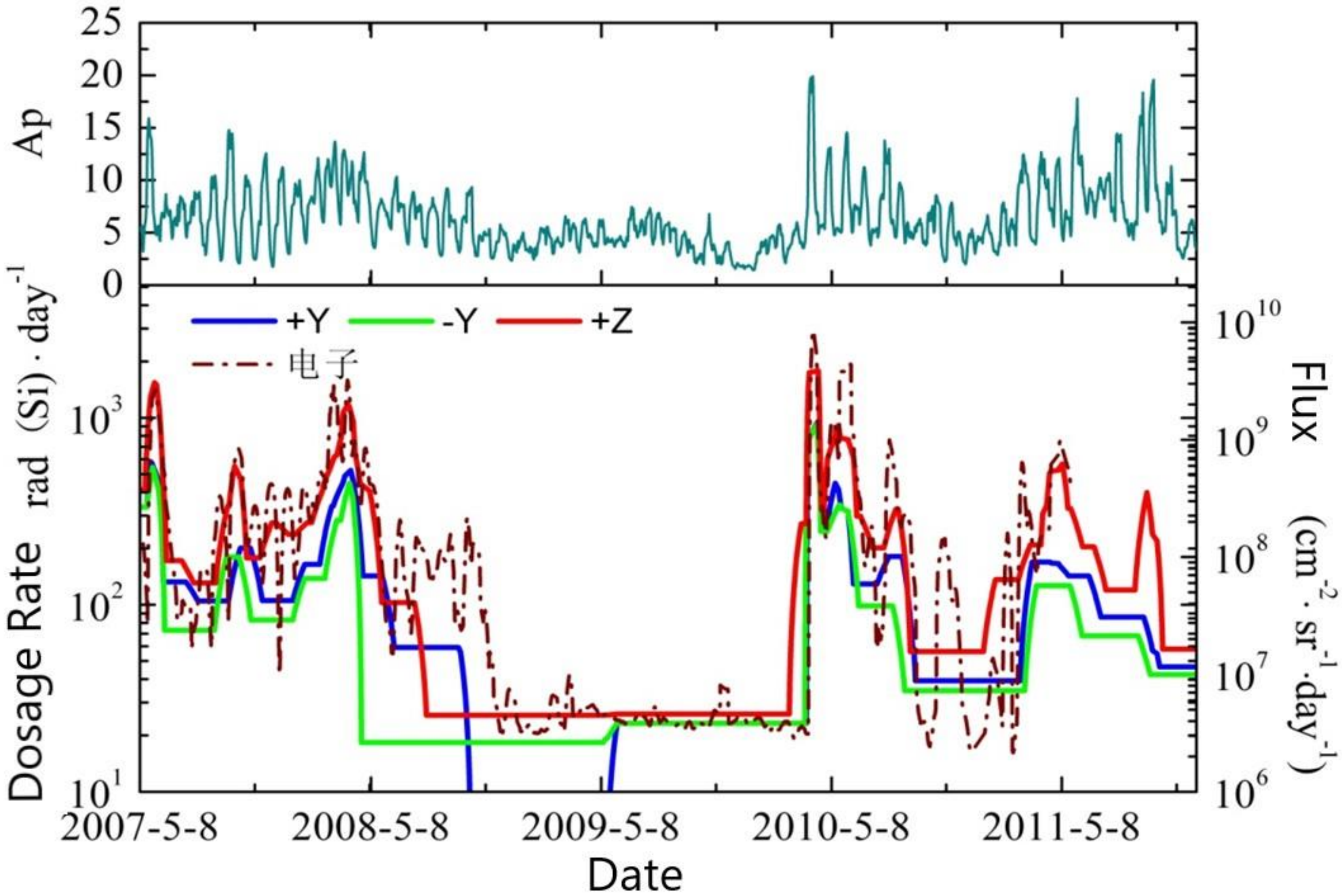
Observation of the high energy proton detectors in MEO orbits



Observations during solar proton events

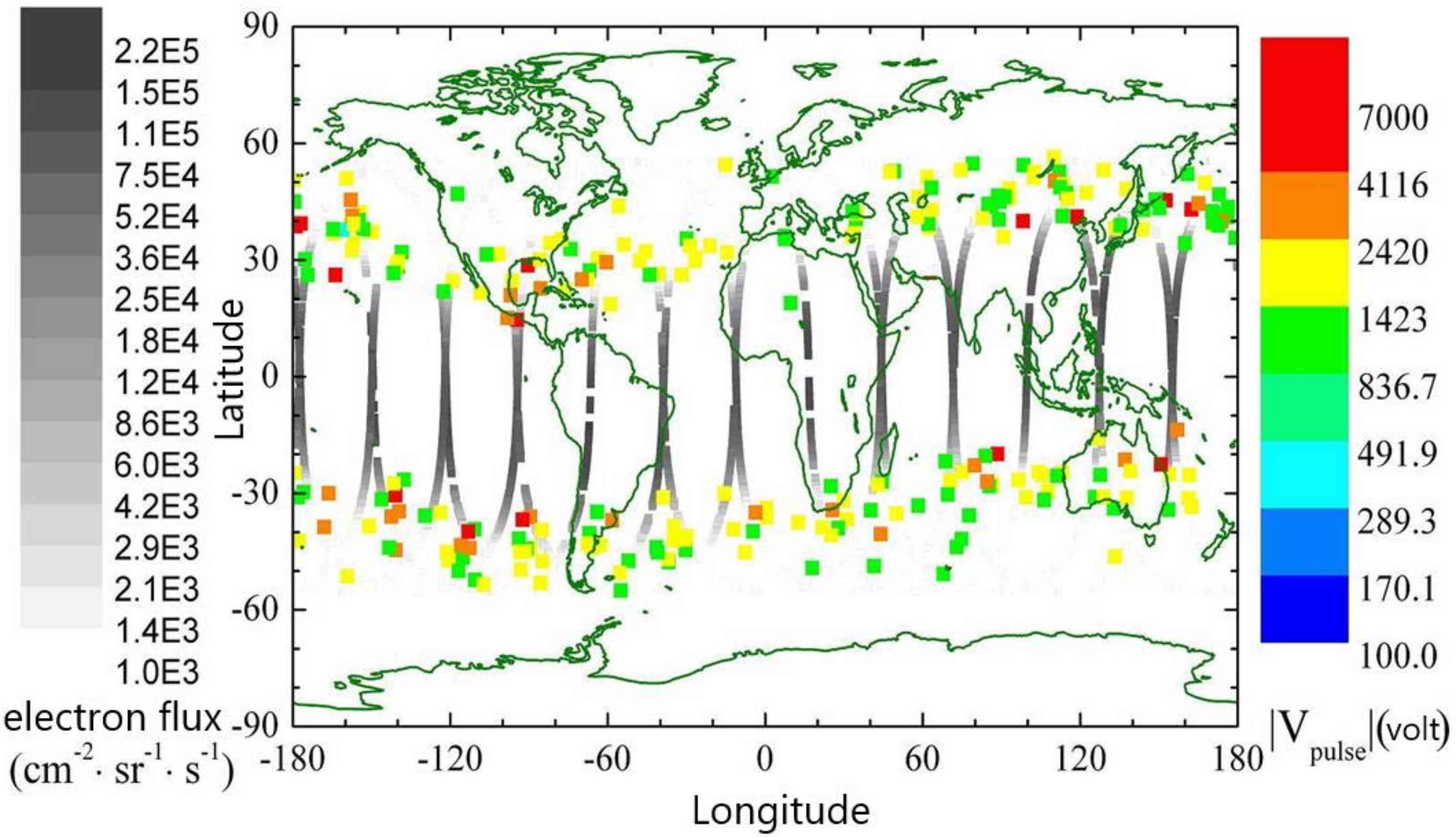
The high energy proton in MEO orbits distribute mainly in the middle and high latitude regions, and the distributions of different energy channels tend to be similar.

Observation of radiation dosage in MEO orbit



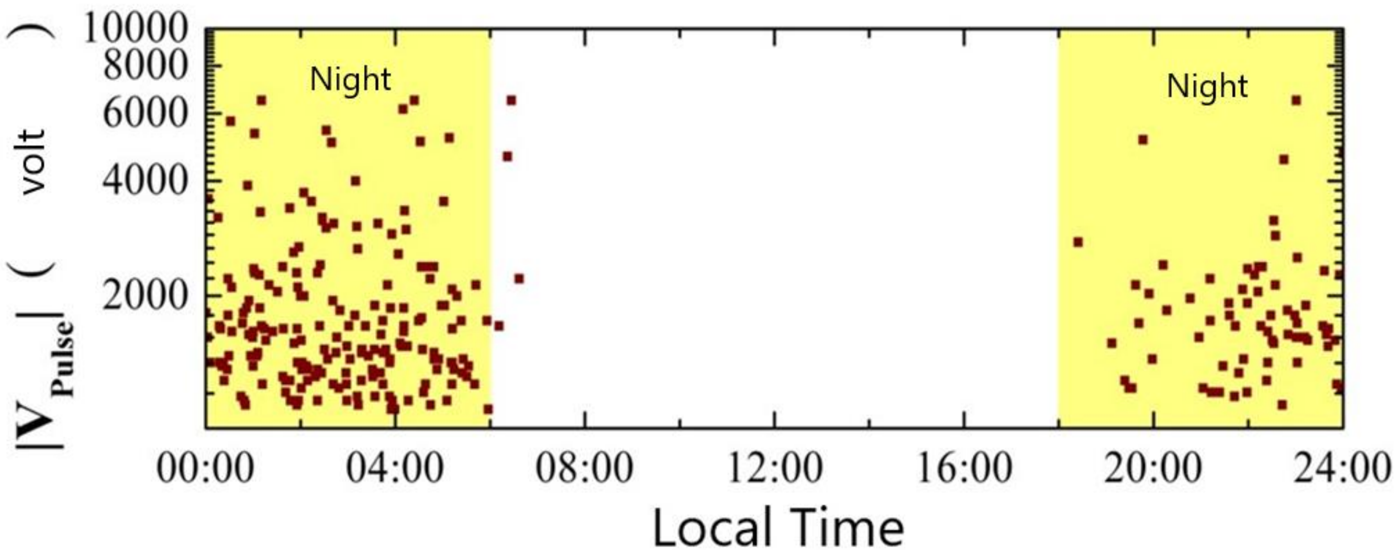
It can be seen that the radiation dosage is highly relative with the high energy electron flux, and modulated by the geomagnetic activities.

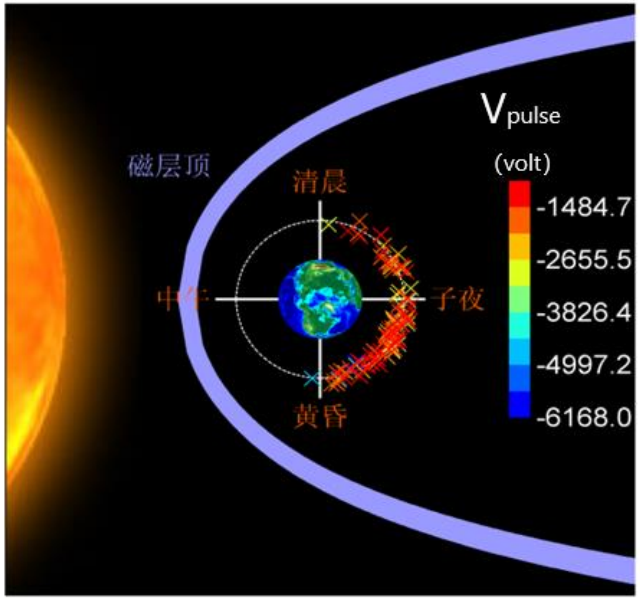
Observation of surface potential in MEO orbit



Pulse charge-discharge had been observed many times, which can charge the satellite surface to be thousands of volts in minutes.

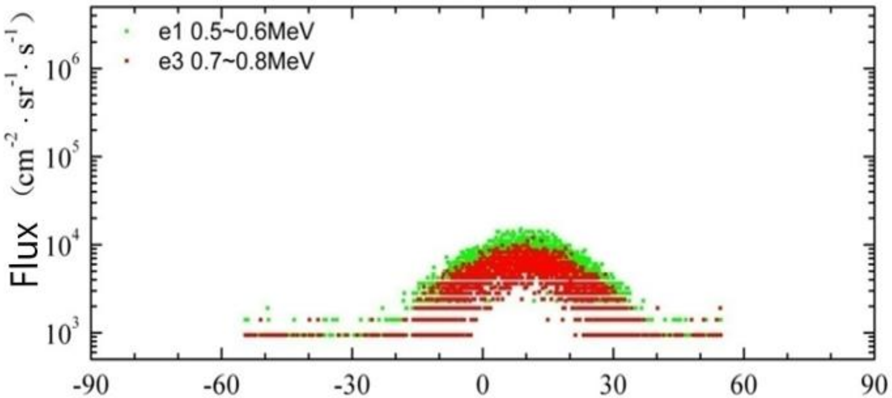
Observation of surface potential in MEO orbit

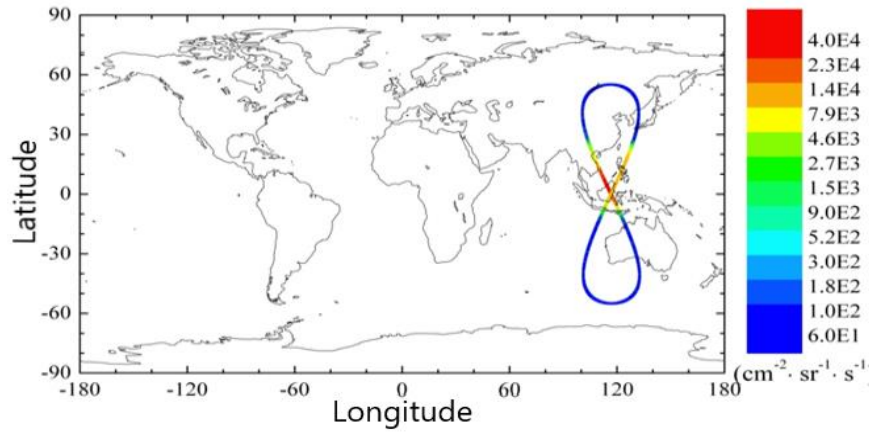




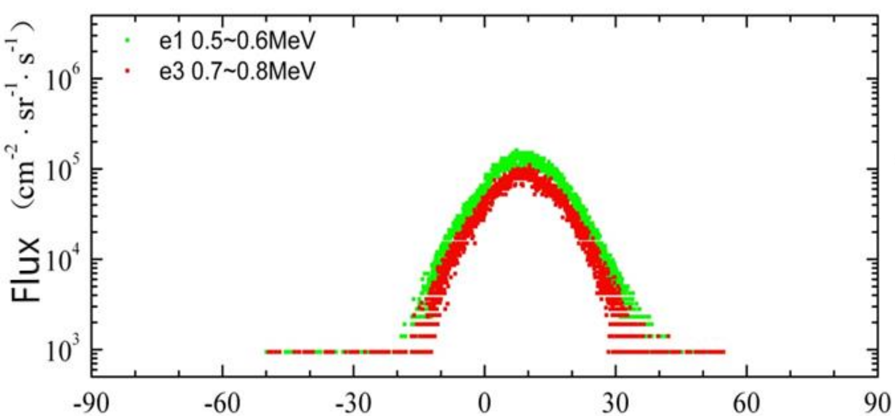
Most of the charge observations happened in the night side, which indicates the charge phenomenon may be relative with the magnetotail plasma injection events.

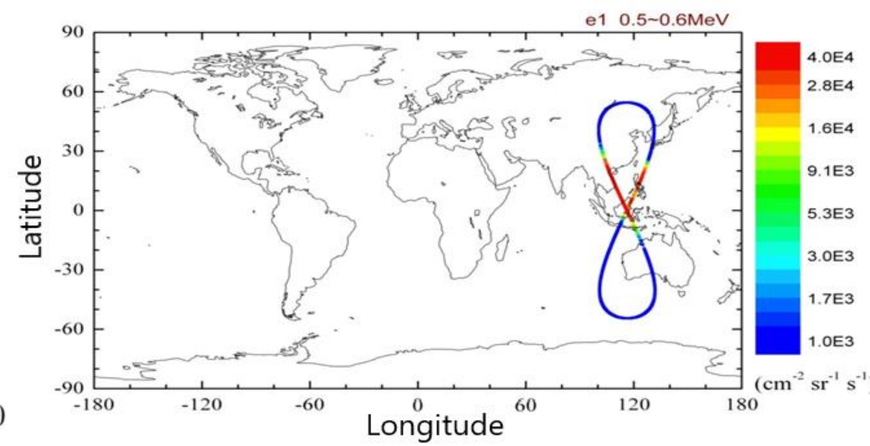
Observation of the high energy electron detectors in IGSO orbits





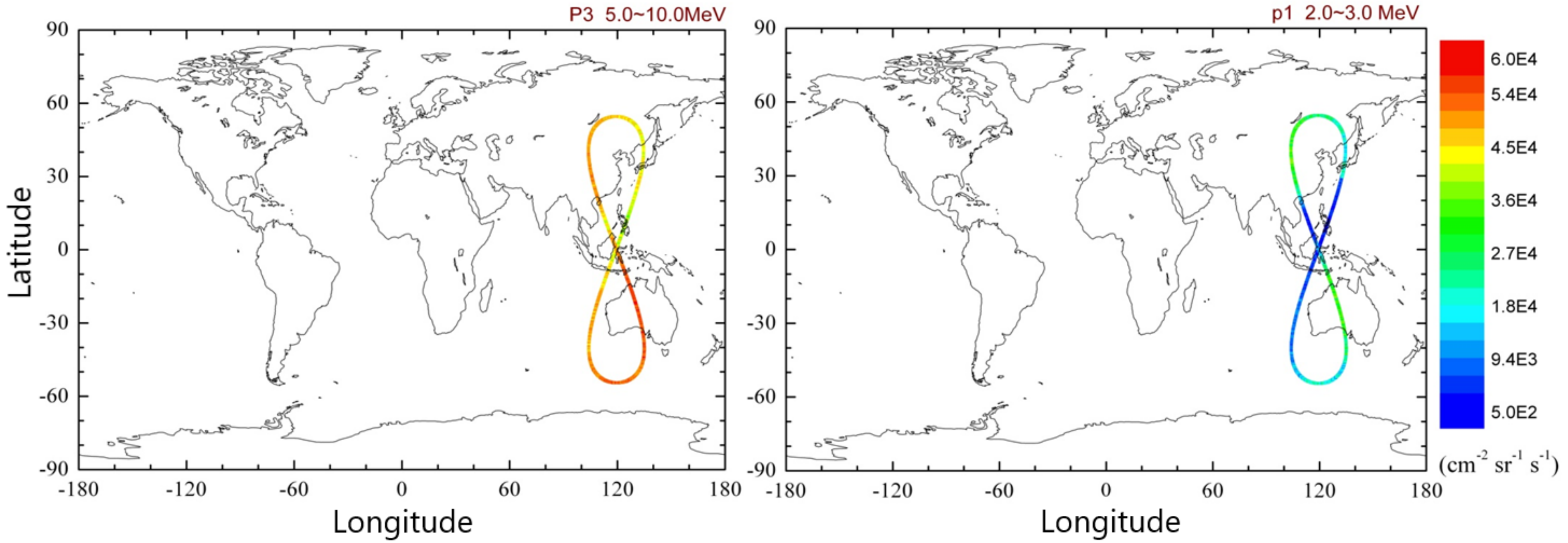
High energy electron distribution in quiet space environment.





High energy electron distribution during magnetic storm.

Observation of the high energy proton detectors in IGSO orbits



Observations during solar proton events

Compared with the MEO orbits, the flux of the high energy proton in IGSO orbits increased in every energy channels, but for different abilities of protons to penetrate into lower L shells with different energies, the increase region are different for different energy channels.

Application of the Payloads Observations

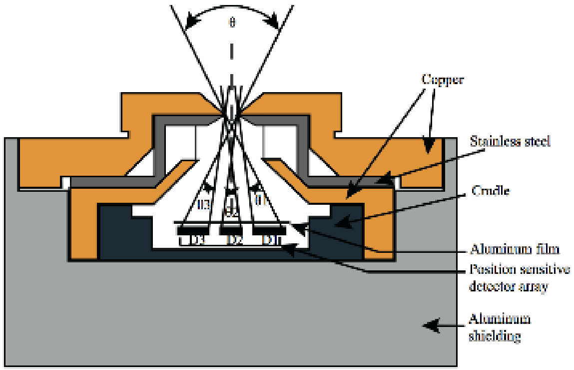
- Applied in the space environment analysis of the navigation satellite.

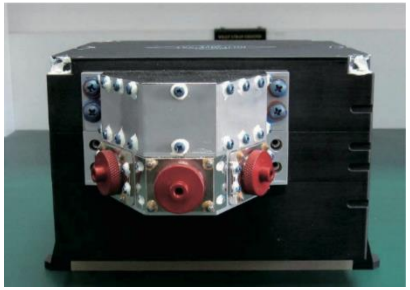
- Applied in the abnormal analysis of the navigation satellite.

- Applied in the radiation environment modeling in MEO orbit.

Space Weather Payloads Onboard BDS-3 Test Satellite

BeiDa-IES in IGSO orbit(I2S)





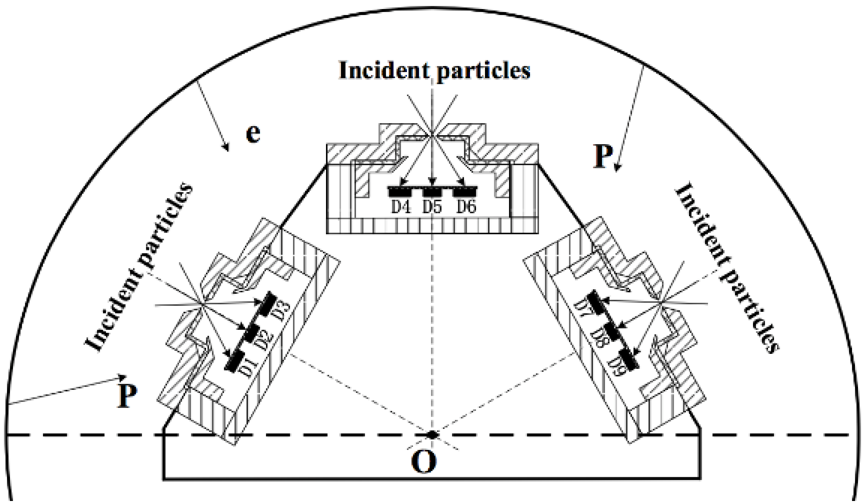


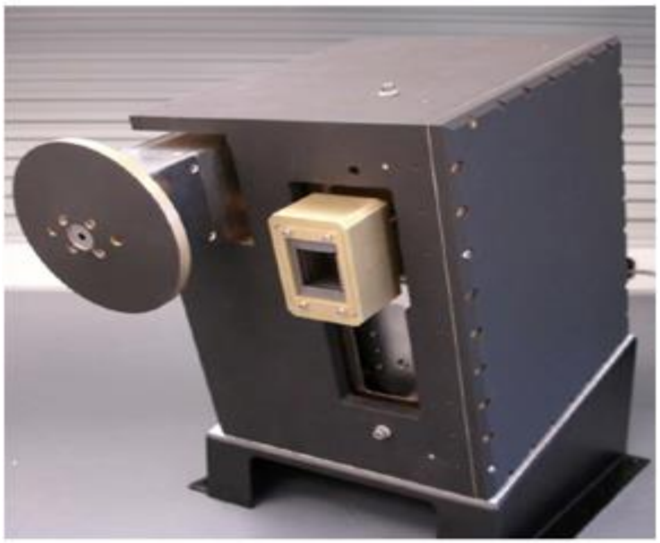
Table 1 Characteristic parameters of BD-IES sensor head

Parameters:	Energy range (50-600 keV)	
Electron channel:	E1	50-68
	E2	68-93
	E3	93-130
	E4	130-170
	E5	170-240
	E6	240-320
	E7	320-440
	E8	440-600
Field-of-view	±15° × 180°	
gular coverage (range/intervals)	180°/9	
Geometric factor (cm^2·sr)	~2.0 × 10^{-3} *(for each direction)	

:he geometric factor is the average value of nine directions.

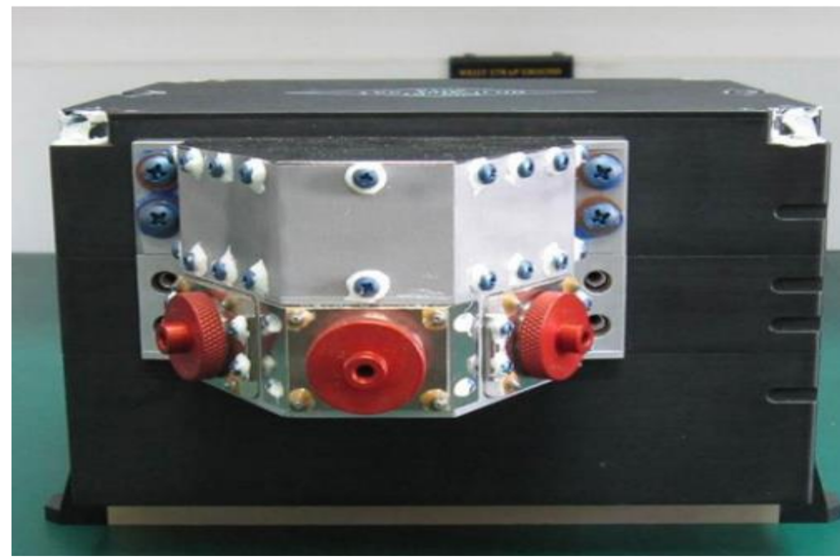
Electron Flux Data

MagEIS



	Energy [keV]						
LOW	32	54	80	108	144	183	226
M75	232	342	464	593	742	902	1078
HIGH	999	1547	1701	2275	2651	3681	4216

BD-IES

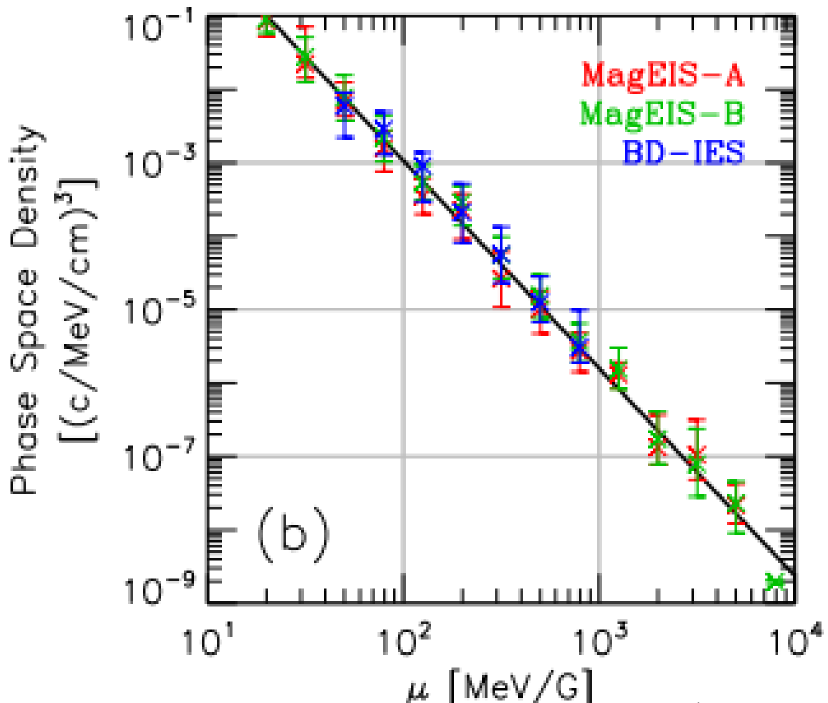


	Energy [keV]			
Channels	50-68	68-93	93-130	130-170
	170-240	240-320	320-440	440-600

Cross Calibration

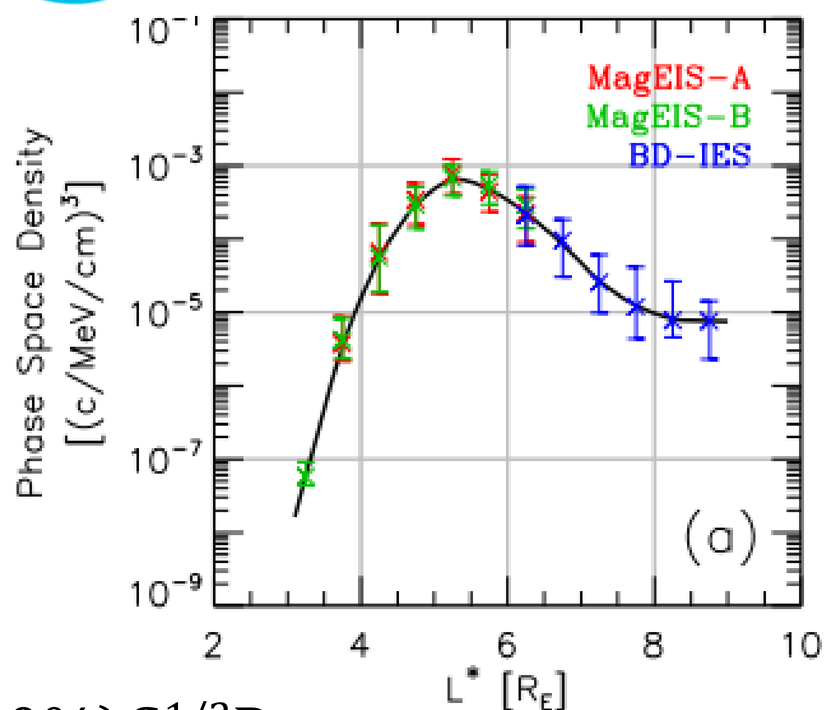
PSD vs. μ

$6.0<L^*<6.5$



PSD vs. L*

$160<\mu<250$ MeV/G



K: $(0.1\pm20\%)G^{1/2}R_E$;

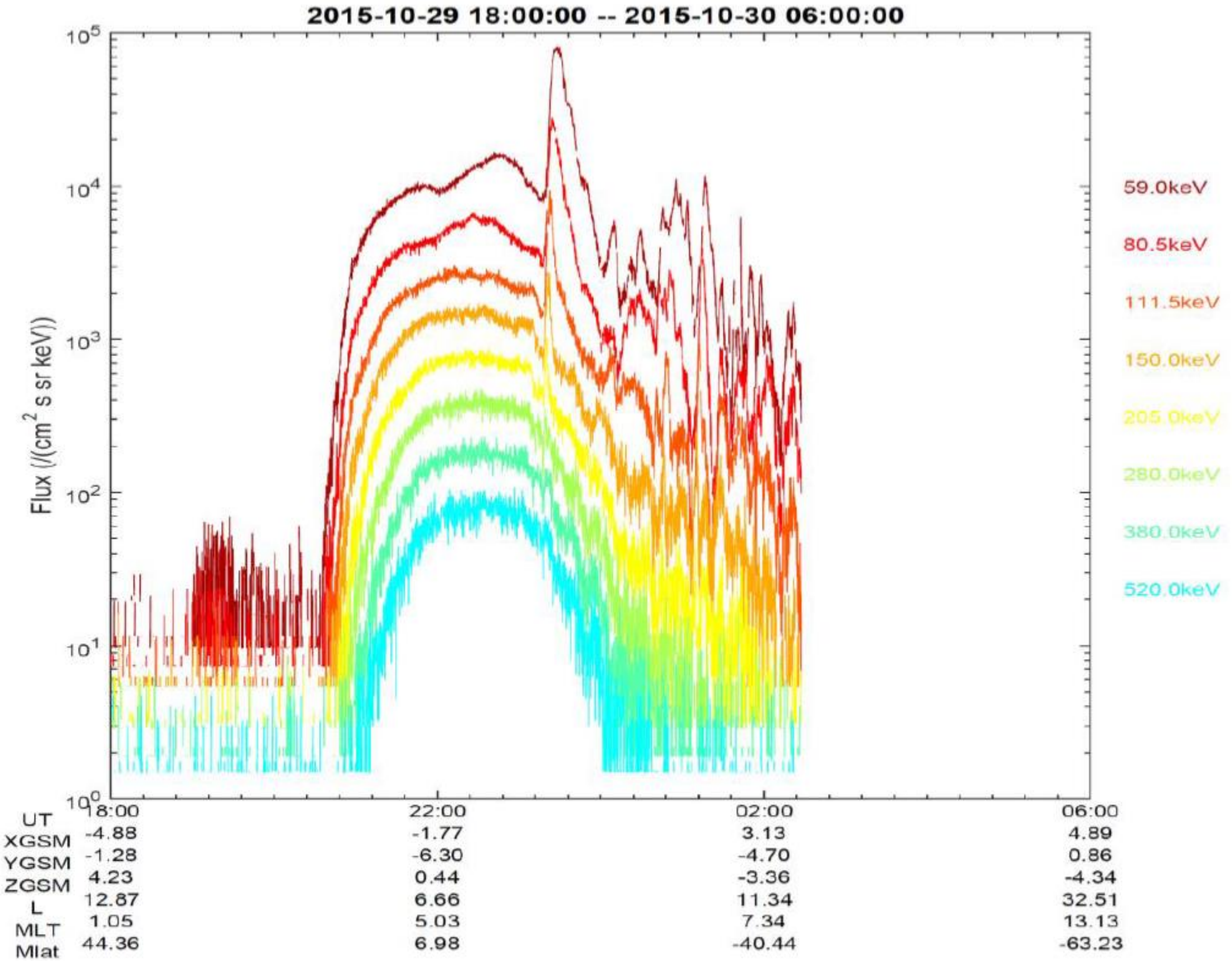
Data coverage: 2015-11-01 to 2016-10-31;

×: Median; **Error bar:** Upper and lower quartile.

Substorm Dispessionless Injections

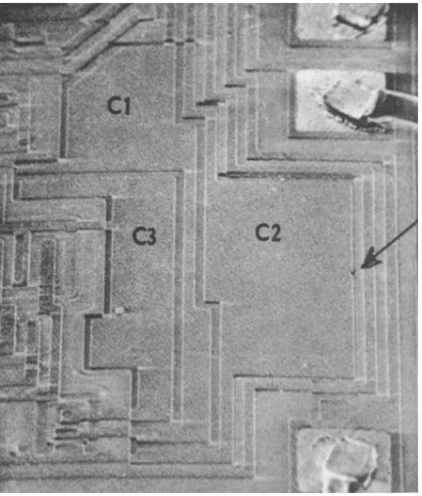
http://www.space.pku.edu.cn/bd-ies/BD_IES_OVERVIEW.html

http://www.space.pku.edu.cn/bd-ies/bd_ies_overview.html



Zong et al, Space weather, 2018

“Killer Electron”

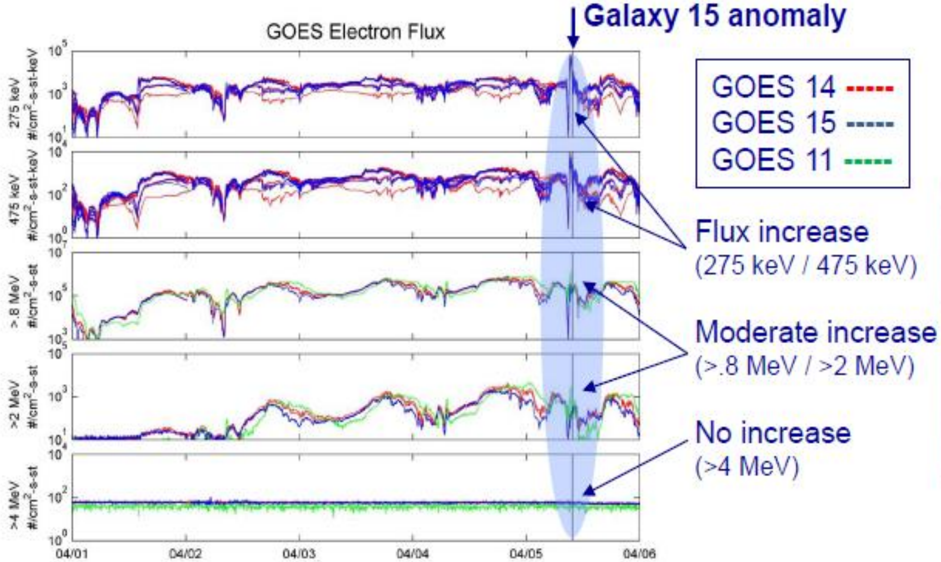


Space Weather Conditions

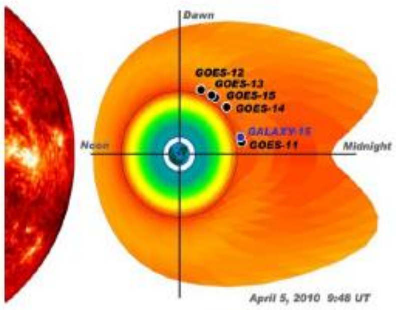
3. Local Environment At Galaxy 15 (3 of 4)

<u>Internal Charging: Electron Environment</u> (Medium-to-High Energy Electrons)

- **April 05 @ 9:00 – 48 minutes prior to the anomaly 275-475 keV electron flux increased at GOES 14 and 15**
  - **Flux of 275-475 keV electrons was the <u>highest observed</u> since GOES 14 was turned on in July 2009 and GOES 15 since April 2010 (GOES 11 does not measure electrons below .8 MeV**
  - **Flux of >.8 MeV electrons measured by GOES 11, 14 and 15 did not increase above prior levels**



Satellite Locations



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Substorm electron injection: IGSO Orbit

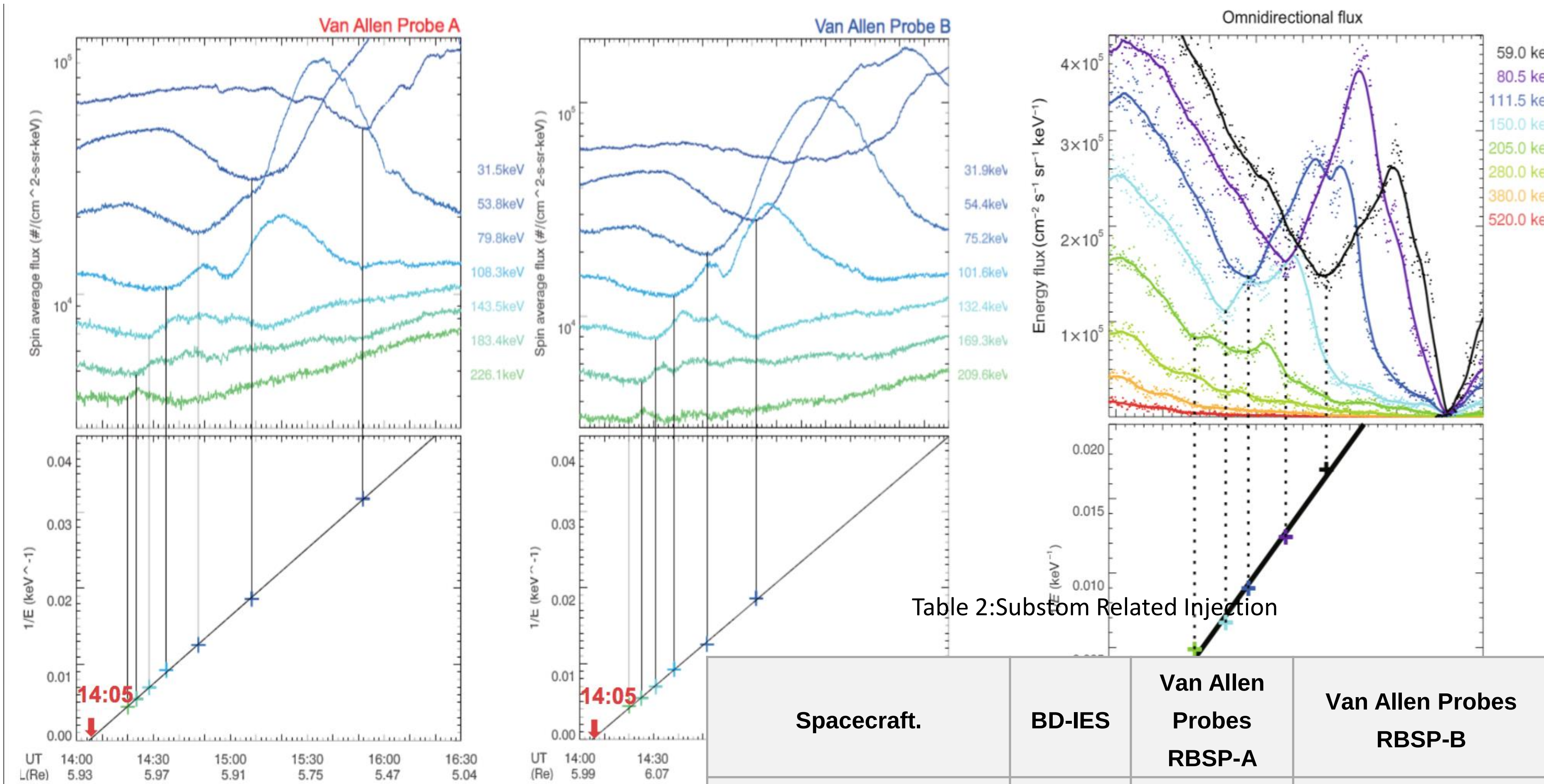


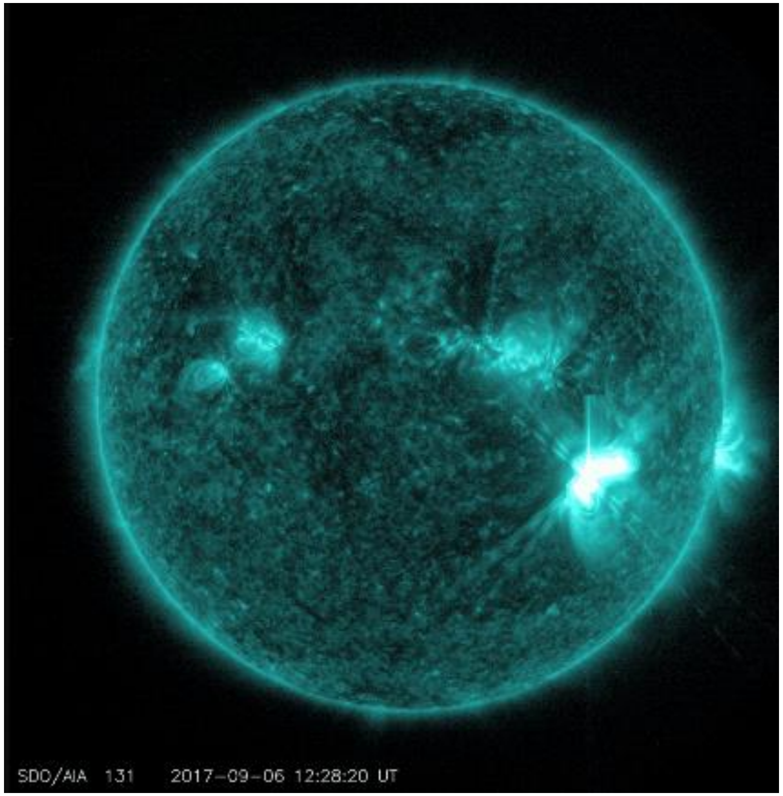
Table 2:Substom Related Injection

Spacecraft.	BD-IES	Van Allen Probes RBSP-A	Van Allen Probes RBSP-B
Injection Onset Time (UT)	14:18	14:05	14:05
Injection Outermost (R_E)	10.0	6.1	5.9
Injection Innermost (R_E)	7.4	3.7	3.7

Determining the onset time of subst

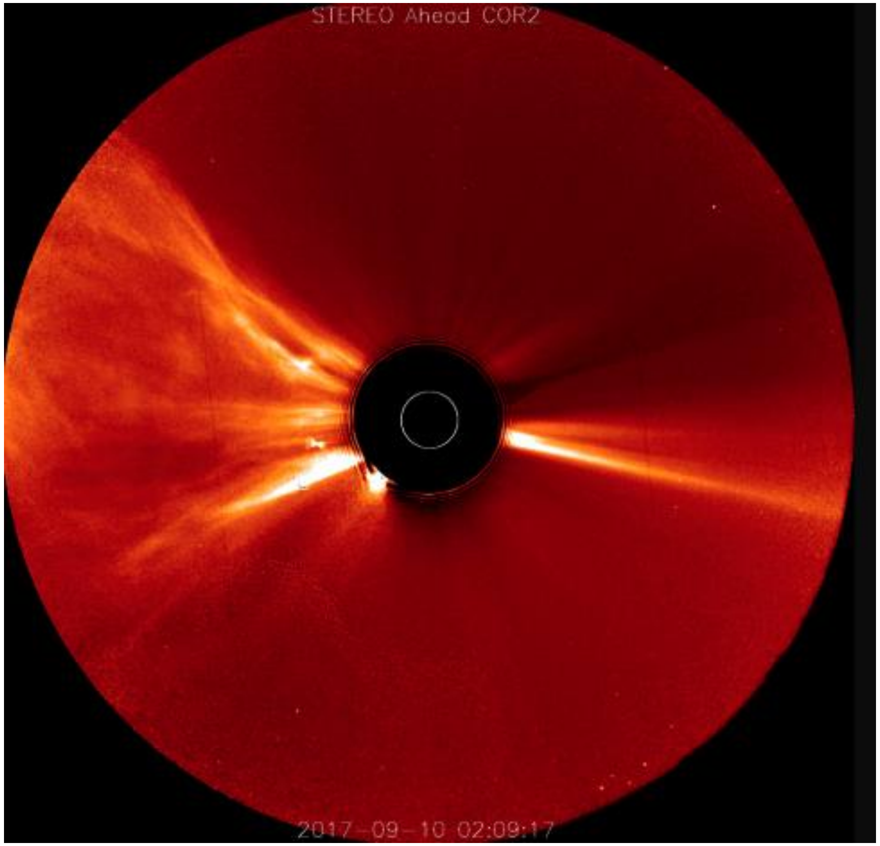
Zong et al, 2016

Magnetic Storm

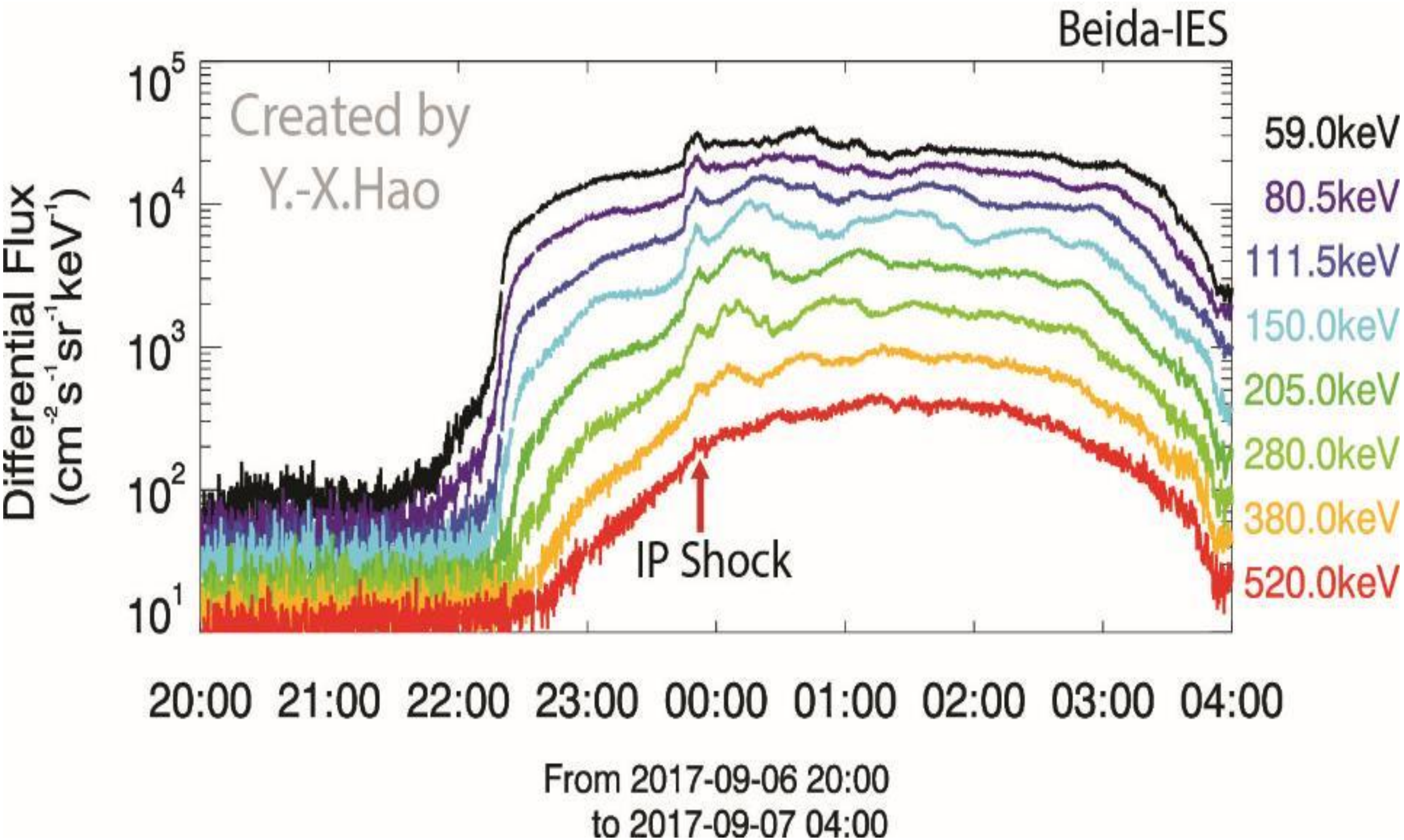


X9.3 flare
(the most intense flare
recorded during the current
solar cycle)

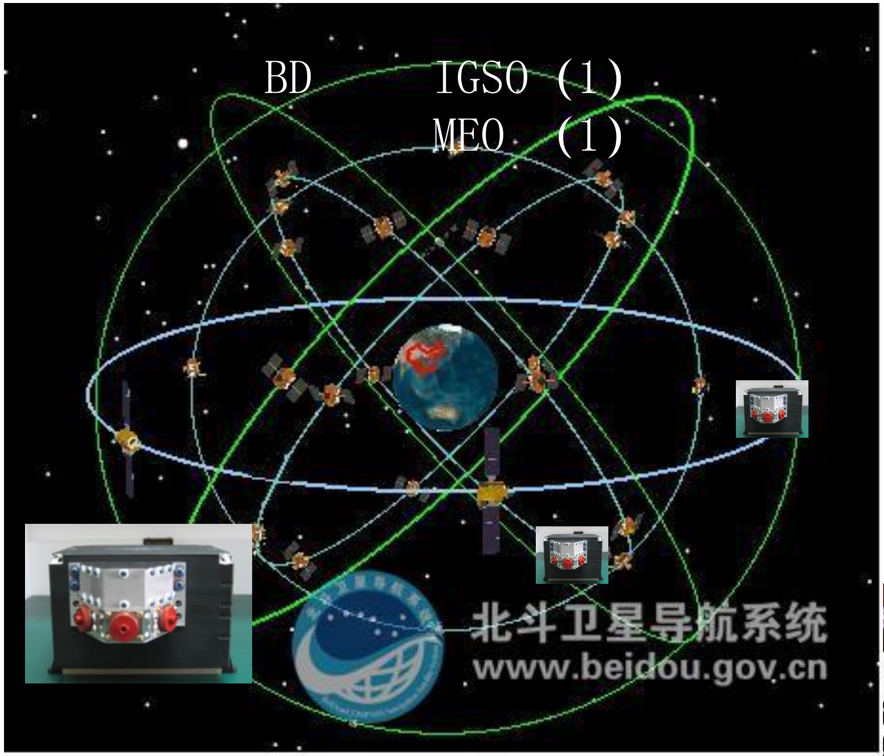
One of the fastest CME
Ever recorded. Side-swiped the earth's
Magnetosphere (Dst_{min}=-109nT)
2017 Sept

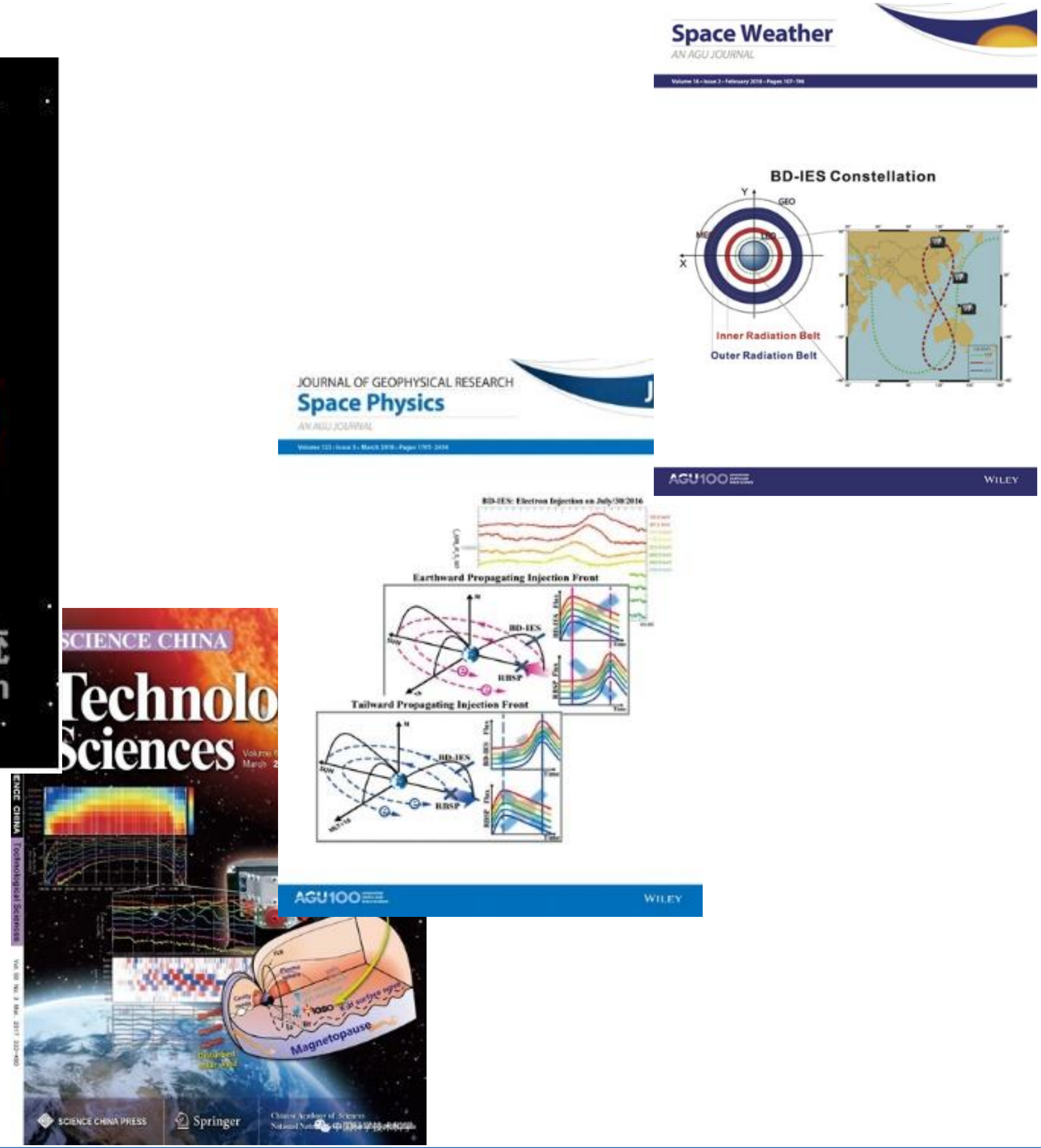


Magnetic Storm



BD-IES onboard BDS-3





Journal Covers

Recommendation about Sharing Space Weather Data

Recommendation: Share GNSS Space Weather Data

- **Title: Share Operational Space Environment Data**
- **Background/Brief Description of the Issue:**

- Space weather model and forecast outputs is the base to protect the safety and stability of the GNSS system. In order to improve model performance and forecast accuracy, such as the ionosphere model, radiation belt model, space weather data is required as much as possible.
- If the data of the space weather payloads onboard GNSS satellites can be shared, the space weather model performance and forecast accuracy will be much improved.

Recommendation: Share GNSS Space Weather Data

➢ **Discussion/Analyses:**

- At present, space environment payloads have been on board most of the GNSS satellites. Considering the differences between the orbits of different GNSS systems, the detect data will be unique in some special orbit.
- If the different data can be combined together, space weather data sharing in ICG will improve the space weather model performance and forecast accuracy, which is essential to protect the safety and stability of the GNSS system.
- We propose that the space weather data detected by the payloads onboard GNSS satellites should be shared.

Recommendation: Share GNSS Space Weather Data

➢ **Recommendation of Committee Action:**

- That information about the space environment payloads onboard GNSS satellites should be introduced in ICG.
- That dedicated mechanism should be investigated to share space weather data.
- That free and unrestricted sharing of space weather data policies should be adopted.
- That exchange of the space weather models and forecast outputs should be encouraged.

THANK YOU!

13th Meeting of the International Committee on Global Navigation Satellite Systems