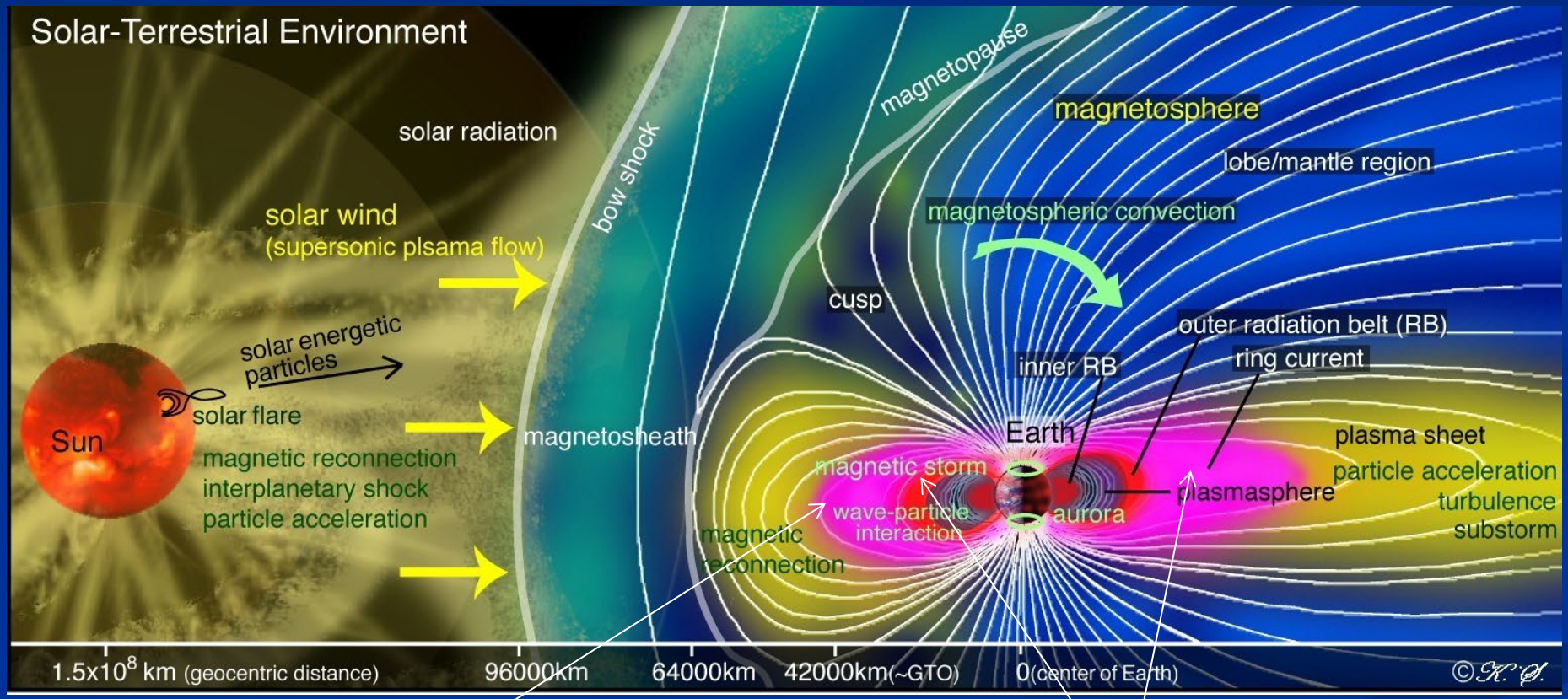
Geospace Research with the Arase Satellite: Advancing Space Weather Science through Japan–Czech Collaboration

Y. Miyoshi
Institute for Space-Earth Environmental Research, Nagoya University

NAGOYA UNIVERSITY

Introduction: Geospace

Geospace refers to the region shaped by the interactions between the solar wind and Earth's magnetic field.

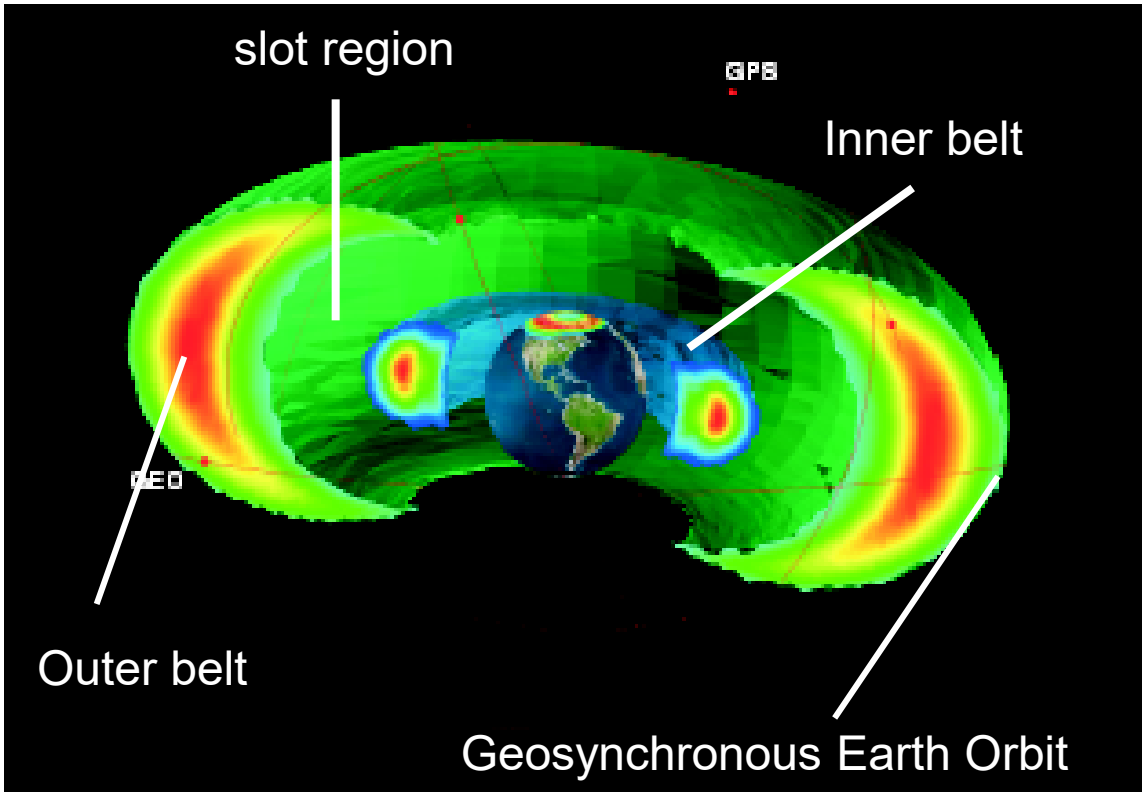


Geosynchronous Earth Orbit
(Meteological/Telecommunication Satellites)

Radiation Belts

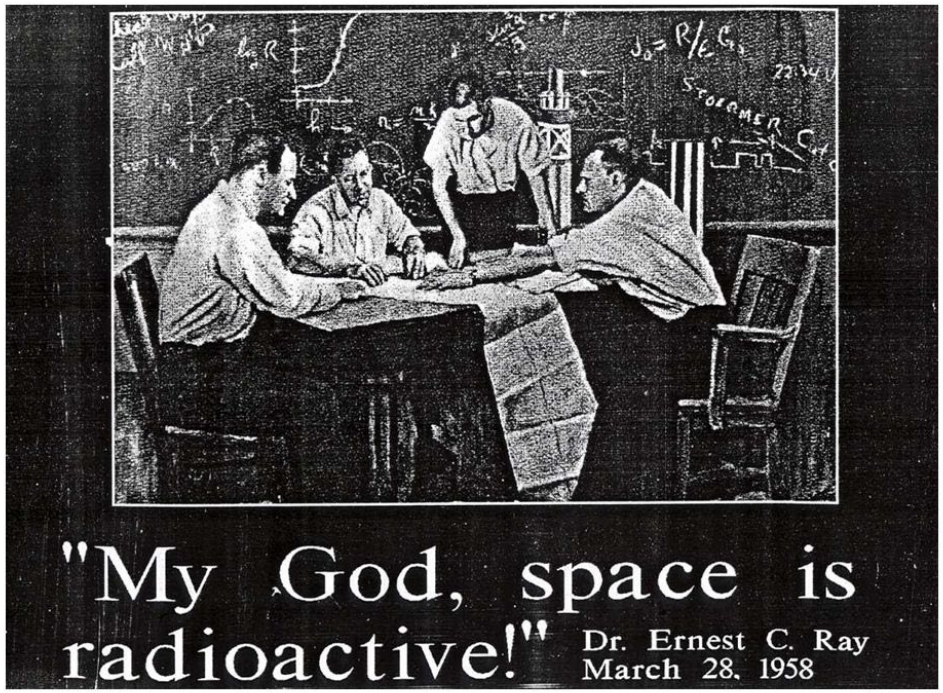
Radiation Belts (Van Allen Belts)

Population of MeV electrons



Typical energy: 100 keV ~ 10 MeV (electron)
Highly variable associated with the solar wind disturbances

Discovery of Van Allen Belts: Dawn of Space Age

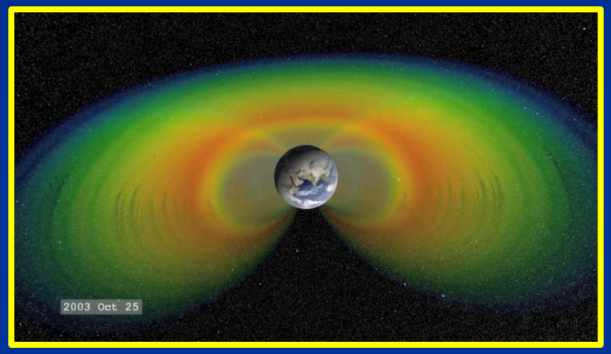


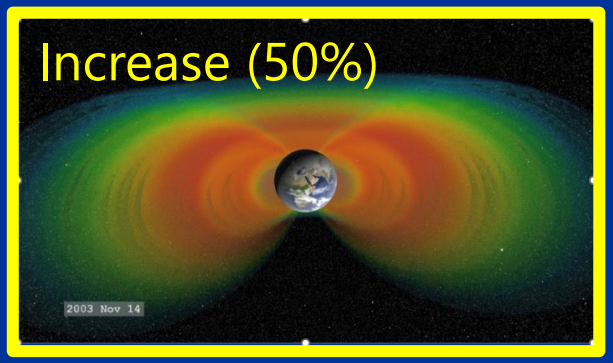
NASA/GSFC

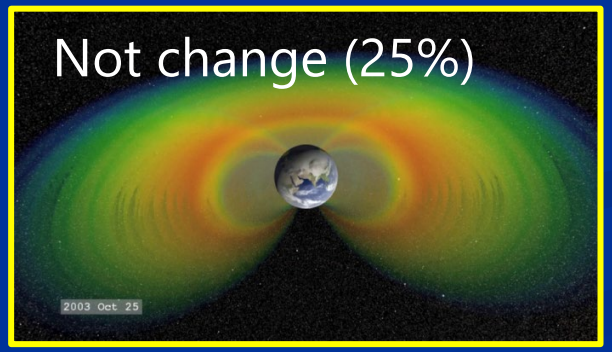
US first satellite “Explore”
discovered “Trapped Radiation”
so-called “Van Allen Belts” [1958]

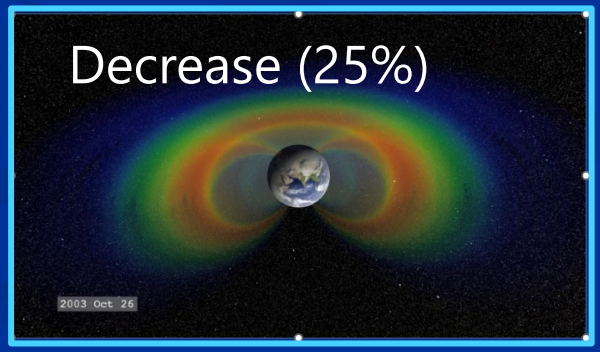
Variations of the radiation belts during geospace storm

- Geospace storms occur when the solar wind changes.
- The variations of relativistic electrons in the radiation belts during geospace storms are diverse.
- Predicting flux variations remains very difficult.







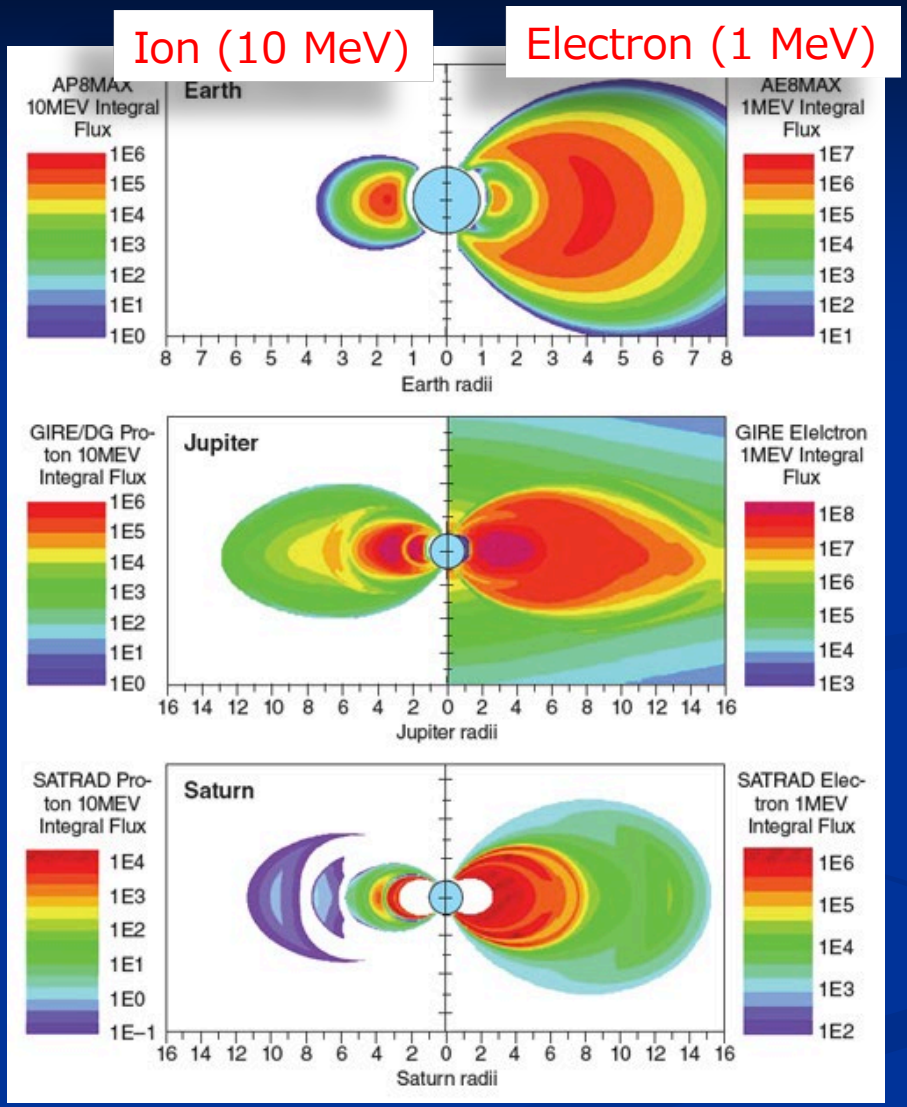


The radiation belts exit other planets

Earth

Jupiter

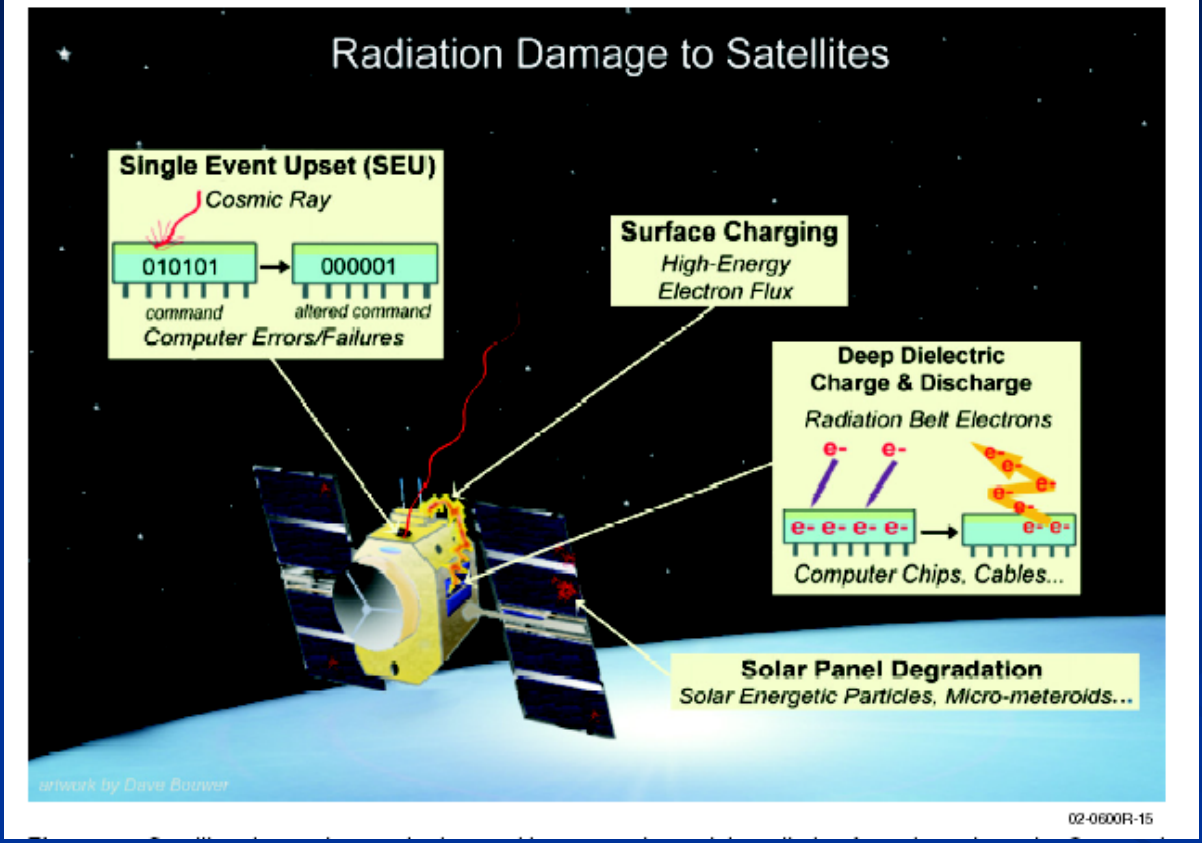
Saturn



[Baker +, 2014]

Radiation belts also exist around Jupiter, Saturn, Uranus and Neptune, and are universal regions of magnetized planets.

Space Weather killer electrons of the radiation belts



(NASA TM 2002)

MeV electrons of the radiation belts cause satellite anomaly, therefore, understanding radiation belt dynamics is one of the key issues in space weather research.

JAXA/Arase satellite mission (launch in 2016)

Objectives:

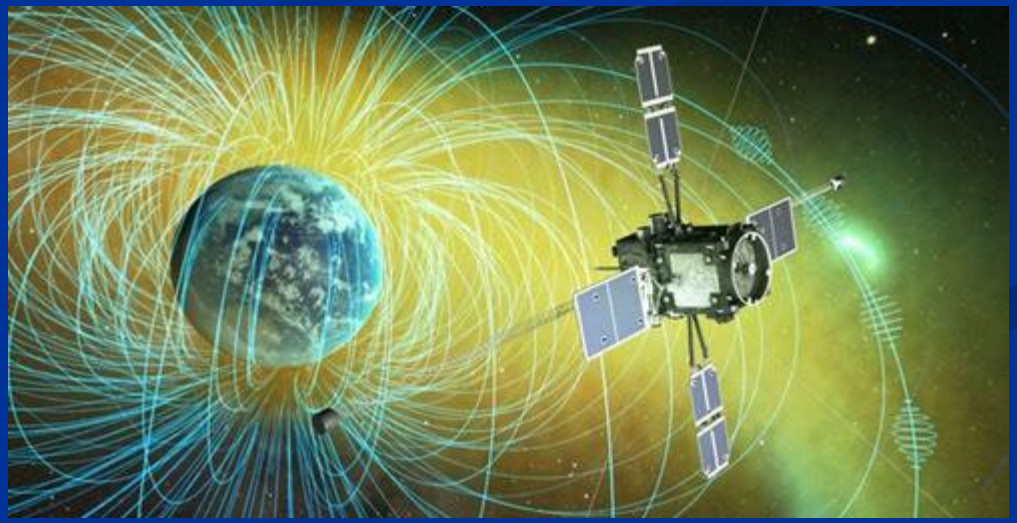
- Identify the mechanisms that cause increases or decreases in relativistic electrons during geospace storms.
- Identify the mechanisms responsible for geospace storms.

Where? :

- Inside the radiation belts (400 km x 32,000 km)

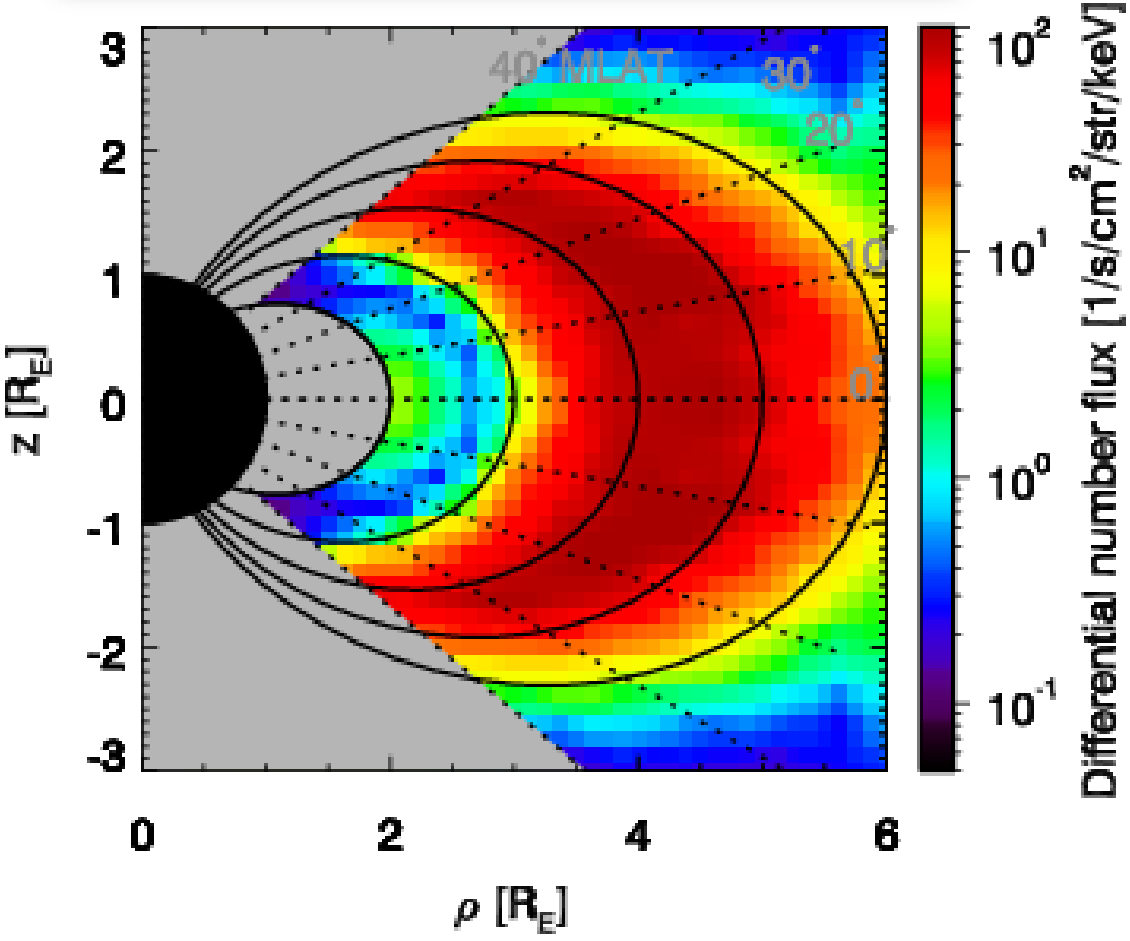
What? :

- Wide energy electrons and ions (10 eV - MeV) with 6 instruments
  Electric fields/Magnetic fields (DC – 10 MHz) with 2 instruments



Radiation Belts seen by Arase

Radiation Belts (2 MeV electrons)

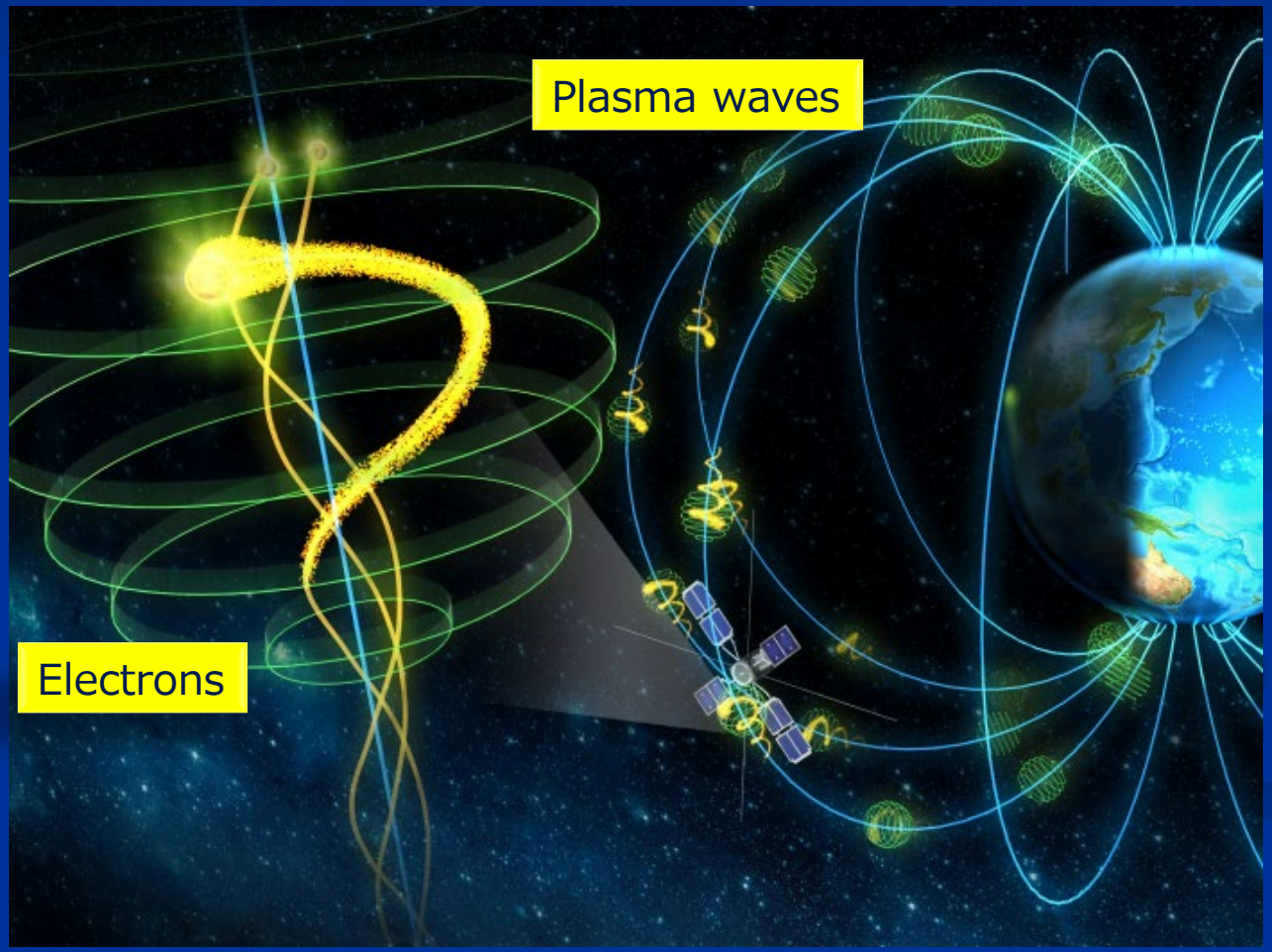


Miyoshi+[Space Sci. Rev.,2022]

Interactions between electrons and plasma waves

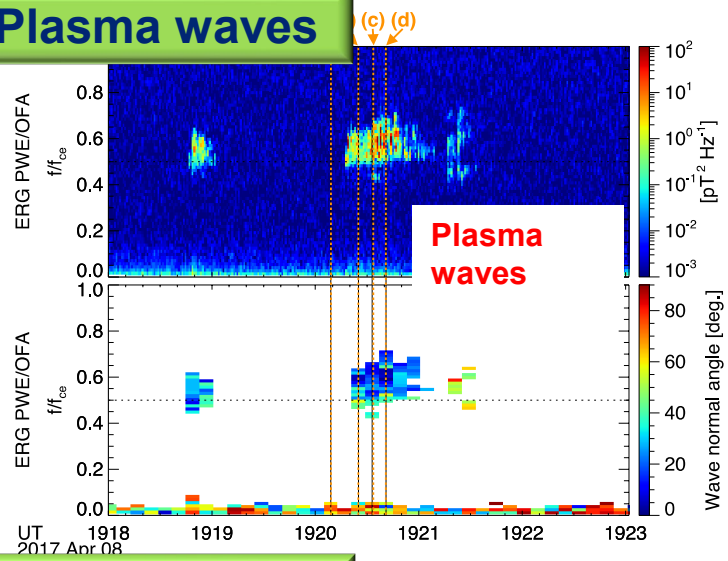
Acceleration and scattering of plasma/particles

- **-Acceleration of energetic electron**
- **-Scattering of energetic electrons into atmosphere**



Acceleration of energetic electrons by plasma waves

Plasma waves

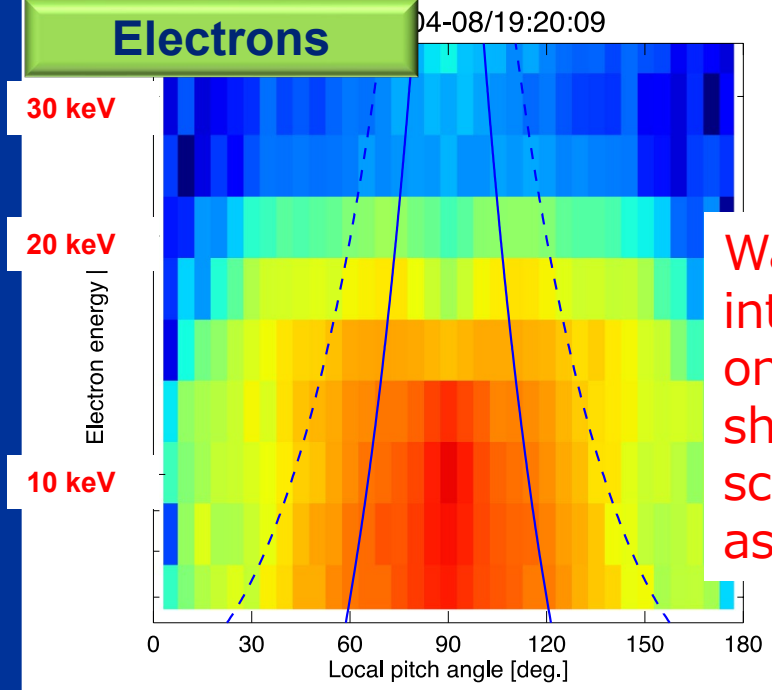


Wave-particle interactions cause large enhancement of relativistic electrons.

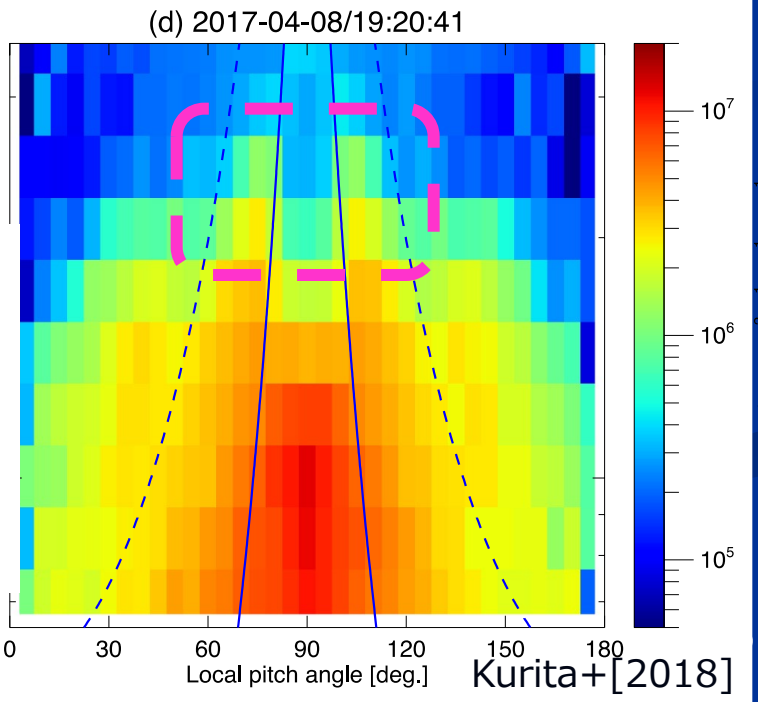
Miyoshi+[2021]

R=5.5 Re, MLT=4.3-4.5

Electrons



Wave-particle interactions on remarkably short time scales, as brief as 40 seconds.



Kurita+[2018]

Japan-Czech Collaboration

- 10+ years partnership with Prof. Santolík's group (Czech Academy of Sciences)
- Bilateral Project between JSPS and CAS
- International Joint Laboratory Program between ISEE Nagoya University and CAS

Joint Achievements

- Plasma wave research: Theoretical advice from Prof. Santolik was directly implemented in the onboard software of Arase.
- Joint papers and conferences
- Establishing human networks

JGR Space Physics

Technical Reports: Methods | Open Access

Inter-Calibrated Measurements of Intense Whistlers by Arase and Van Allen Probes

Save | Related Papers | Chat with paper

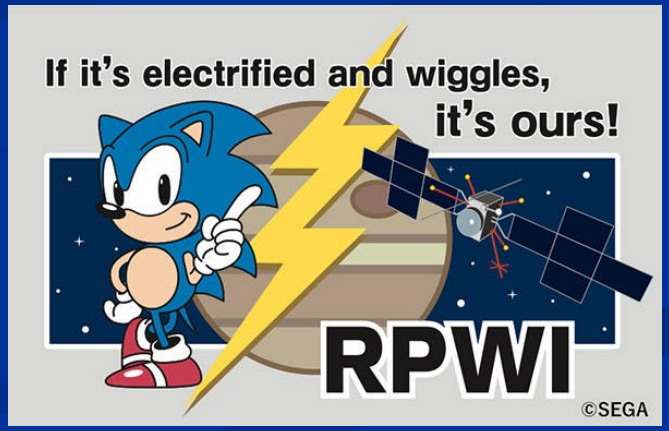
O. Santolík, Y. Miyoshi, I. Kolmašová, S. Matsuda, G. B. Hospodarsky, D. P. Hartley, Y. Kasahara, H. Kojima, A. Matsuoka, I. Shinohara, W. S. Kurth, C. A. Kletzing

Japan-Czech Collaboration in the future

JUICE Mission (Jupiter Icy Moon Explorer Mission: ESA/JAXA)

JUICE will arrive at the Jupiter system in 2029

Our Japan–Czech team is working on the radio/plasma waves instrument (RPWI).



We aim to confirm whether wave-particle interactions play the same essential role in particle acceleration in the Jovian radiation belts as they do on Earth.

Summary and Future Outlook

The Arase satellite has made key contributions to space weather science through studies of radiation belts and geospace storms.

The Japan–Czech collaboration has been a long-standing partnership and a successful model of international cooperation.

Together, we have built mutual trust, established strong international networks, and trained the next generation of scientists.

We are opening new scientific frontiers together united in science, united in shaping our shared future.

Thank you very much !

Scan a QR-code to download booklets about space weather

Accelerations of electrons by whistler waves

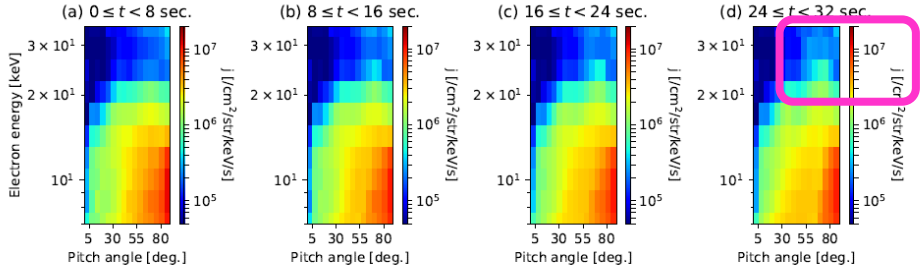
Data-driven Simulation

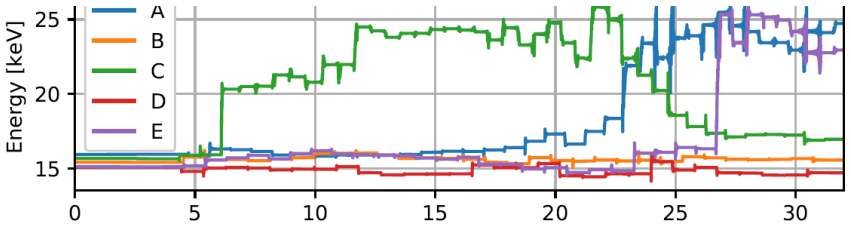
Test-particle simulation using Arase observed waves has successfully reproduced the observed evolutions of the distribution function.

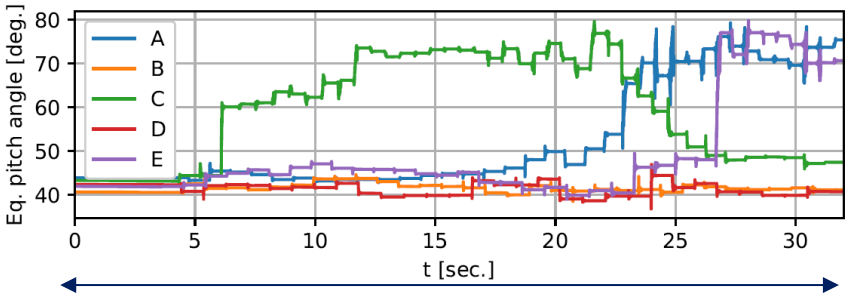
Distribution function (simulation)

Energy

Pitch angle



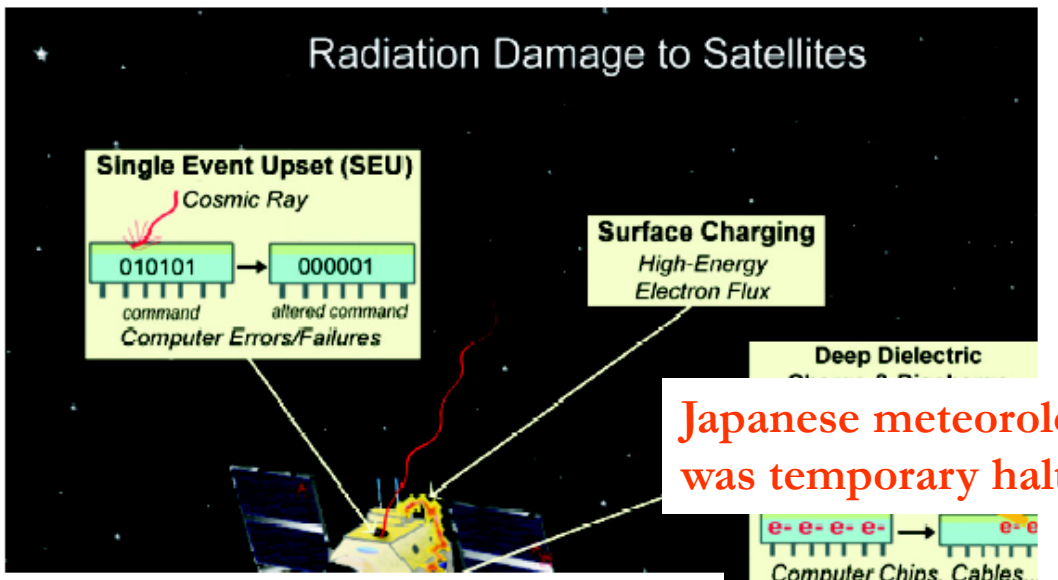




32 sec

Saito, Kurita, Miyoshi+[2021, JGR]

Space Weather killer electrons of the radiation belts



ひまわり」不具合

十七日未明、気象観測を続けるが、六め、通信用アンテ
時間に一度の観測になる上を向かなくなっ
ため、天気予報などに影響が出そうだ。このため同日午
五十七分から観
気象庁によると、ひまわり6号は衛星に搭載した姿勢制御用ソフトが何らかの原因で停止、衛星と通信し、午前に衛星の姿勢が崩れて回り始

Japanese meteorological satellite was temporary halted.

異常
能に

カメラなどはクーラーによる冷却が必要で、機能の完全回復に半日から一日程度の時間がかかる見込みという。
今回のトラブルで、国内の関係機関のほか、ひまわり6号の画像を受信して天気予報などに役立てているアジア太平洋諸国にも影響が広がっている。
ひまわり6号は昨年六月から本格運用を始め
ラブルで一時観測不能に陥った。
昨年七月と九

日本経済新聞
2004年(平成16年)2月15日(日曜日)

BSデジタル放送一時中断
NHKと一部民放

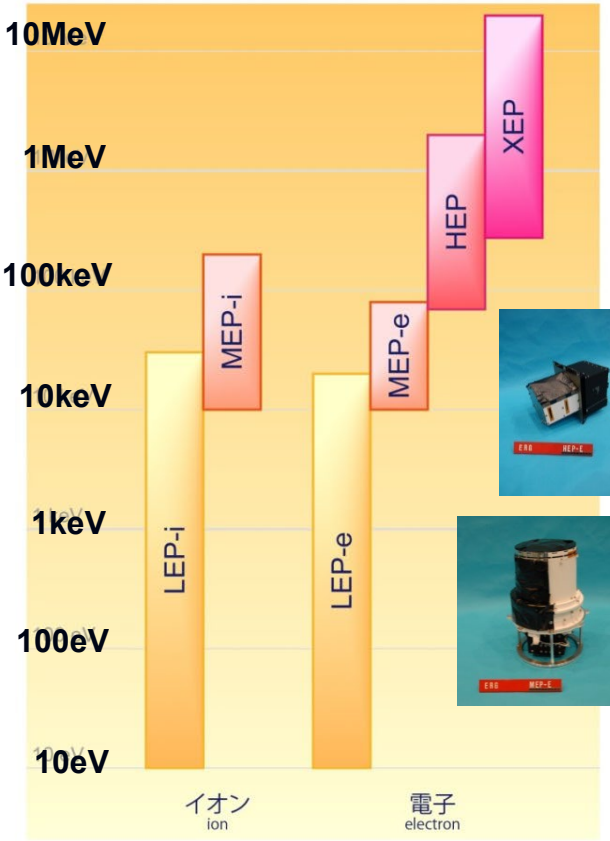
NHKと一部民放のBSデジタル放送で、日午後四時五十五分から約四十五分間に、全国で放送が中断したのはNHBS1、BS2、B

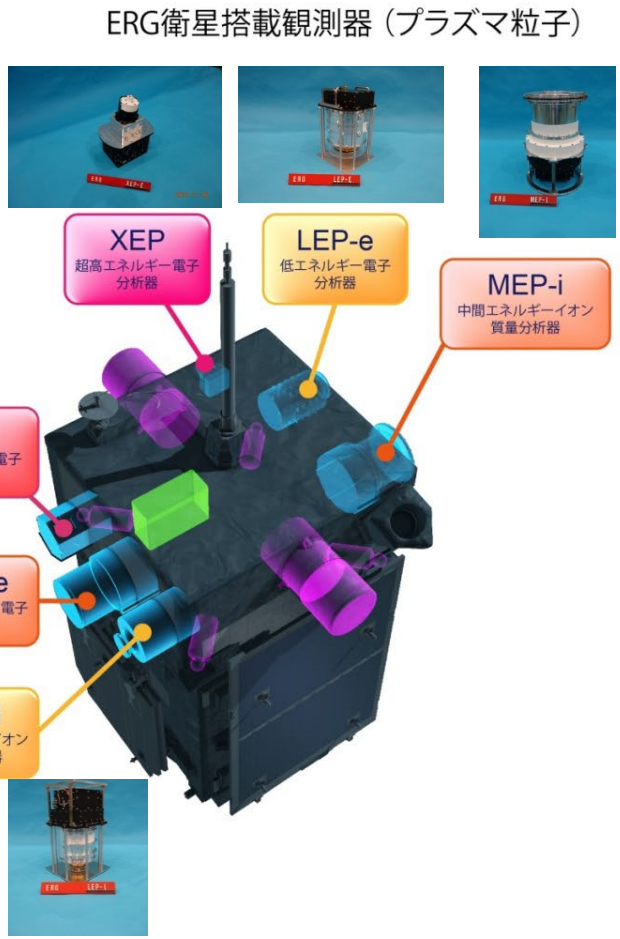
イビジョン、民放の映画専門局「スター・チャンネルBS」、音声放送「ミュージックバード」、データ放送など。民放キーシタル放送にかった。NH、放送が映ら、画面が固まかなくなるな聴者から問い伏いだ。
民放などが出運用会社の放テム（東京）星(BS)を予切り替え復旧フルのあった星の中継器をり、この中継県因とみて調、当時、NHとBSハイビ不相撲の韓国継していた。

A satellite broadcasting link for Sumo was temporary halted due to satellite trouble.

se satellite ar
elt dynamics i
y.

Science Instruments (plasma/particles)

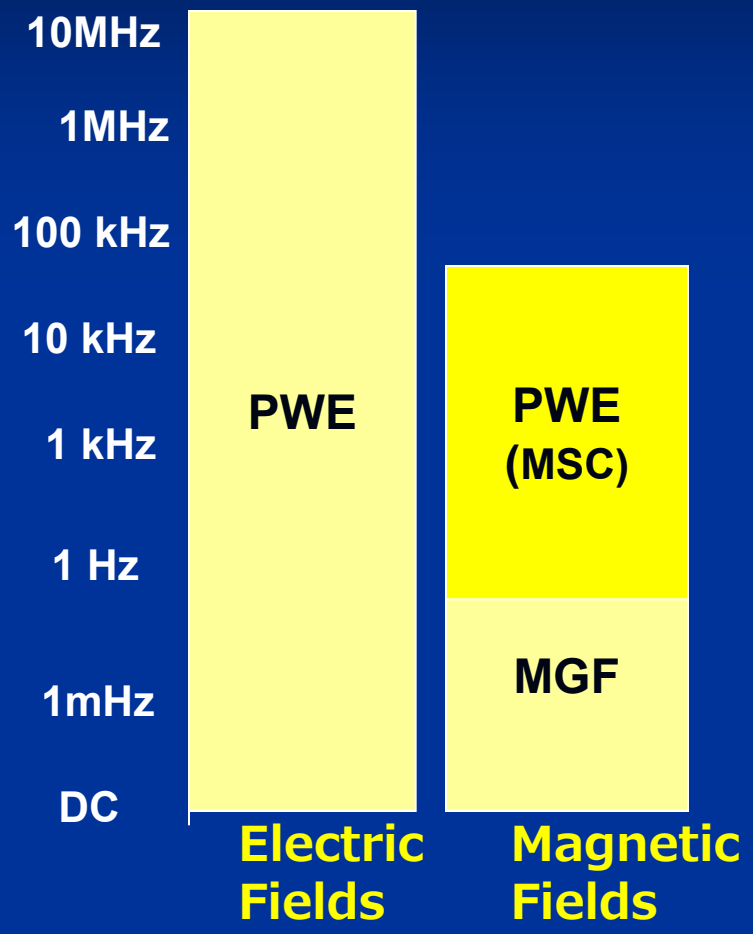


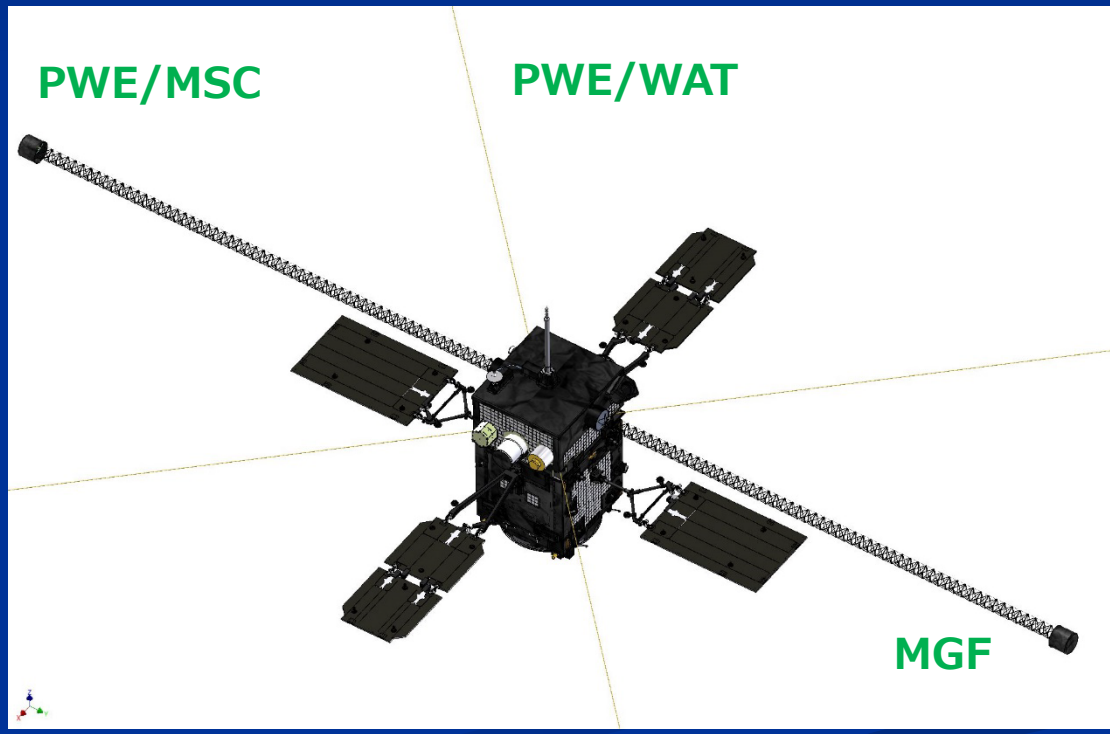


- Wide energy plasma/particles from 10eV – 20 MeV can be observed.

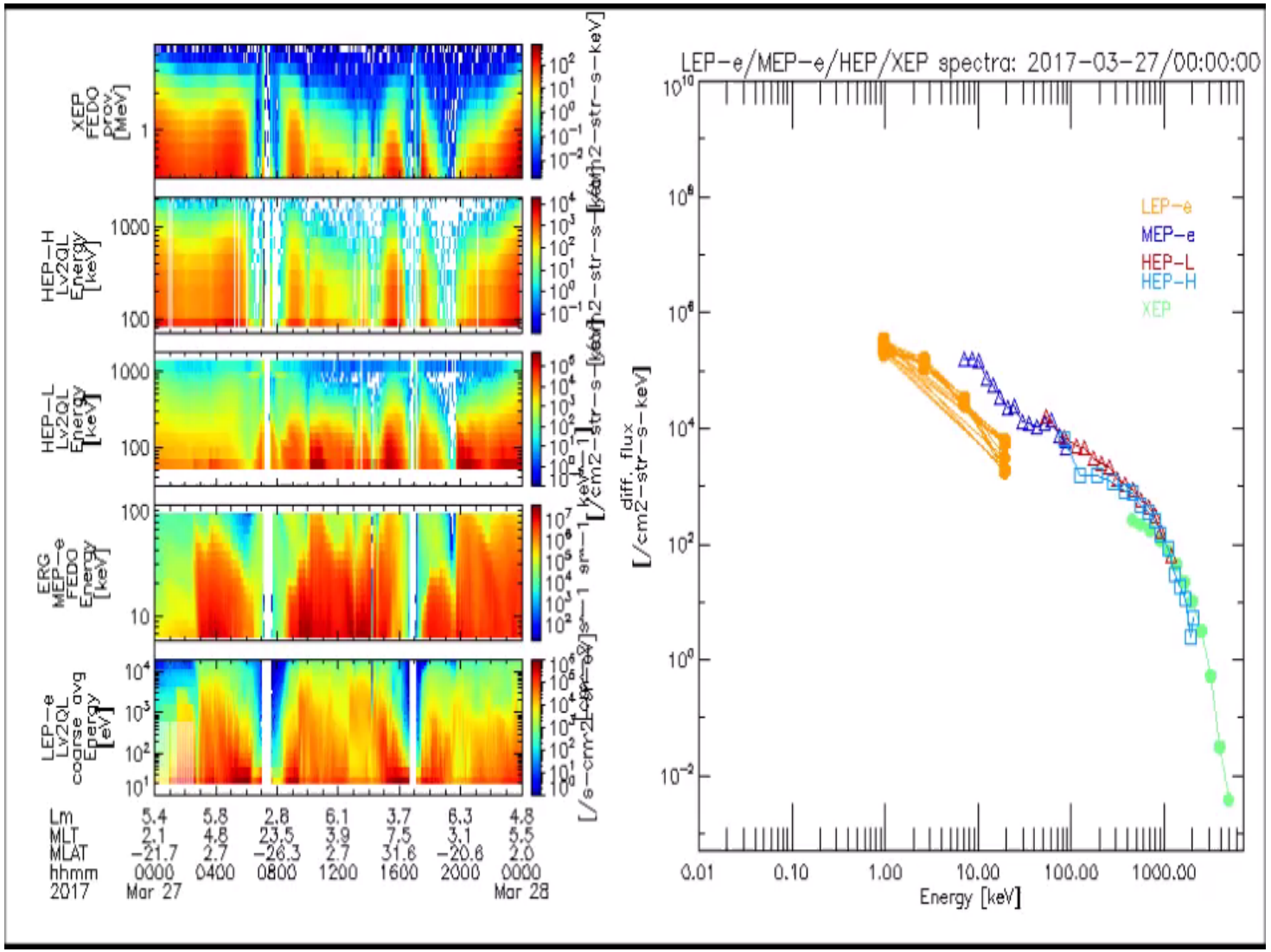
Science Instruments (Fields/Waves)

PWE: Plasma Wave and Electric Field Experiment (DC-10MHz)
MGF: Magnetic Field measurement (DC-100kHz)





Comprehensive plasma/particle observations



Seamless observations from ~20 eV to 20 MeV

First year observations of Arase

Arase/XEP

Solar wind speed

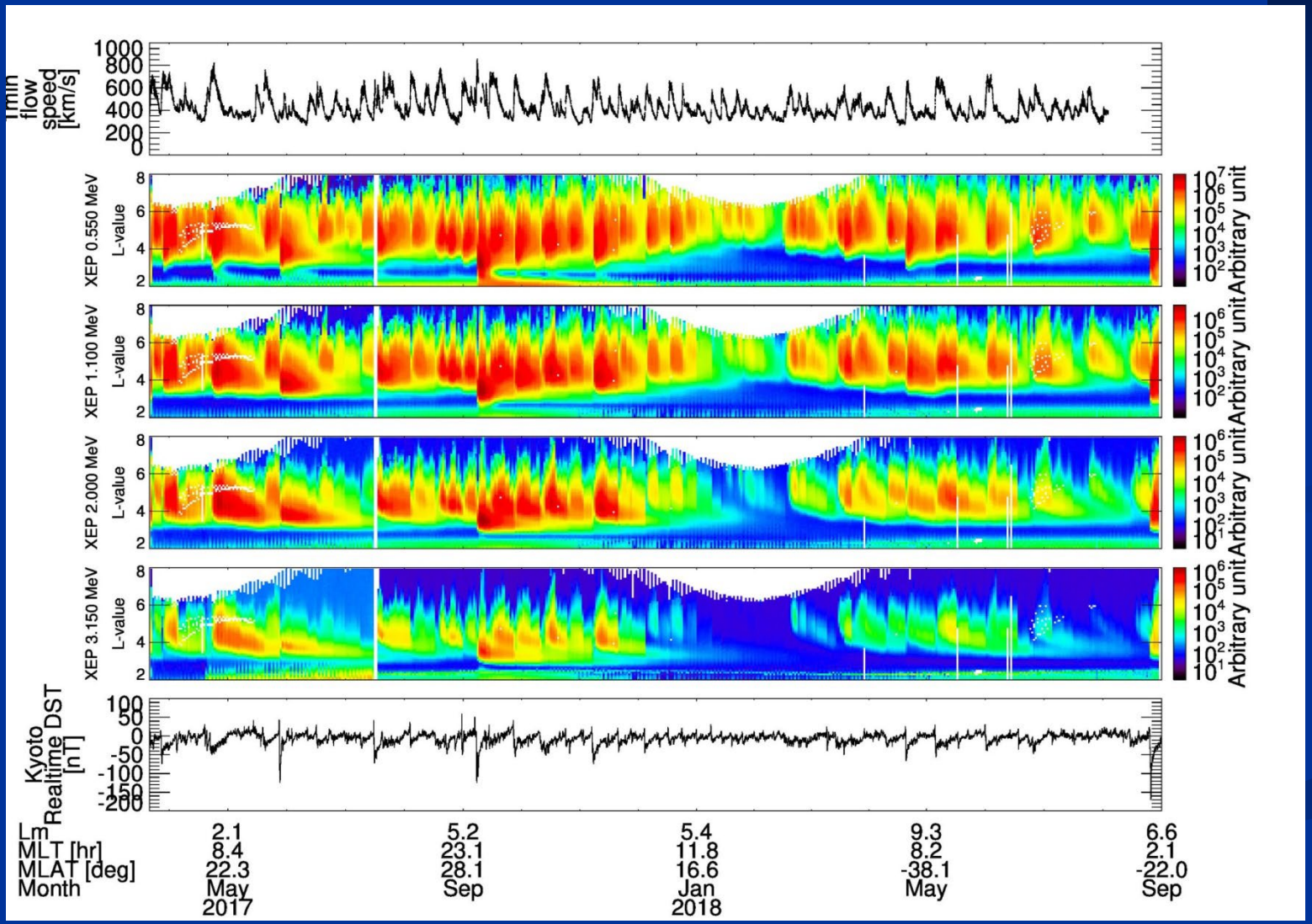
450 keV

1650 keV

2500 keV

4850 keV

Dst



2017/05 2017/09 2018/01 2018/05 2018/09