Plasma/particle instruments and Japan-Taiwan collaboration for the Geospace magnetosphere/ionosphere explorations

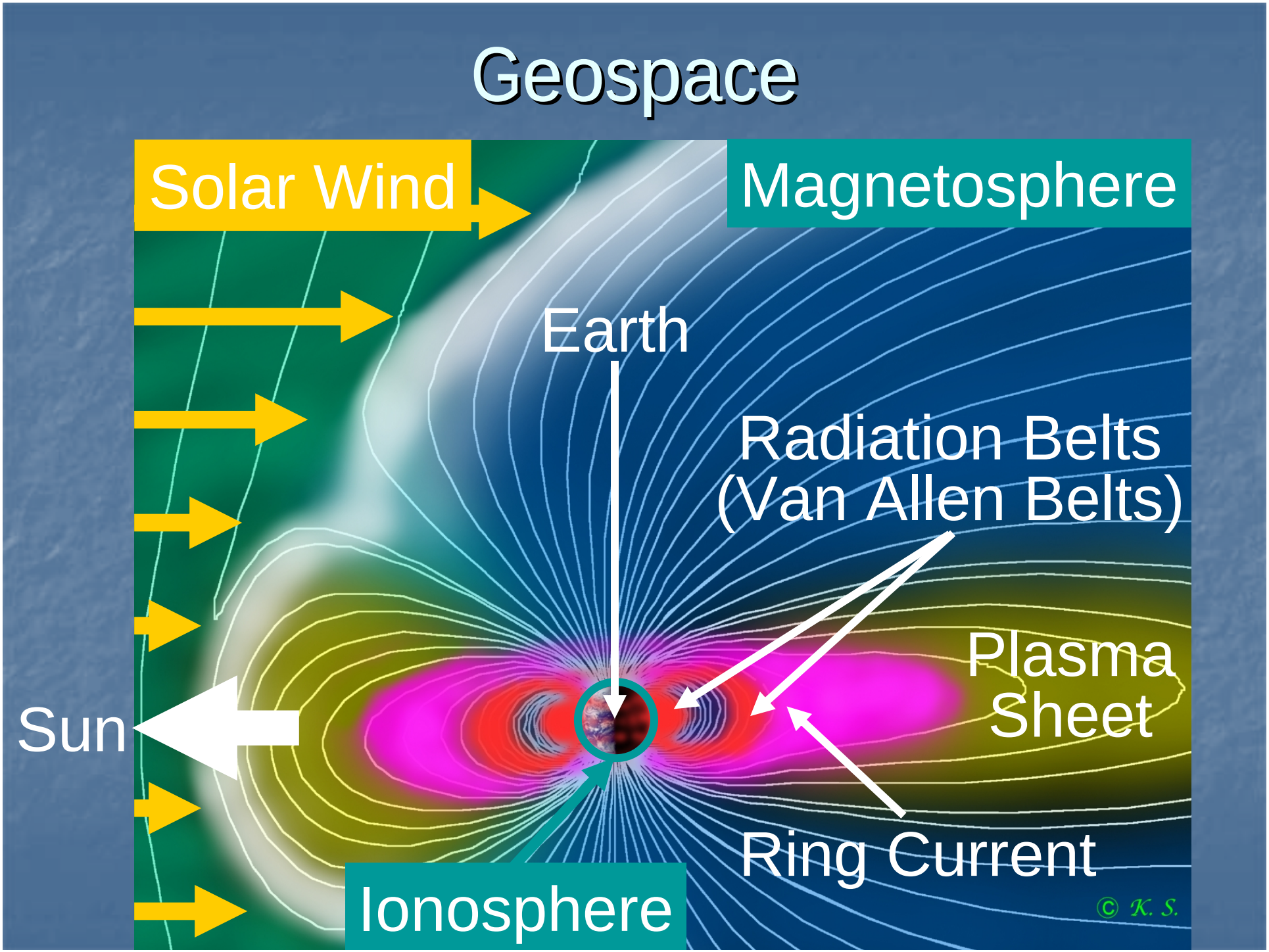
Masafumi Hirahara

Space and Planetary Science Group,
Department of Earth and Planetary Science,
Graduate School of Science,
The University of Tokyo

Key words: Collisionless space plasma,
Particle accelerations by plasma waves or fields,
In-situ (direct) measurement, Geospace,
Plasma/particle sensor development,
Satellite exploration mission,
International collaboration

My Background in Space Physics

- Experimental research in space physics
  - Instrumental developments and observations for space plasma
  - Satellite/spacecraft missions for terrestrial/planetary magnetosphere/ionosphere explorations
- Many-sided space physics
  - Elucidation of plasma acceleration/transport/loss mechanisms as a fundamental science
  - Contribution to development/maintenance of social infrastructure in space as an environmental science
  - Lead of planetary exploration with space expertise
  - Driver of international cooperation and interchange in scienfic, engineering, and human aspects


Geospace
Solar Wind
Magnetosphere
Earth
Radiation Belts
(Van Allen Belts)
Plasma
Sheet
Sun
Ring Current
Ionosphere
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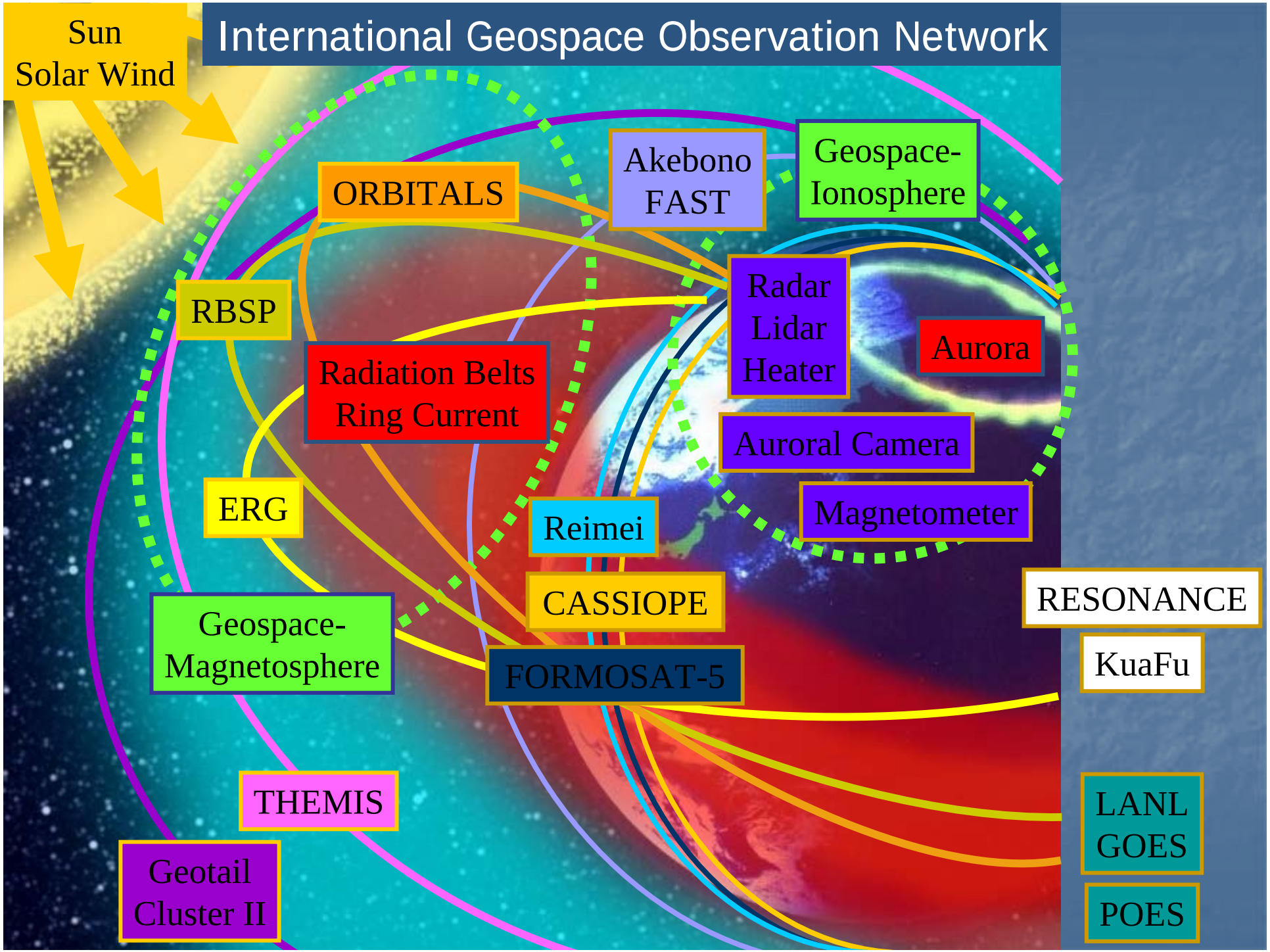

Sun
Solar Wind
International Geospace Observation Network
ORBITALS
Akebono
FAST
Geospace-
Ionosphere
RBSP
Radar
Lidar
Heater
Aurora
Radiation Belts
Ring Current
Auroral Camera
ERG
Magnetometer
Reimei
CASSIOPE
RESONANCE
Geospace-
Magnetosphere
KuaFu
FORMOSAT-5
THEMIS
LANL
GOES
Geotail
Cluster II
POES

Plasma Observations in Space

- In-situ (direct) measurement of collisionless plasma
  - Plasma waves, magnetic/electric fields dominantly interact the plasmas
  - Simultaneous observations for these are crucial
- Full energy/velocity distribution function
  - 2-D Energy-pitch angle distribution
  - 3-D velocity distribution function
- Wide ranges for energy, field of view, and counting rate
  - <1 eV for plasmasphere or cold component (1-1000#/cm^3)
  - 0.1 - 10 keV for plasma sheet (0.1-10#/cm^3)
  - 10 - 100 keV for ring current (<0.01#/cm^3, <10^8#/cm^2 s sr)
  - 100-10 MeV for radiation belt electrons (<10^6#/cm^2 s sr)
- Appropriate energy, angular, time resolutions
  - 10 μ sec. for wave(1kHz whistler mode)-particle(sub-MeV electron) interaction
  - msec. for full distribution function of electron dynamics
  - 100 msec. for full distribution function of ion dynamics
  - 10 sec. for common Geospace observations

Outline of this talk

- Reimei
  - Micro-satellite mission for fine-scale auroral exploration in Geospace-ionosphere
  - Launched in 2005
- FORMOSAT-5
  - Launch planned in 2011
  - Taiwan-Canada-Japan collaboration
  - Magnetic field and electron/ion measurements
  - Auroral Electron Sensor (AES) based on Reimei expertise
- ERG (Energization and Radiation in Geospace)
  - Small-satellite mission for high-energy particle acceleration mechanisms in Geospace-magnetosphere
  - Proposed to launch in 2013-2014
- Calibration facilities
  - Ion/electron beam line for up to 130-200 keV

Movie of auroral images (January 3, 2006)

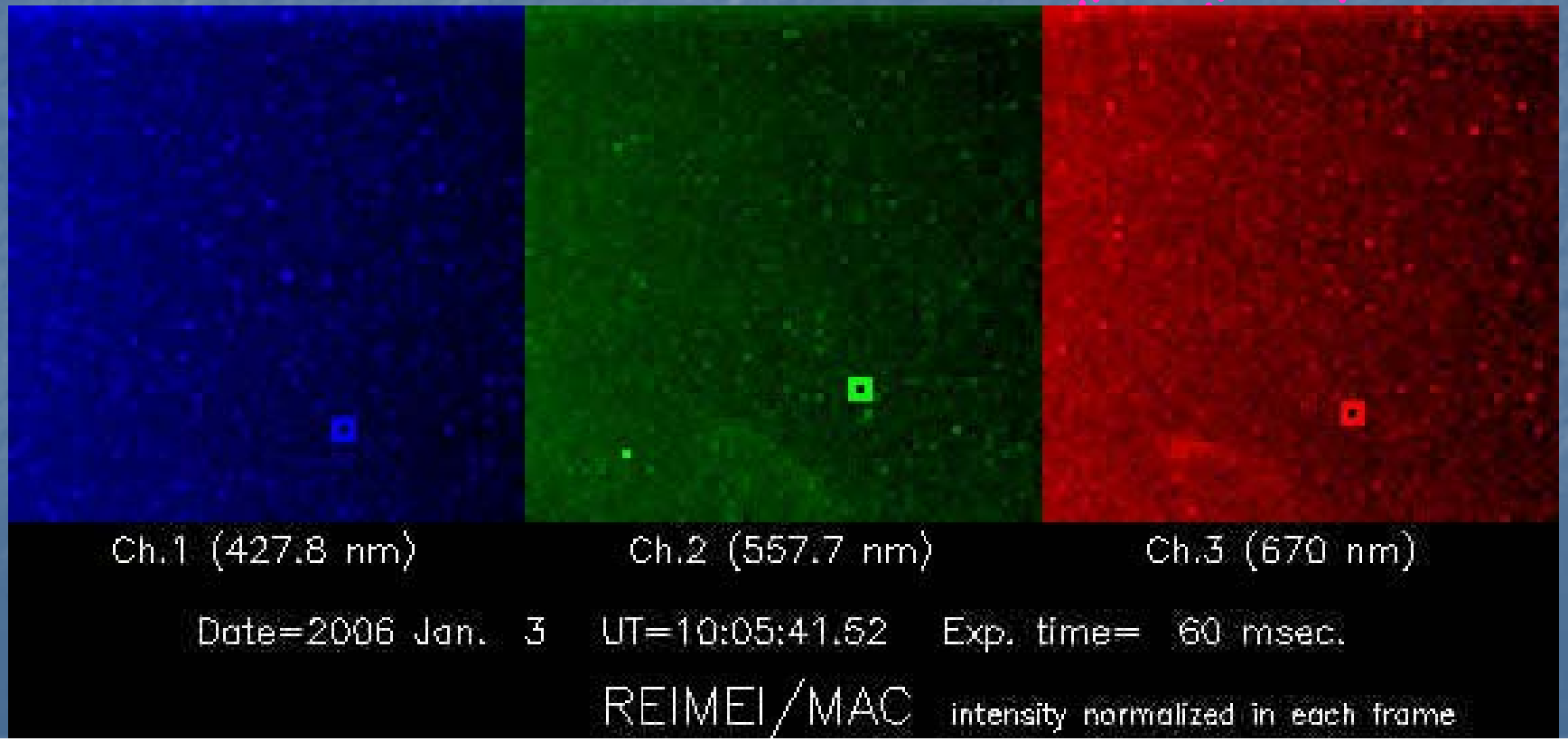
Exposure time: 60 msec.
Exposure cycle: 120 msec.

Footprint of S/C mapped onto 110-km altitude along field line

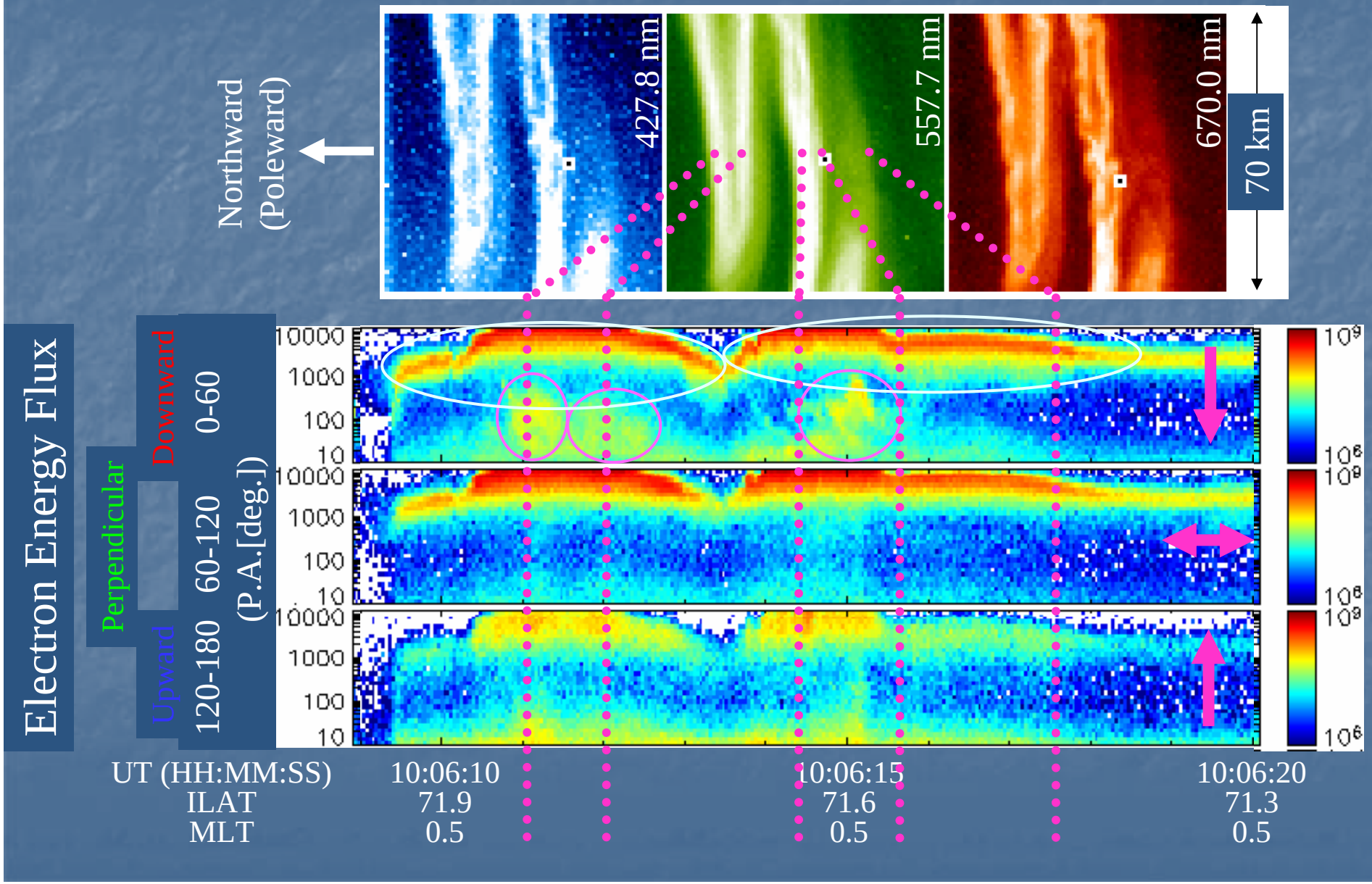
70 km (64 bins) at 110-km altitude

Northward (Poleward)

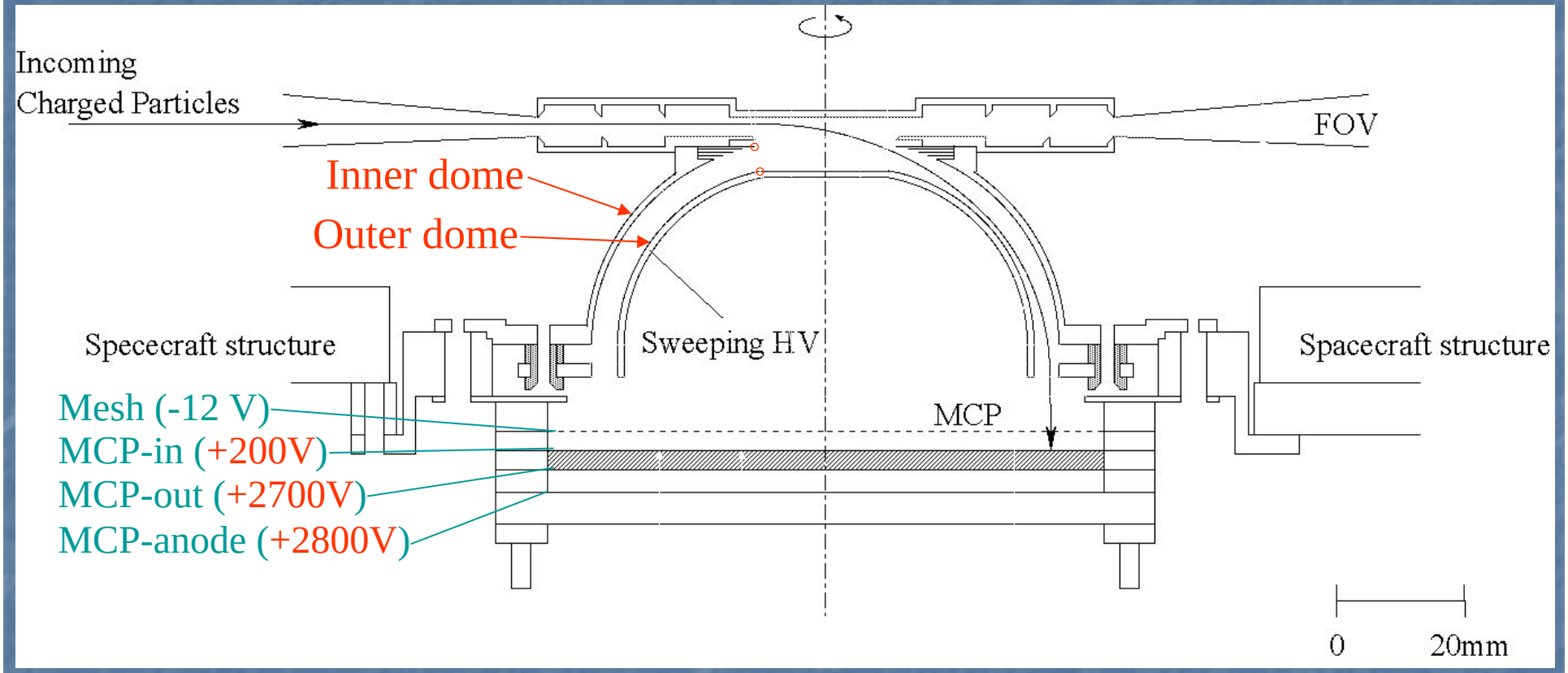
70 km (64 bins)



Auroral emissions and electrons (January 3, 2007)

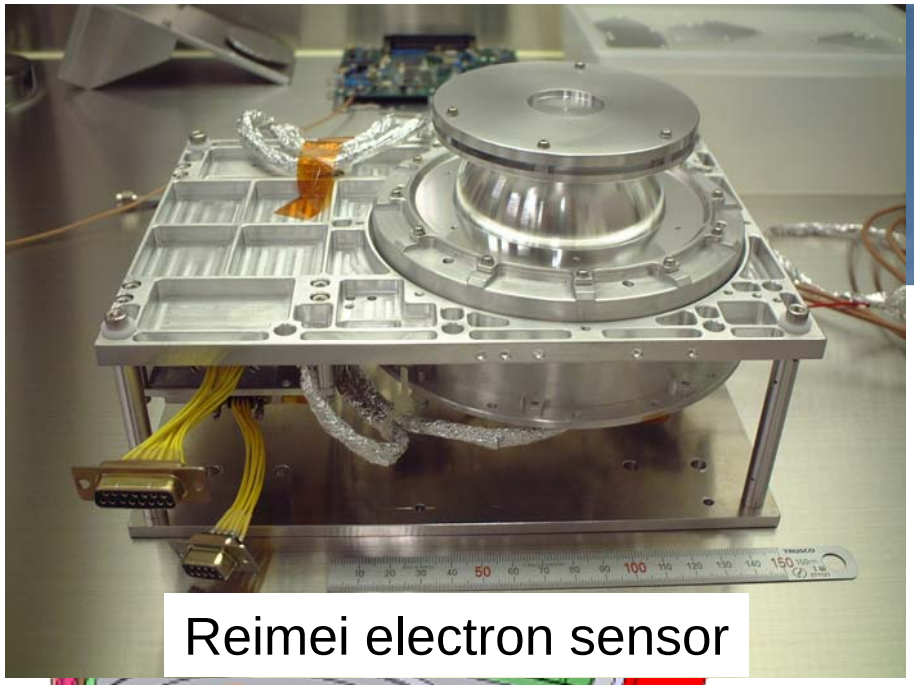


Auroral electron sensor (AES) for FORMOSAT-5

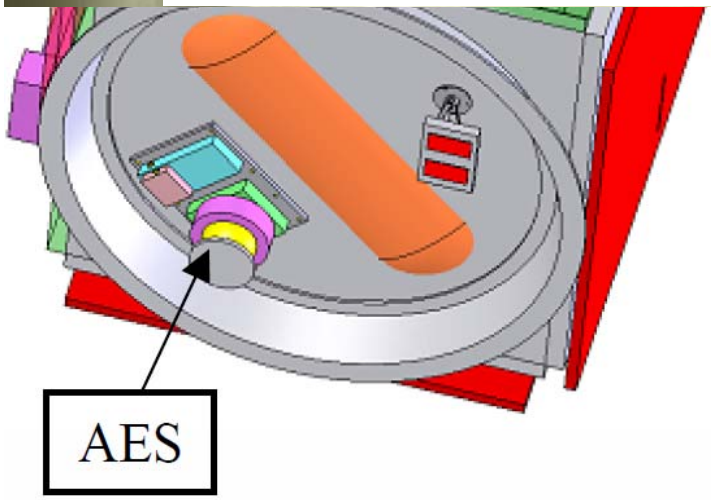


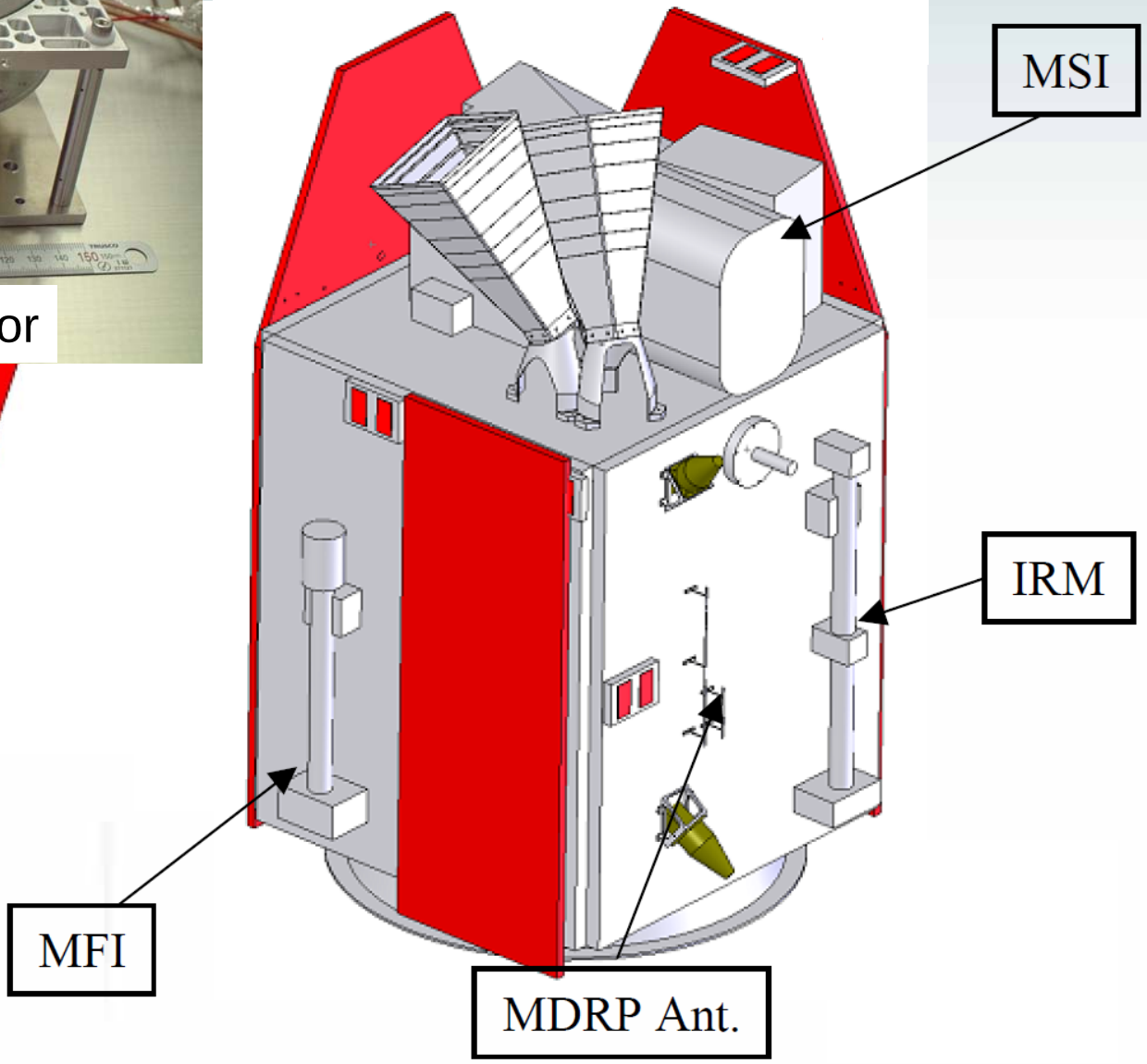
- ✓Higher-performance of high-voltage power supply for electrostatic analyzer could increase maximum energy level from 12 keV of Reimei to 18 keV for FORMOSAT-5.
- ✓Time resolution may decrease from 20 msec. to 100 msec. because of limitation on telemetry data, which could cause a problem and should be avoided if possible.

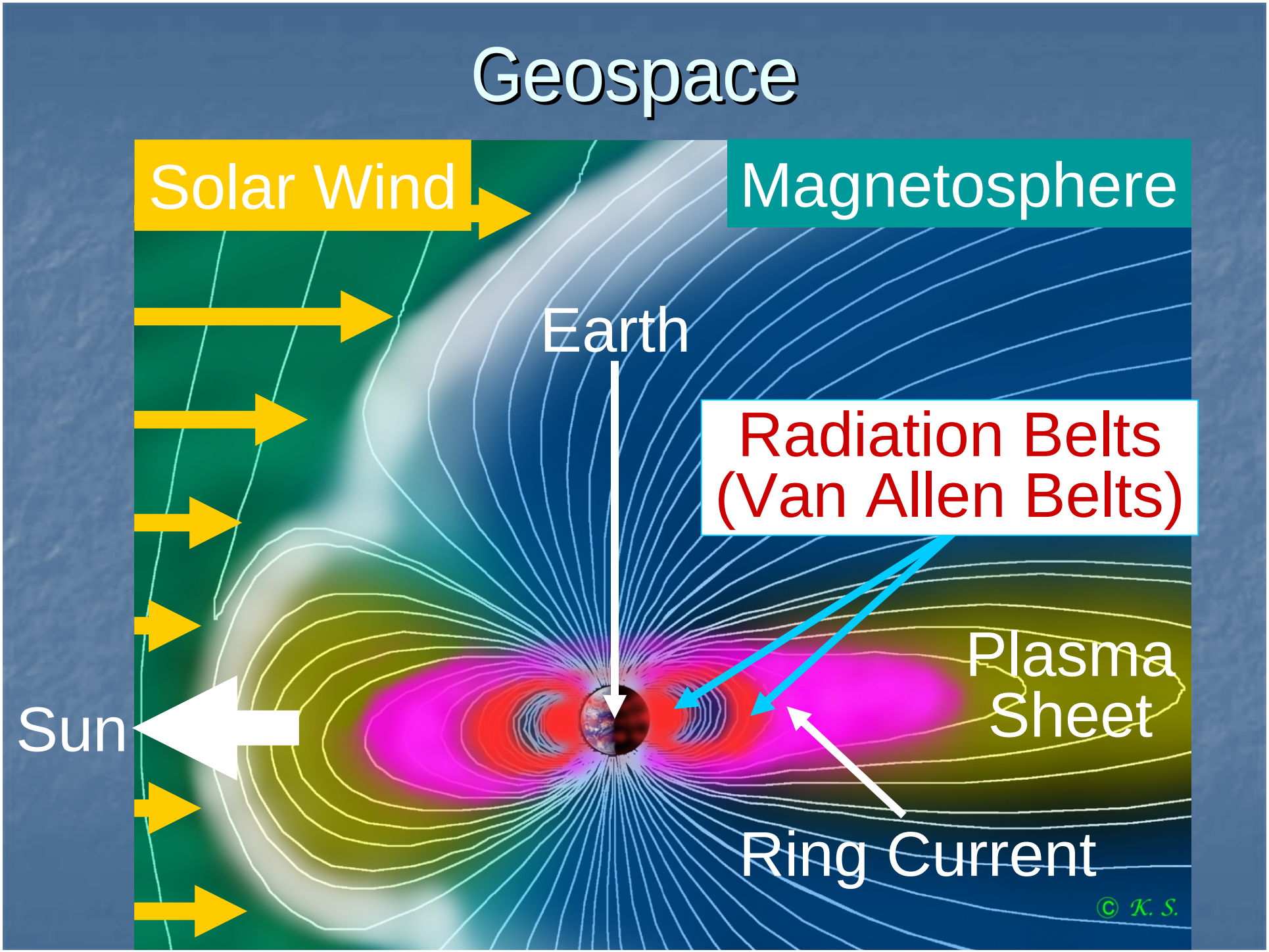
Collaboration in FORMOSAT-5



Reimei electron sensor



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Plasma
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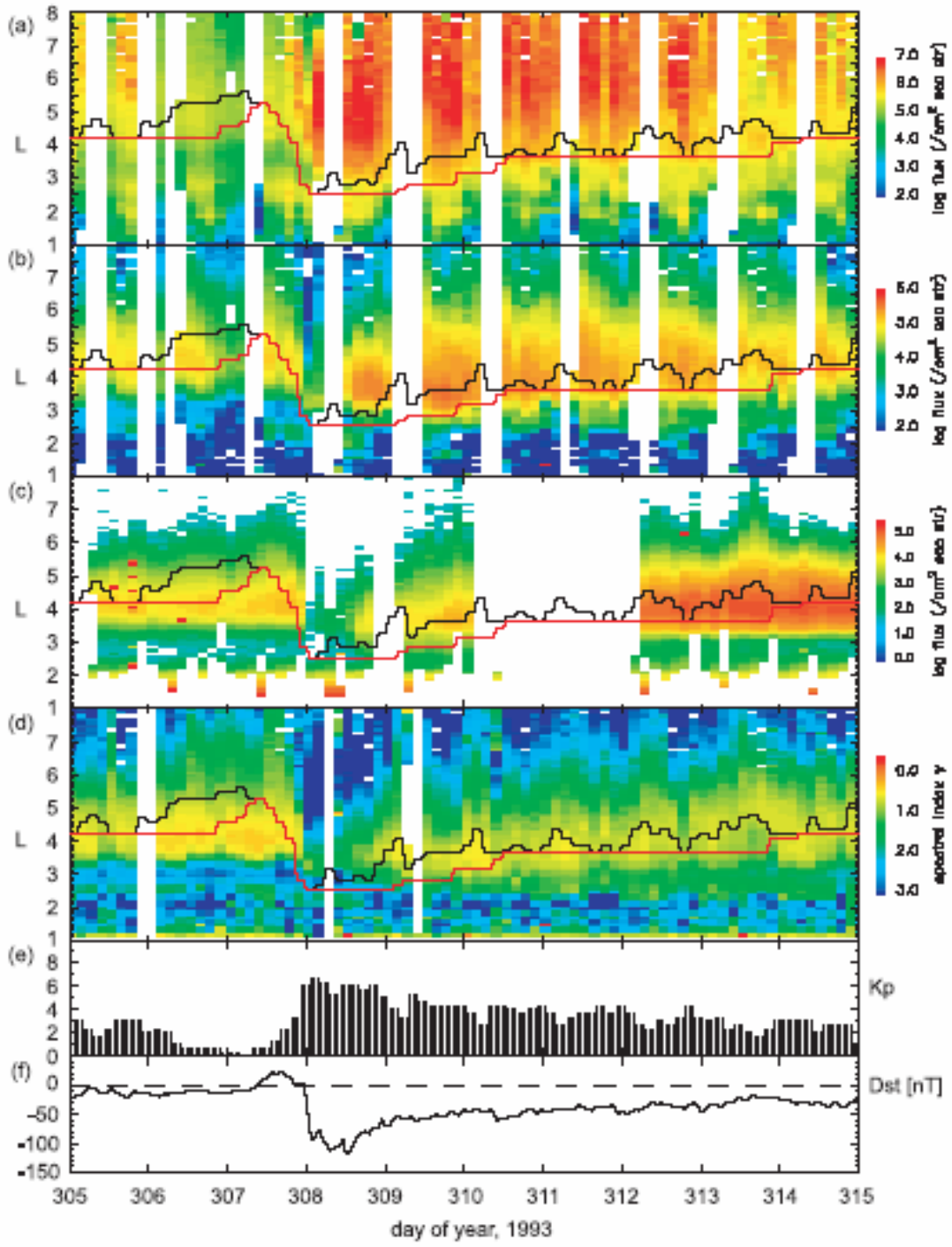
© K. S.



Ele: 30-1100 keV

Ele: 300-1100 keV

Ele: >2500 keV

（Killer electrons damaging space infrastructure like weather/communication/GPS satellites）

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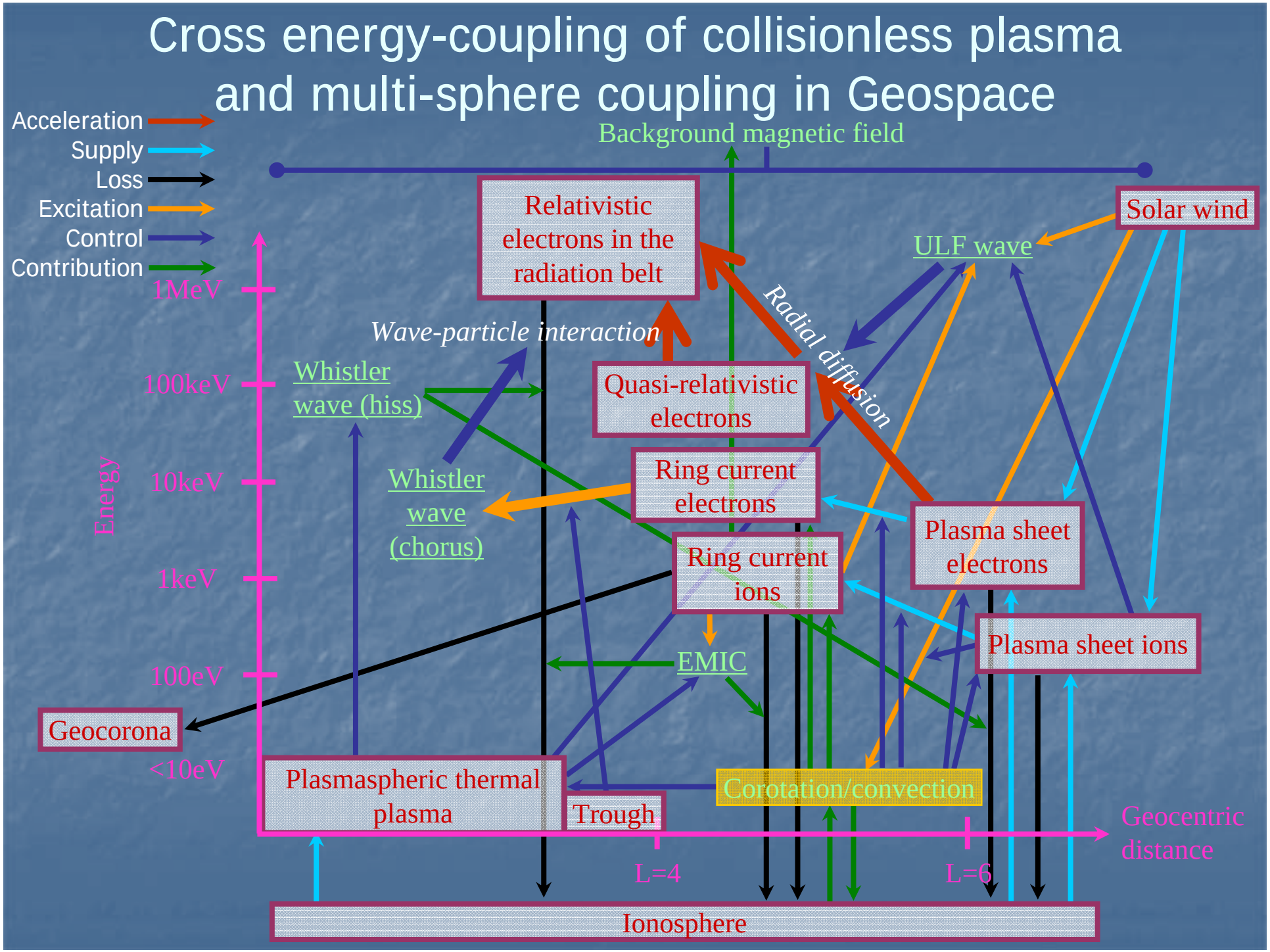
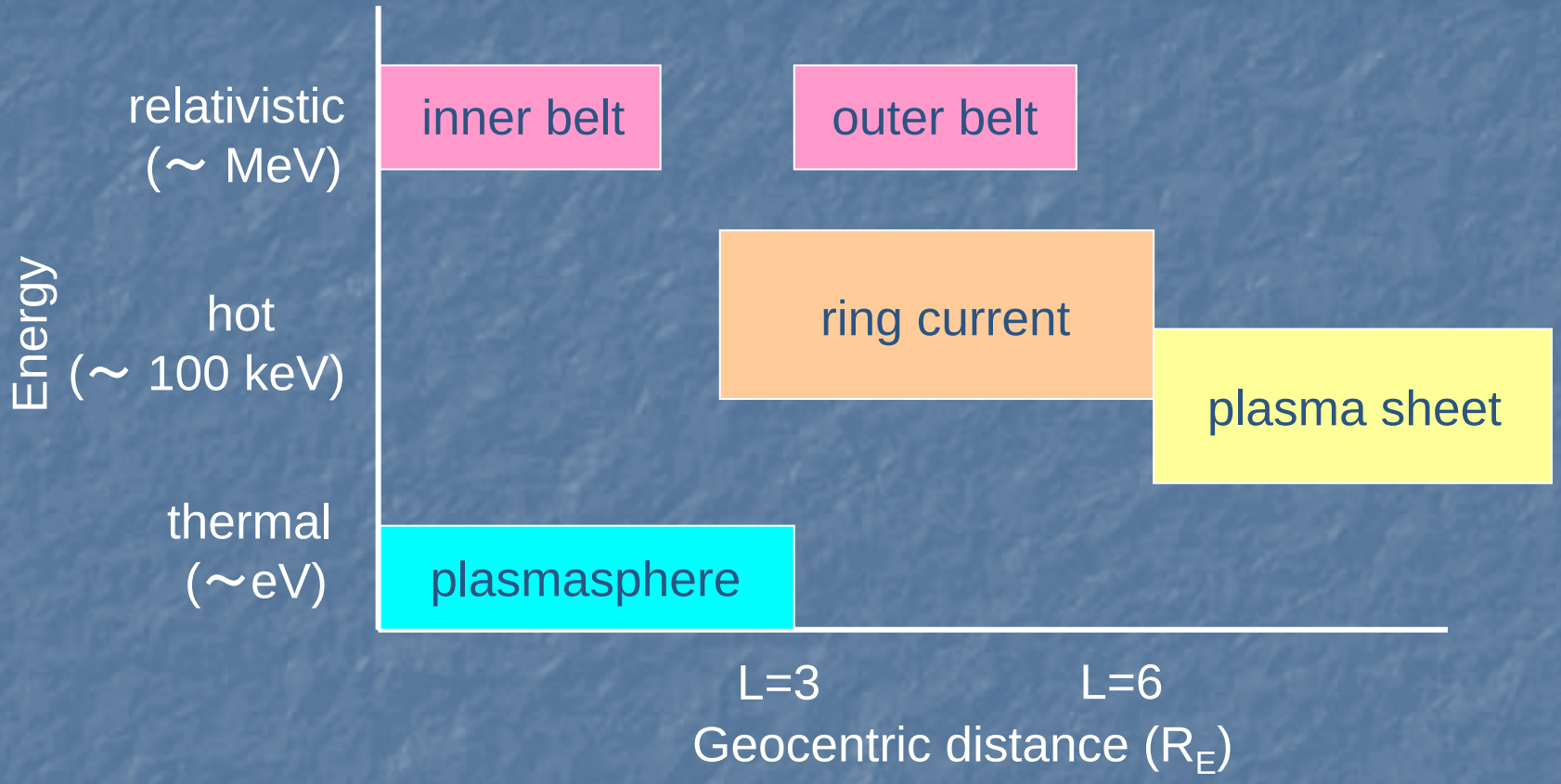
Dst
（Energy stored in ring current）


Cross energy-coupling of collisionless plasma and multi-sphere coupling in Geospace
Acceleration
Supply
Loss
Excitation
Control
Contribution
Background magnetic field
Relativistic electrons in the radiation belt
Solar wind
ULF wave
Radial diffusion
Wave-particle interaction
Whistler wave (hiss)
Quasi-relativistic electrons
Ring current electrons
Whistler wave (chorus)
Plasma sheet electrons
Ring current ions
Plasma sheet ions
EMIC
Geocorona
Plasmaspheric thermal plasma
Trough
Corotation/convection
Ionosphere
Energy
1MeV
100keV
10keV
1keV
100eV
<10eV
L=4
L=6
Geocentric distance

Plasma/particles in Geospace-magnetosphere

What is the origin of relativistic electrons in Geospace?



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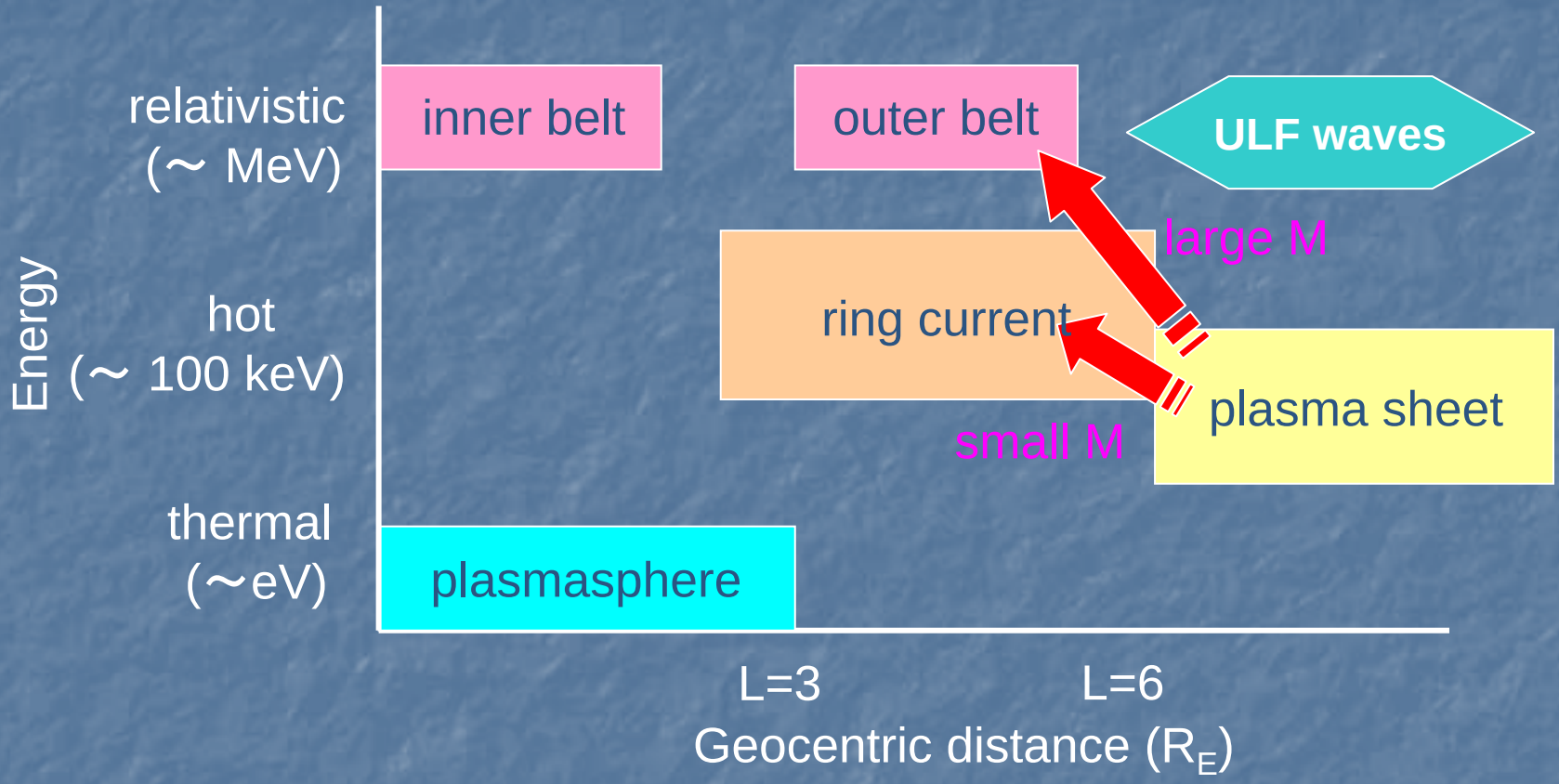
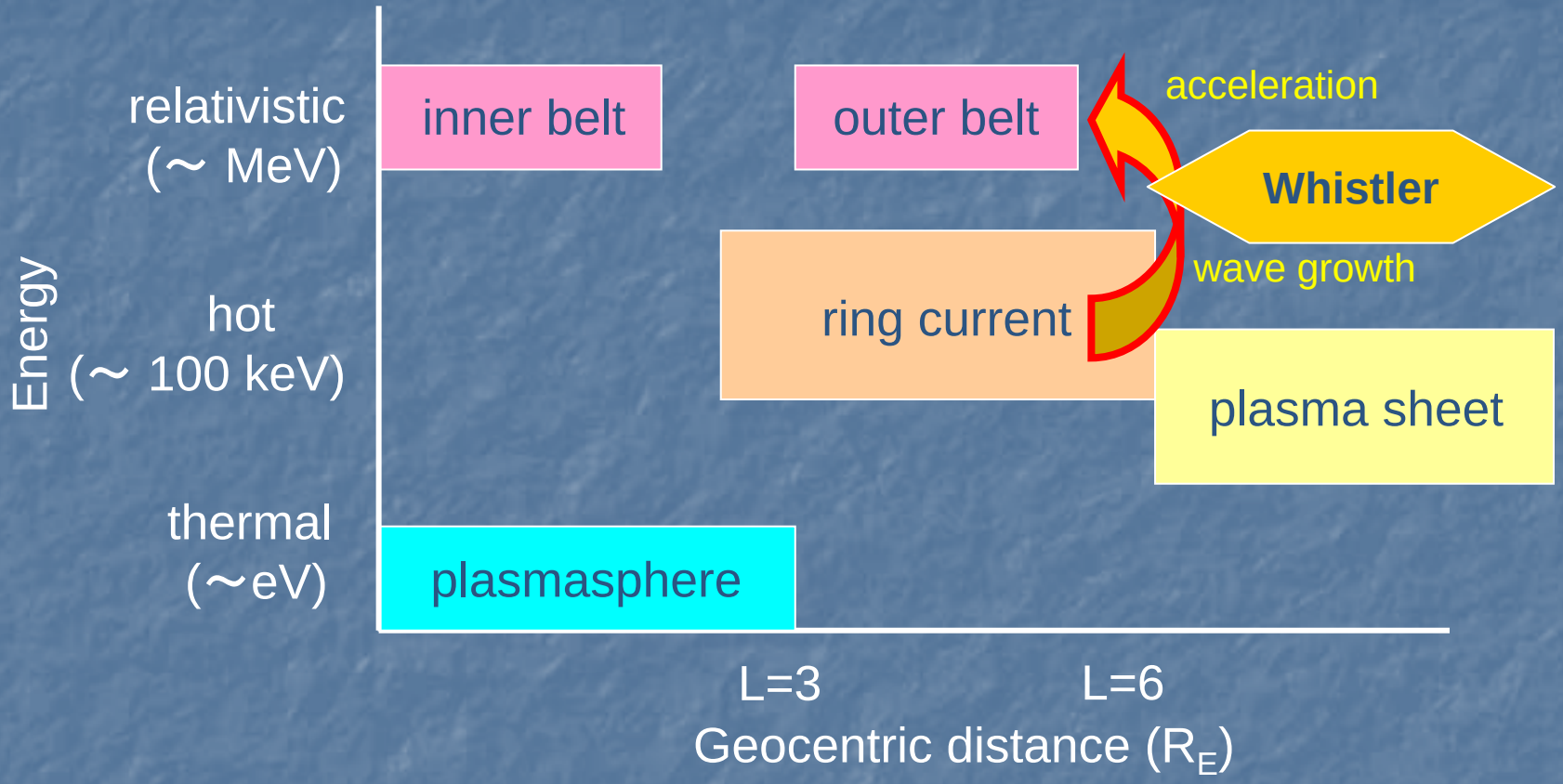


Adiabatic transportation via ULF waves could be important for particle acceleration.

Plasma/particles in Geospace-magnetosphere

What is the origin of relativistic electrons in Geospace?



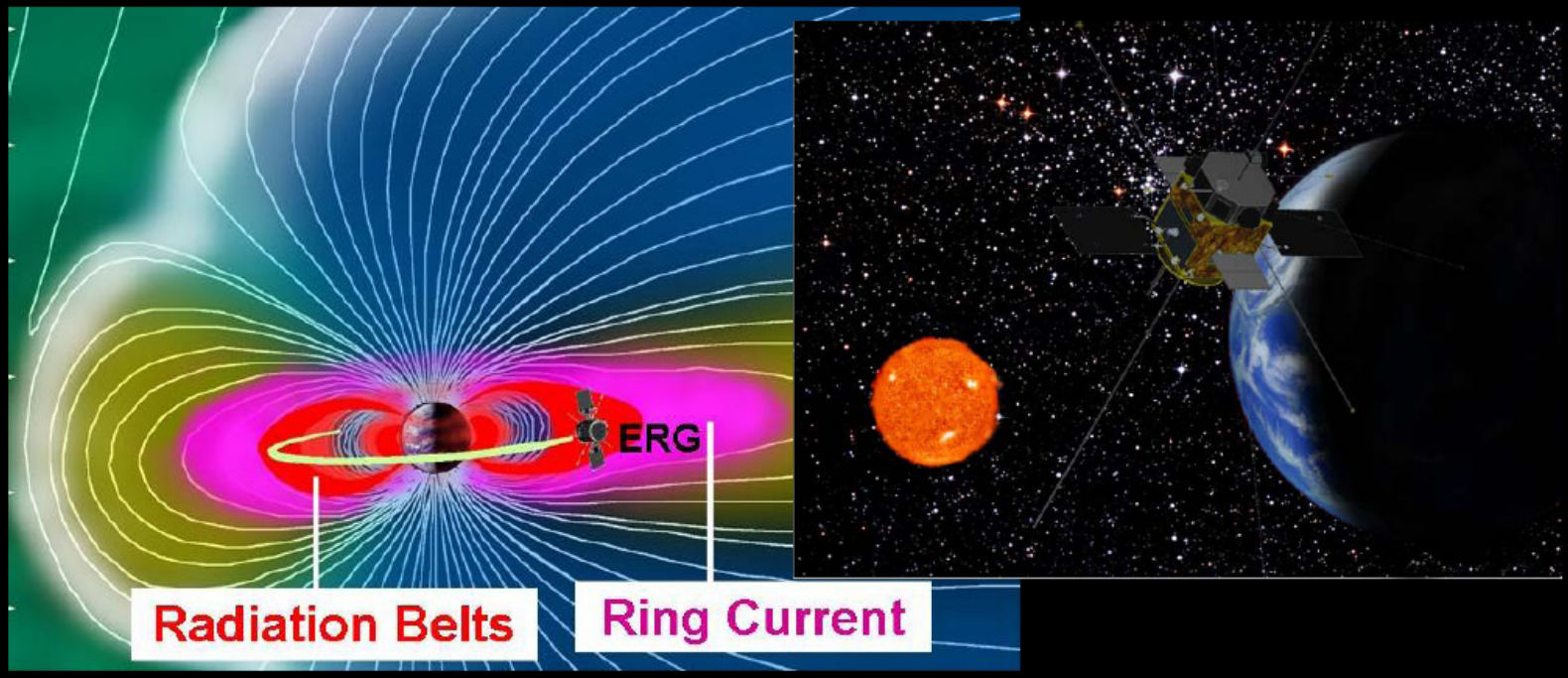
Non-adiabatic processes via plasma waves such as whistler and magnetosonic waves are also important for particle acceleration.

Comprehensive observations have never been performed at the magnetic equator because the observation in the radiation belts is quite difficult due to strong radiation incident.

ERG ---Energization and Radiation in Geospace

A mission to elucidate acceleration and loss mechanisms of relativistic particles in the inner magnetosphere during space storms.

During space storms, Geospace acts as an effective accelerator of electrons and ions, and dynamic variation of Geospace causes various “space weather” phenomena.



ERG mission will achieve comprehensive plasma observations with magnetic & electric field, wave, and particle detectors covering a wide energy coverage (10-10^7 eV) to capture acceleration, transport, and loss of particles in Geospace around the next solar maximum.

The ERG mission

Mission goal

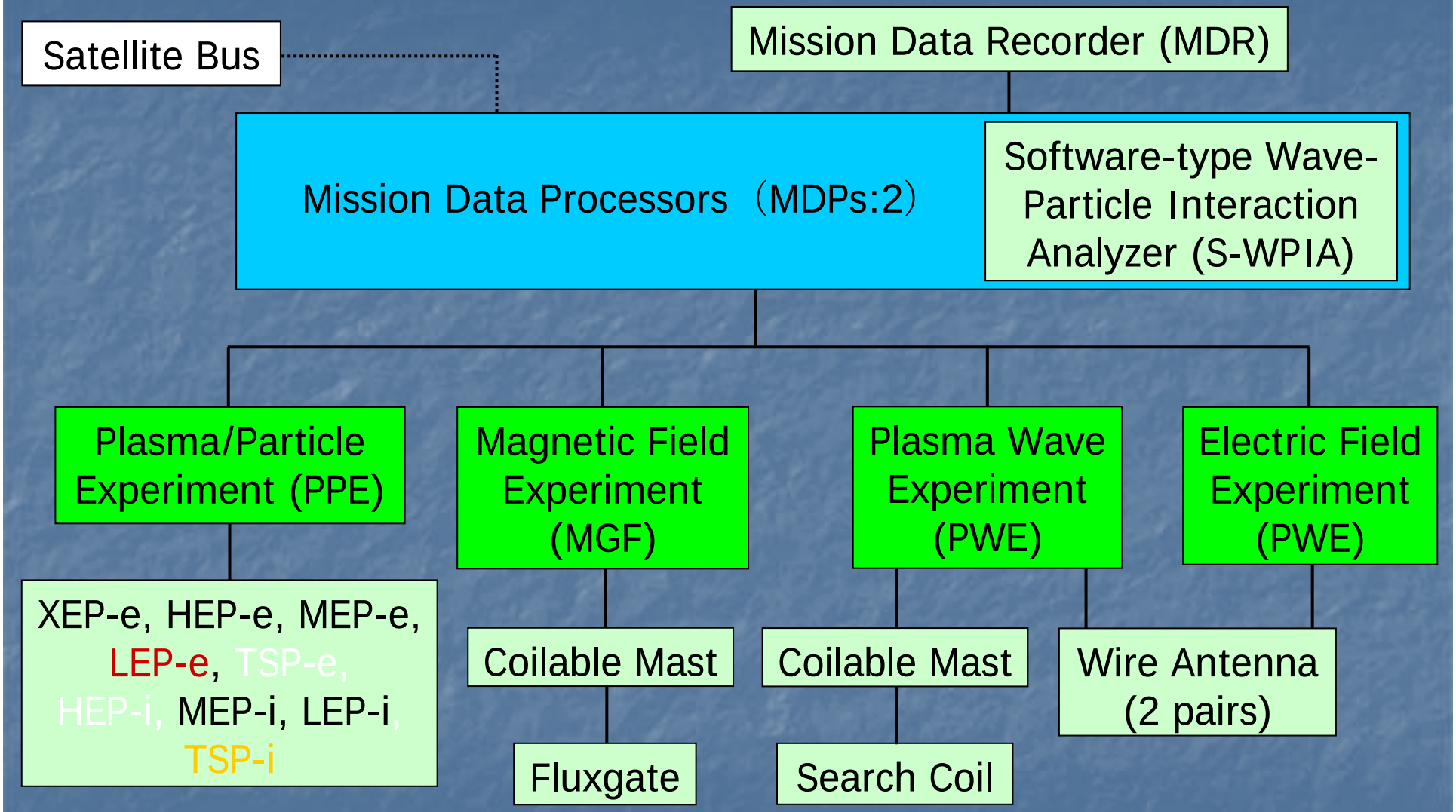
Understanding cross-energy couplings for

acceleration and loss processes of relativistic particles
&
environmental variation of geospace during space storms

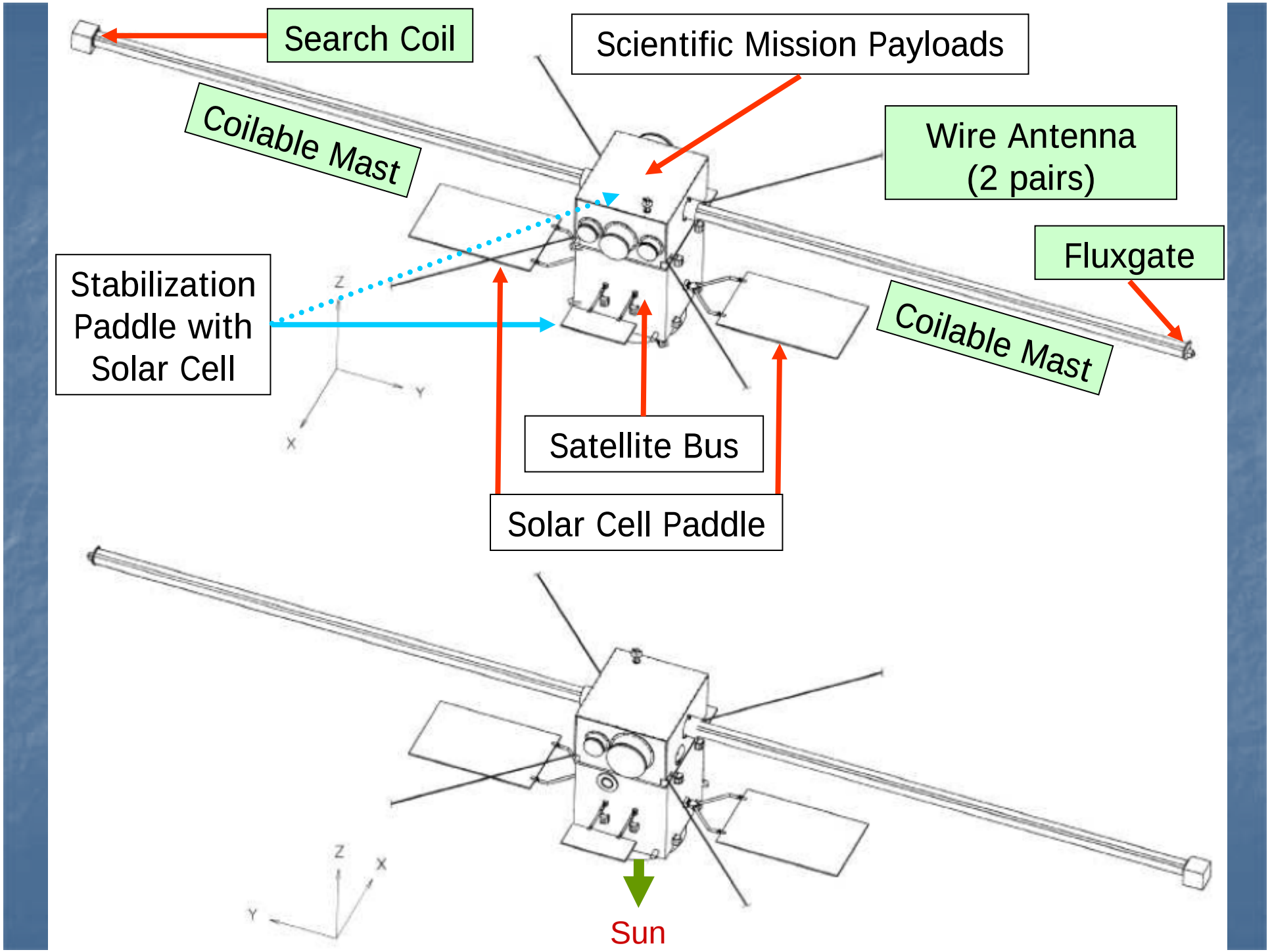
Significance of this mission

- Direct observations on generation of relativistic electrons at the magnetic equator in the Geospace-magnetosphere
  → Contribution to understanding of the particle acceleration
- Instrumental development to measure plasma/wave/fields under the severe radiation belt environment with small satellite
  → Contribution to the future Jovian mission

Scientific Instruments on ERG

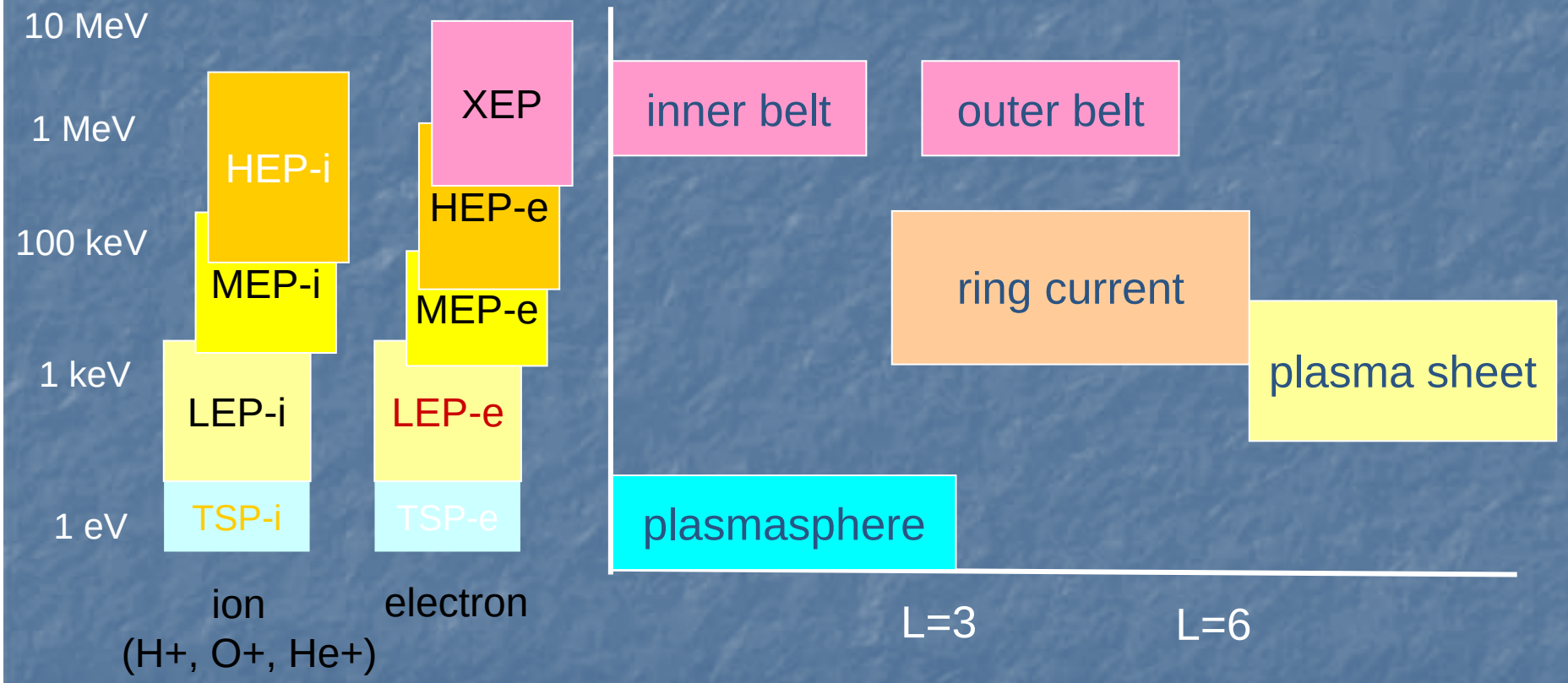


XEP, HEP, MEP, LEP, TSP-e/i stand for
extremely high, high, middle, low, thermal & suprathermal energy particle sensors
for electron/ion of plasma/particle experiment (PPE) of ERG.


Search Coil
Scientific Mission Payloads
Coilable Mast
Wire Antenna
(2 pairs)
Fluxgate
Stabilization
Paddle with
Solar Cell
Coilable Mast
Satellite Bus
Solar Cell Paddle
Z
Y
X
Z
X
Y
Sun

Science instruments of ERG: *plasma/particle*

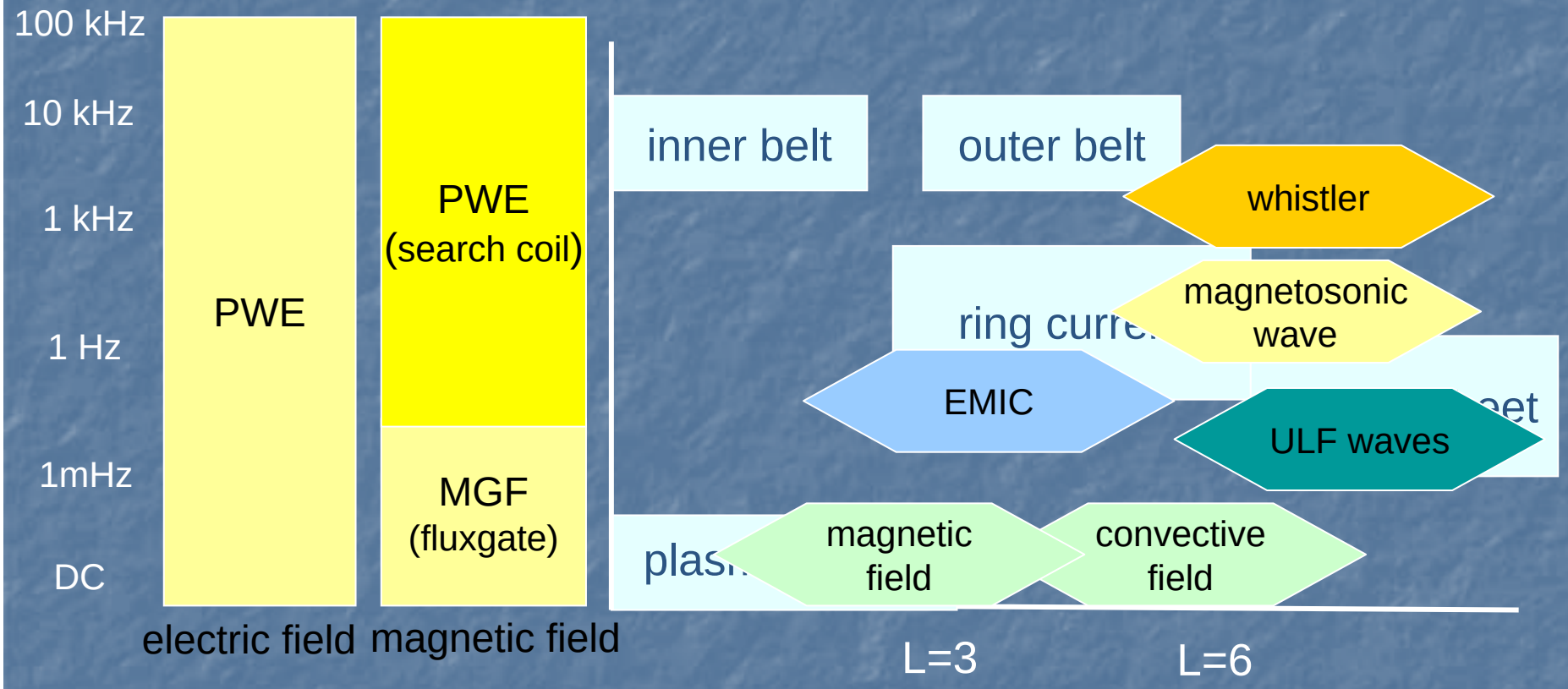
PPE: Plasma and Particle Experiment



ERG-PPE measures a wide energy range over 6 orders.

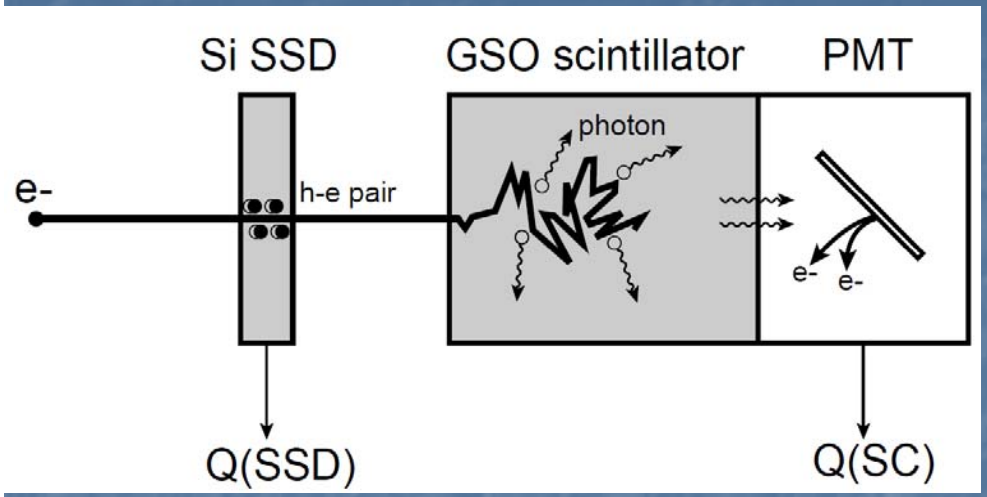
Science instruments of ERG: *wave & field*

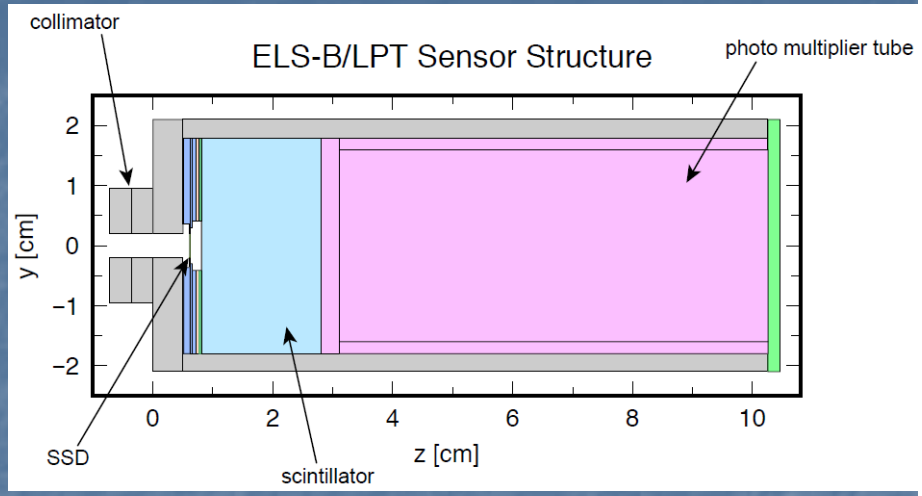
PWE: Plasma Wave and Electric Field Experiment
MGF: Magnetic Field Measurement

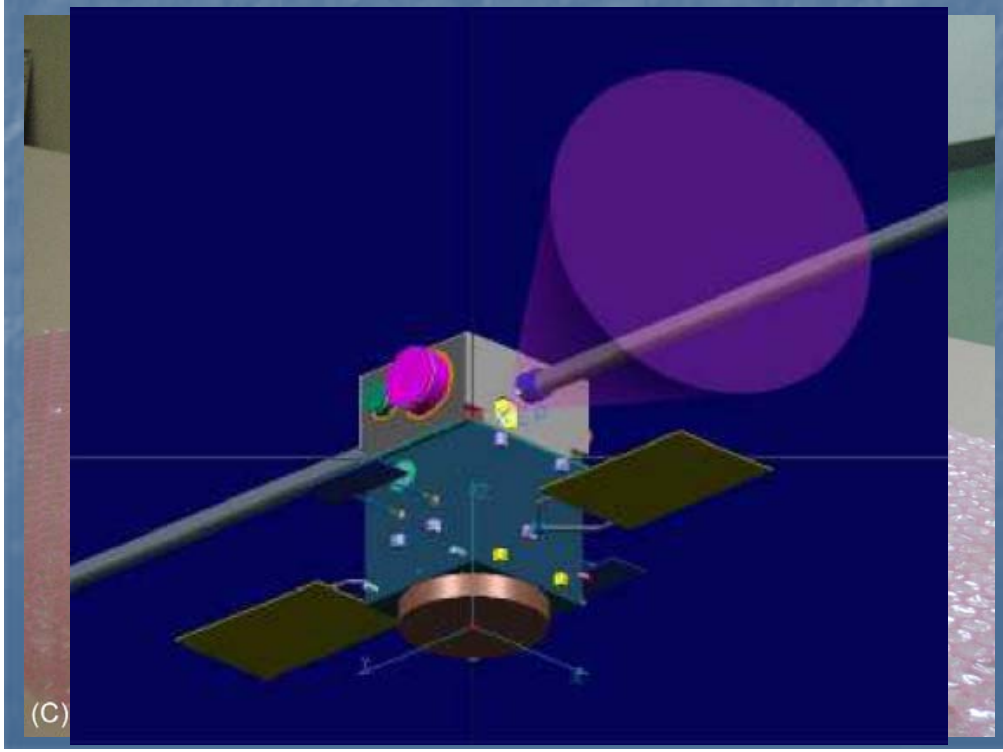


ERG-PWE and MGF measure electric and magnetic fields for a wide frequency range from DC to sub-MHz.

Extremely high-energy electron sensor (XEP-e)







Electron for 0.2 - 20 MeV

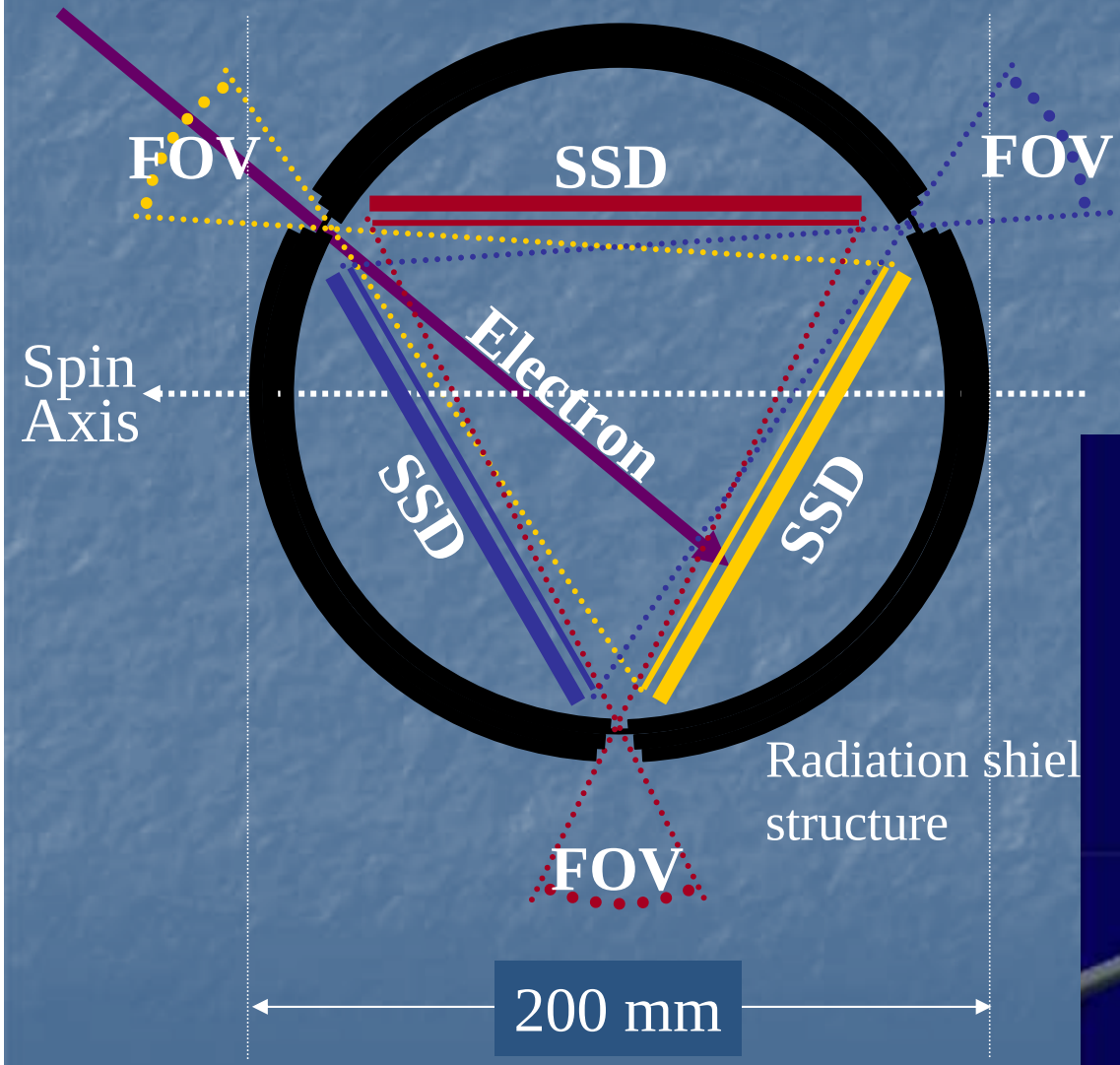
Adoption of the ELS-B sensor design and expertise of JAXA in JASON-2 and GOSAT

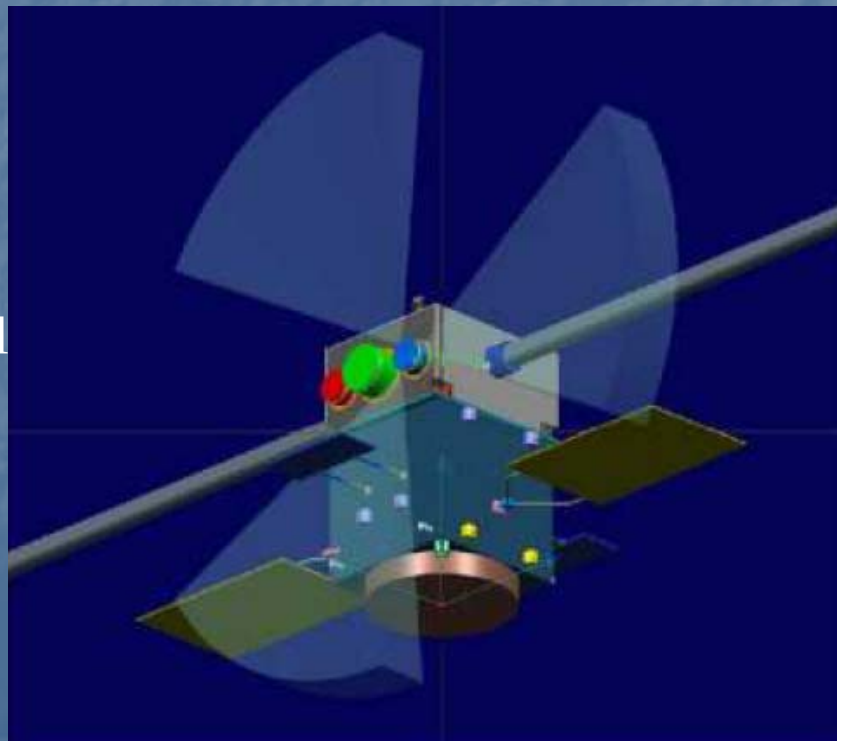
Radiation shields with 7-mm of aluminum and 3-mm copper

High-energy particle sensor (HEP-e)

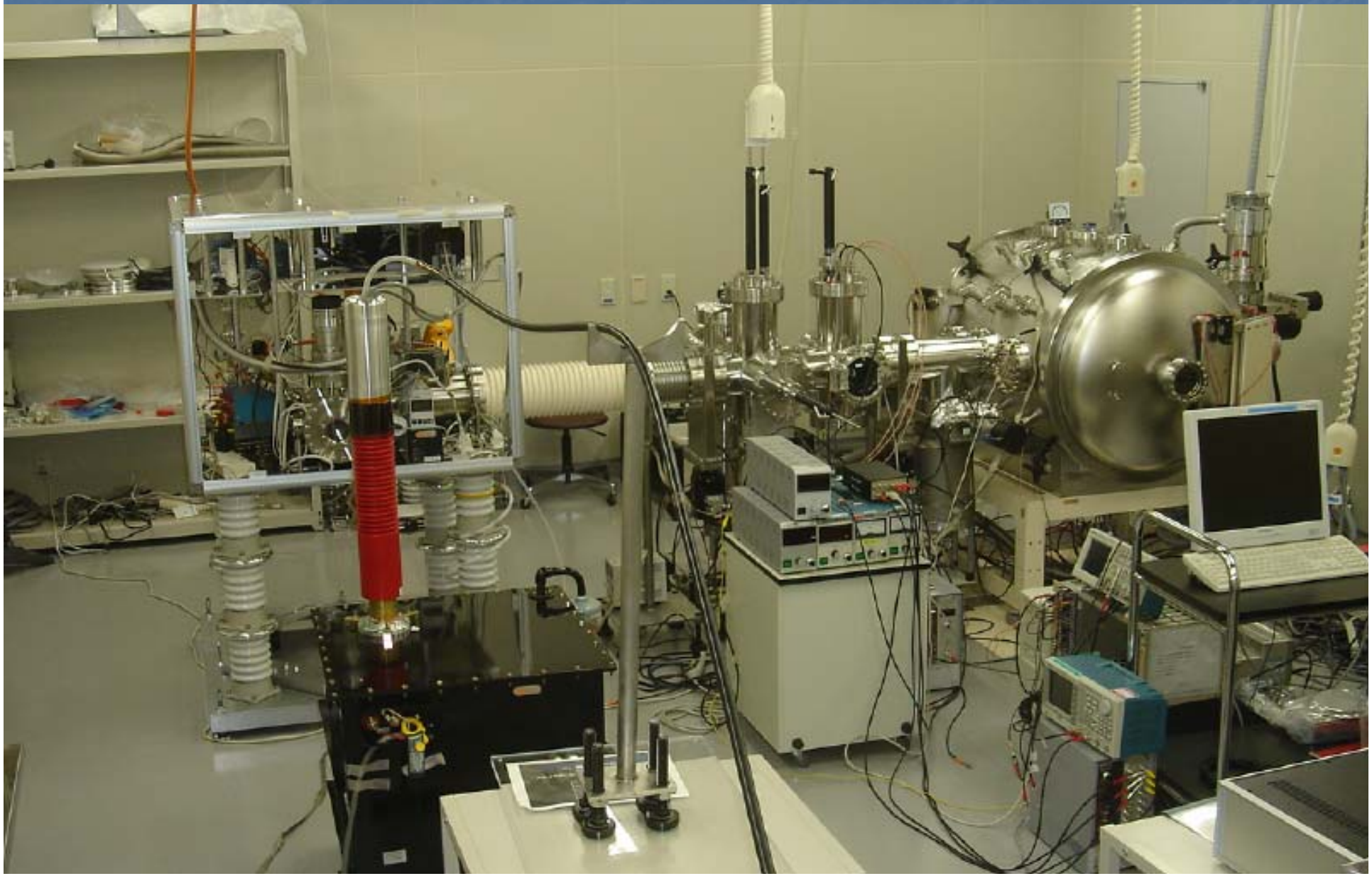
Electron for 0.03 - 2 MeV

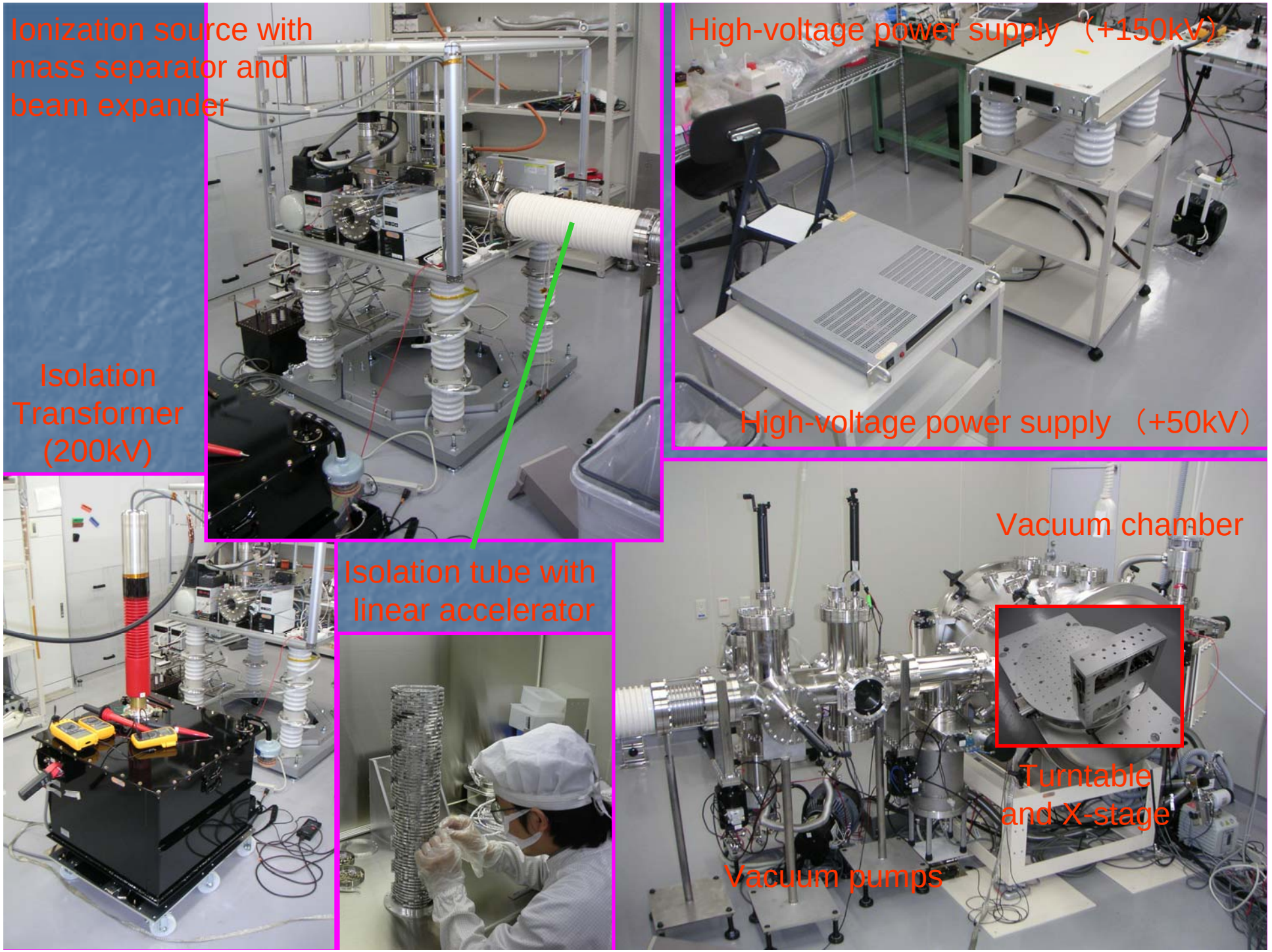
Adoption of pin-hole camera principle using three assemblies of strip solid state detector





Calibration Facility for Space Plasma/Particle Instrument
～170-keV ion/electron beam line in Tokyo




Ionization source with mass separator and beam expander
High-voltage power supply （+150kV）
Isolation Transformer (200kV)
High-voltage power supply （+50kV）
Isolation tube with linear accelerator
Vacuum chamber
Turntable and X-stage
Vacuum pumps

Summary

- Reimei has been observing two types of electron acceleration phenomena in the polar ionosphere.
  - Quasi-electrostatic parallel potential drop
  - Dispersive Alfven wave
- Univ. Tokyo, ISAS/JAXA, and PSSC/NCKU are collaborating for the development of auroral electron sensor for FORMOSAT-5 based on Reimei expertise.
- Our Japanese space physics community is now promoting the Geospace exploration mission with the international collaboration with PSSC/NCKU.
- We are also building the ion/electron beam facilities for space qualification of plasma/particle sensors for the space missions in Japan and Taiwan.