SPACE RADIATION

Near-Earth Energetic Particles & Radiation Effects

Lenka Zychova, Erwin de Donder

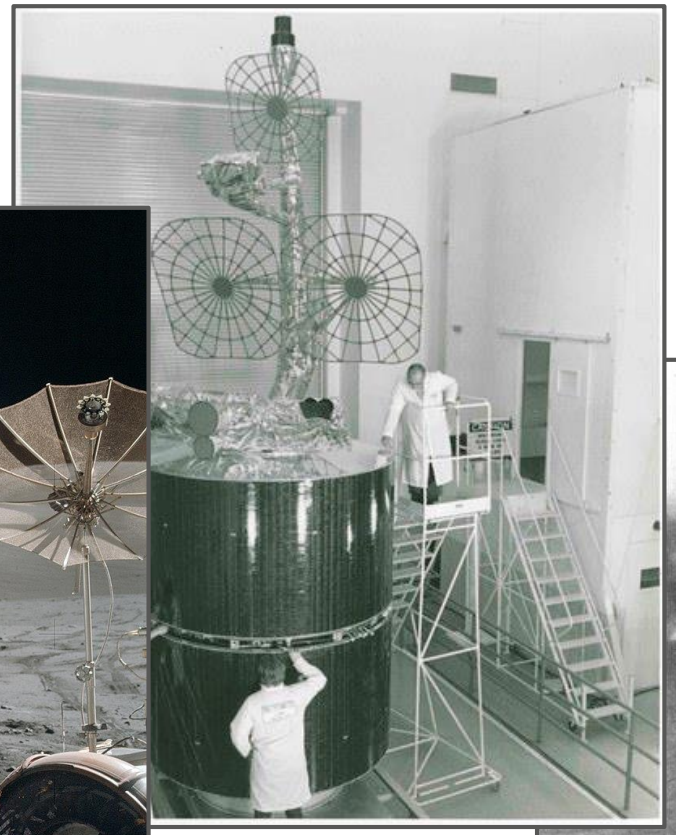
Royal Belgian Institute for Space Aeronomy

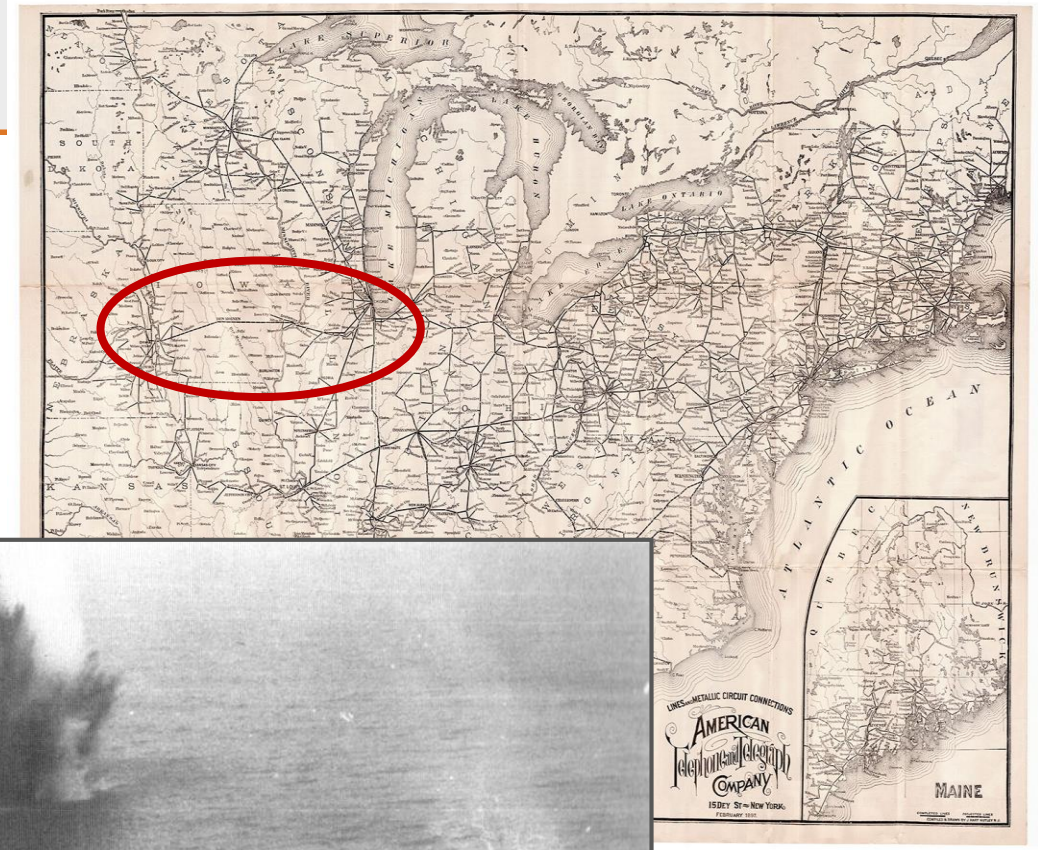
BIRA•IASB

The Dark Side of 1972

NASA

Hughes

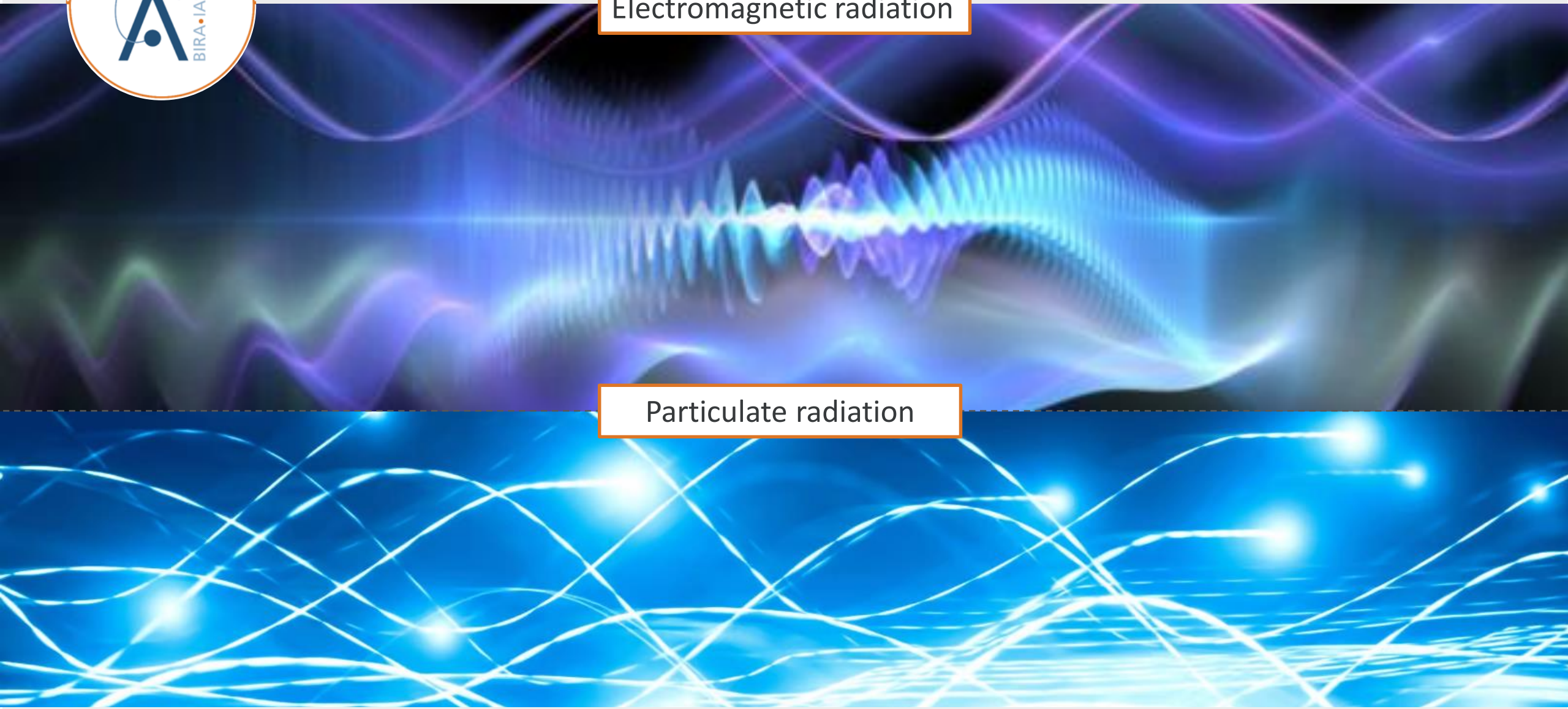




American Telephone and Telegraph Company

Naval Historical Center

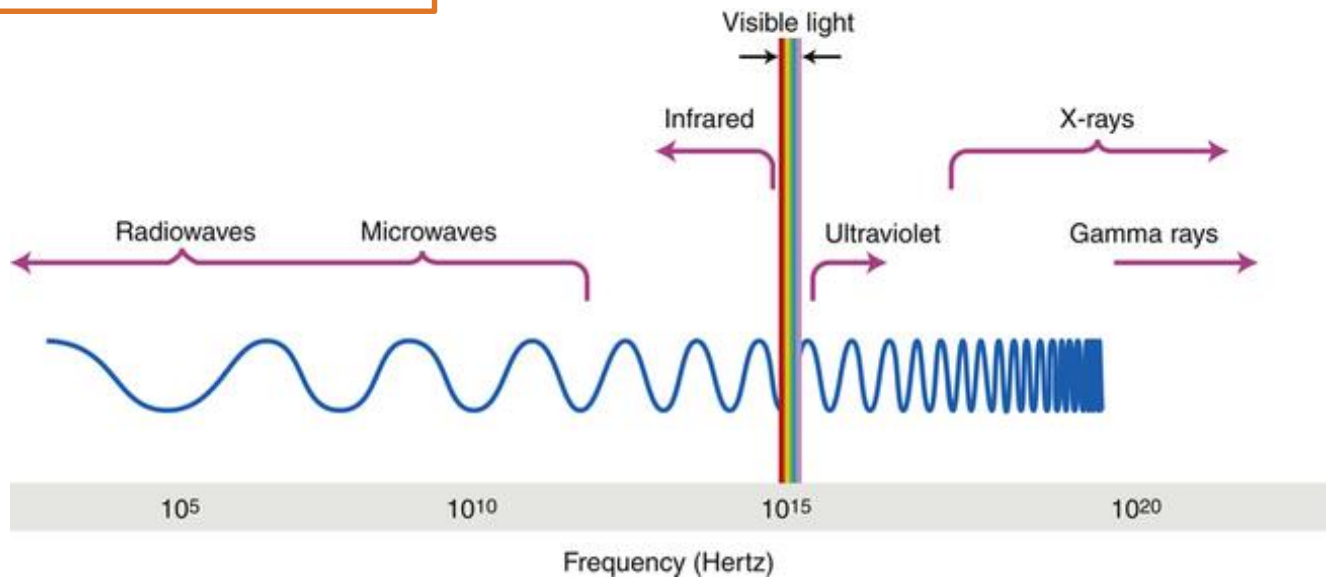
Space Radiation



Space Radiation

Electromagnetic radiation

- Photons / electromagnetic waves
- Speed of light

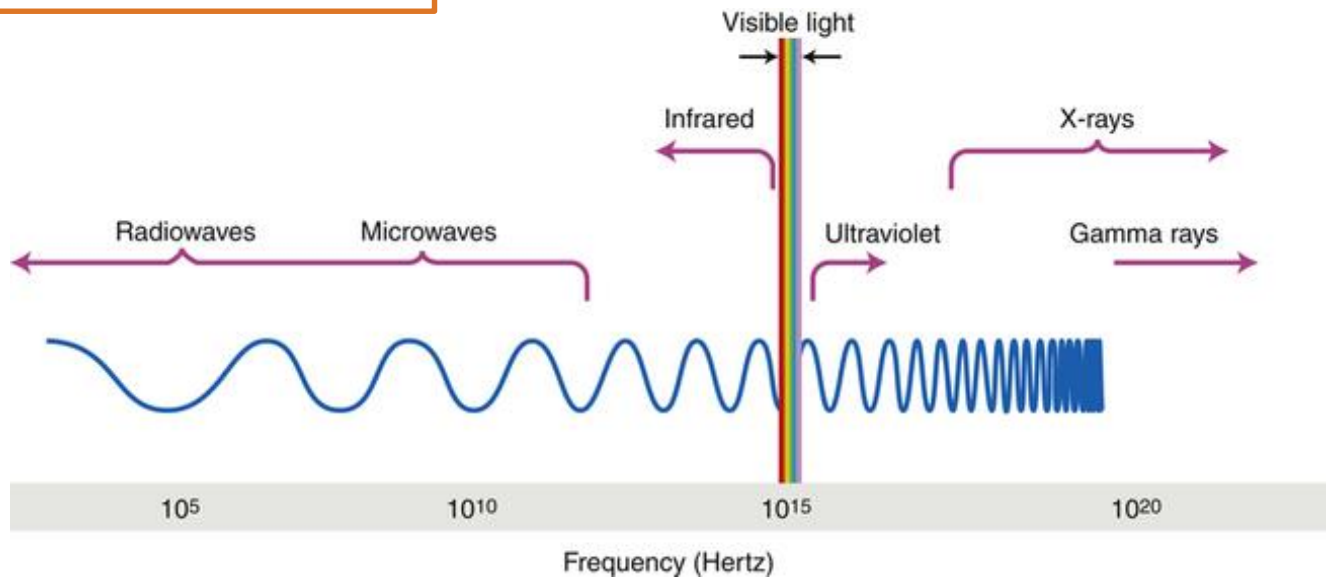


Particulate radiation

Space Radiation

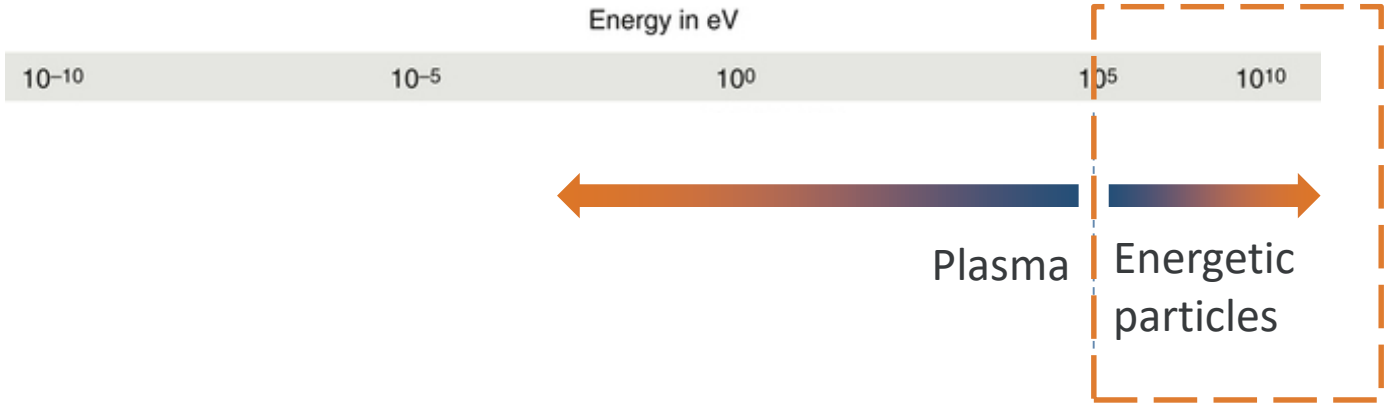
Electromagnetic radiation

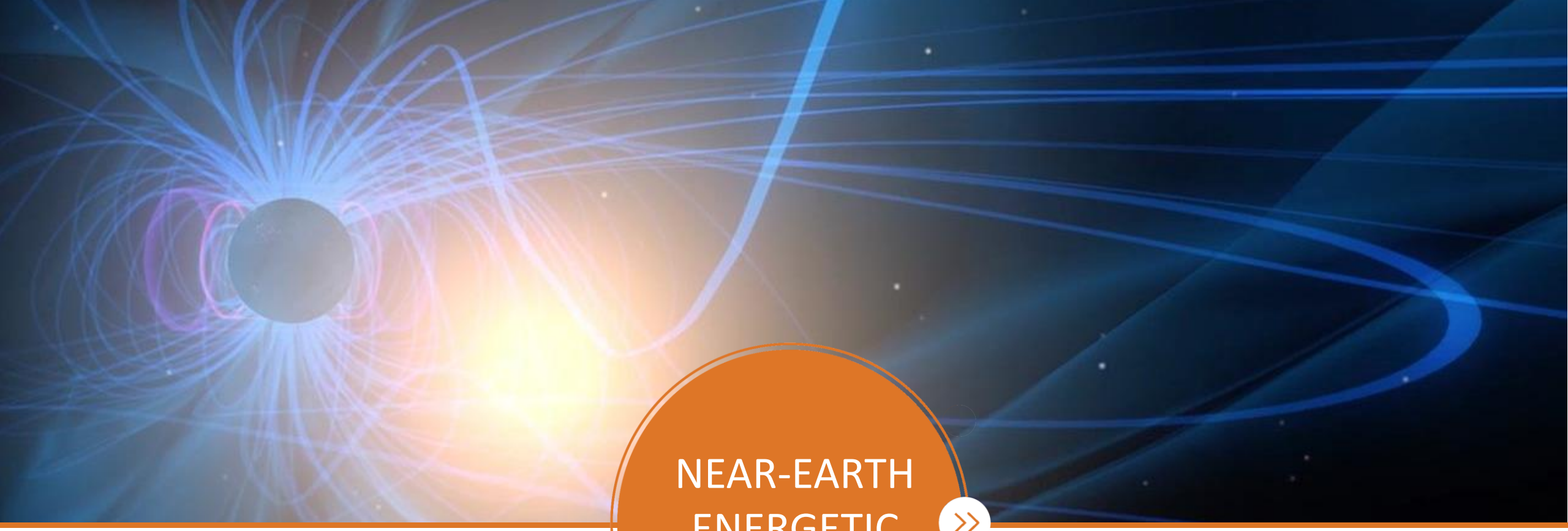
- Photons / electromagnetic waves
- Speed of light



Particulate radiation

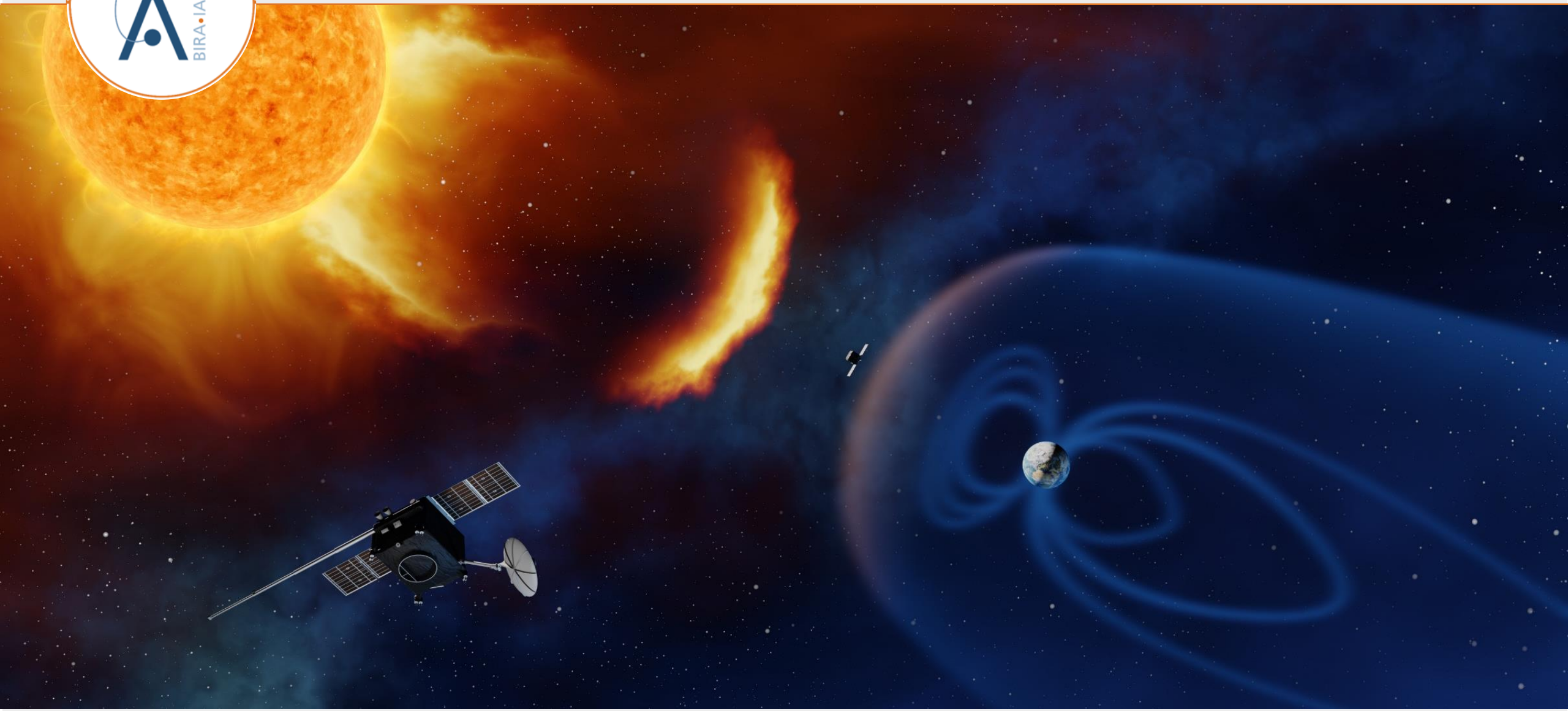
- Atomic & sub-atomic particles
- m/s to fractions of speed of light





NEAR-EARTH ENERGETIC PARTICLES

Energetic particles in the near-Earth environment



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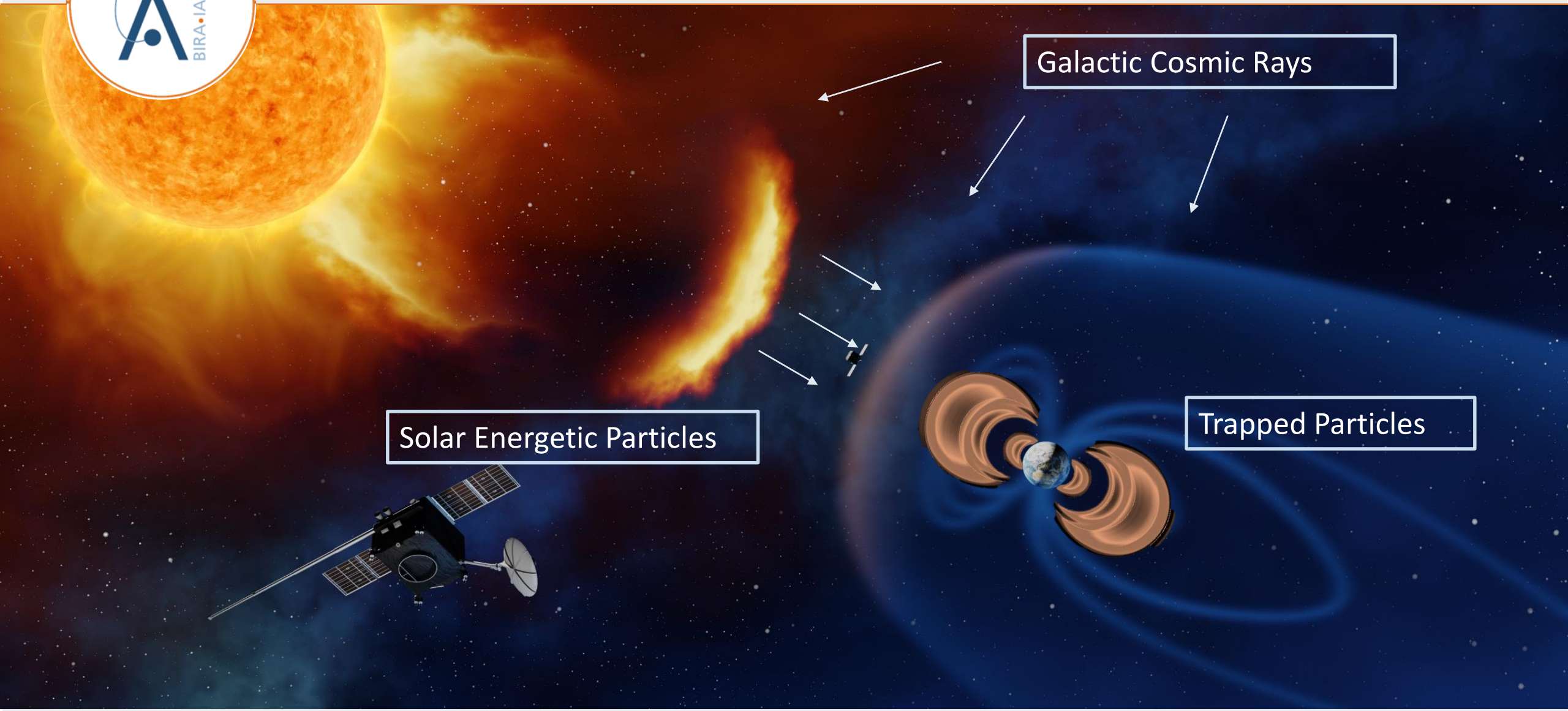
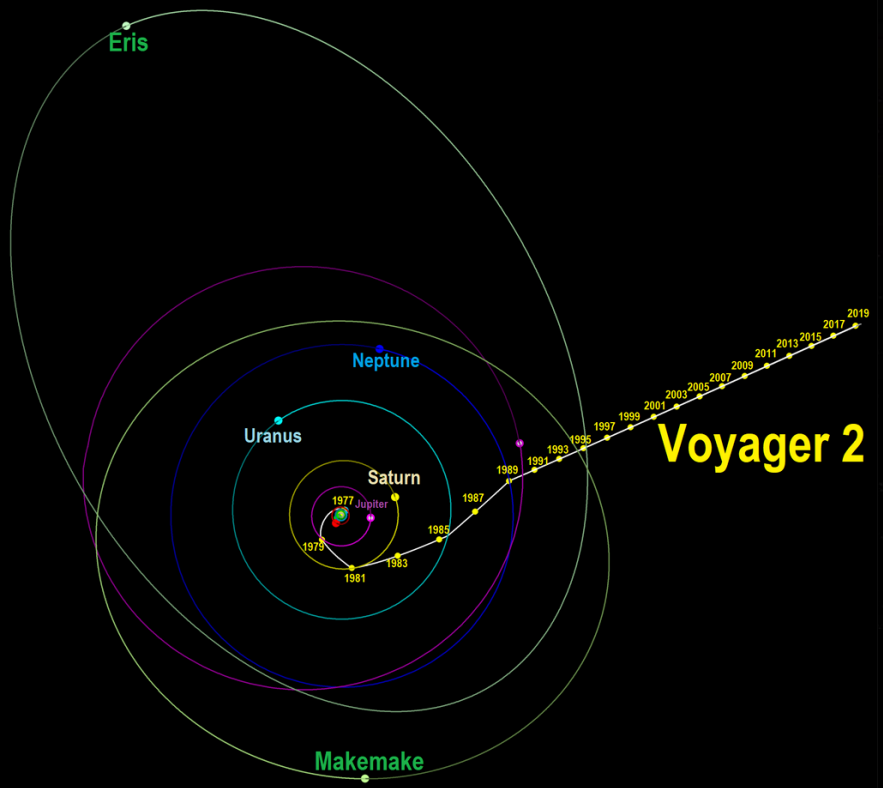
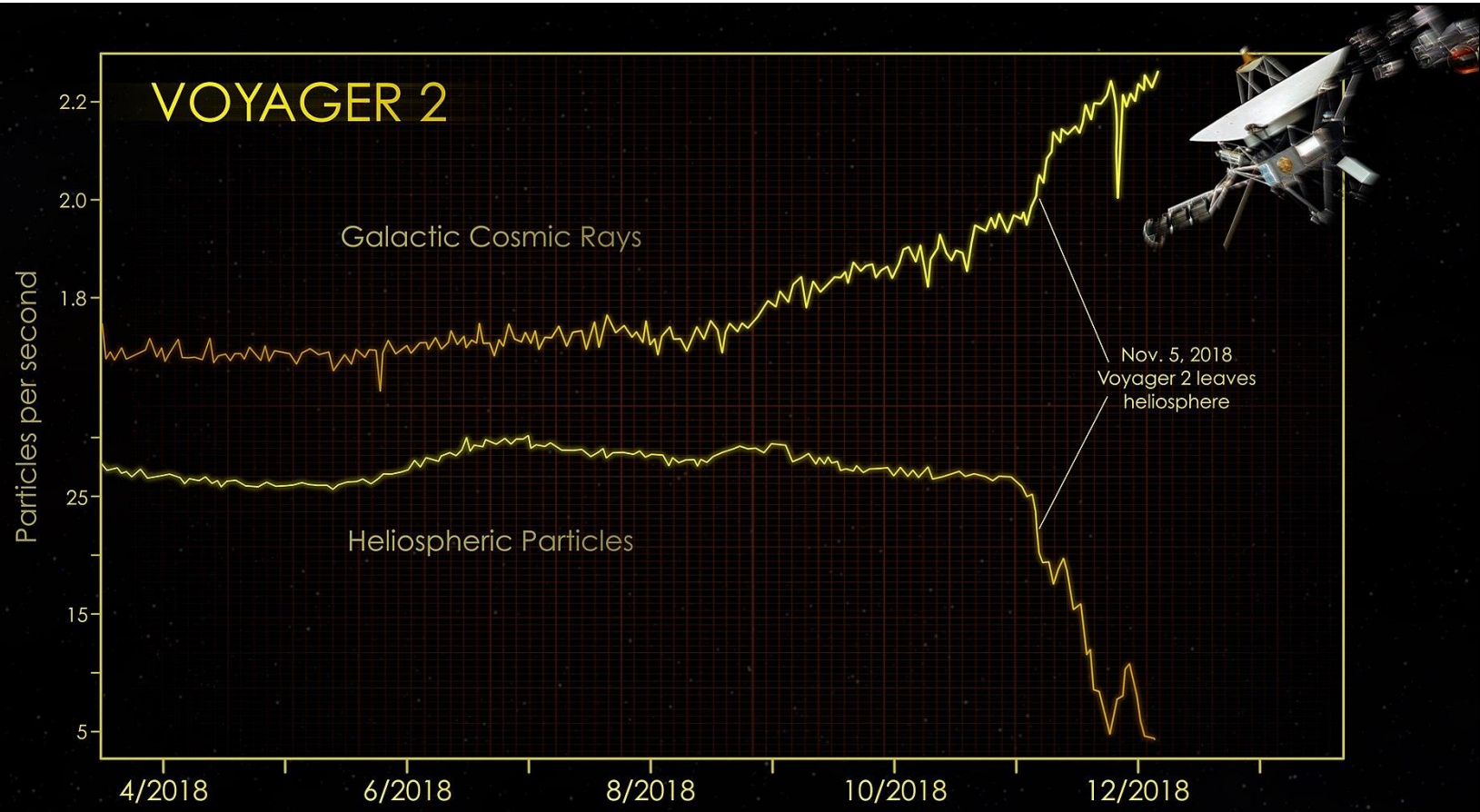


Energetic particles in the near-Earth environment

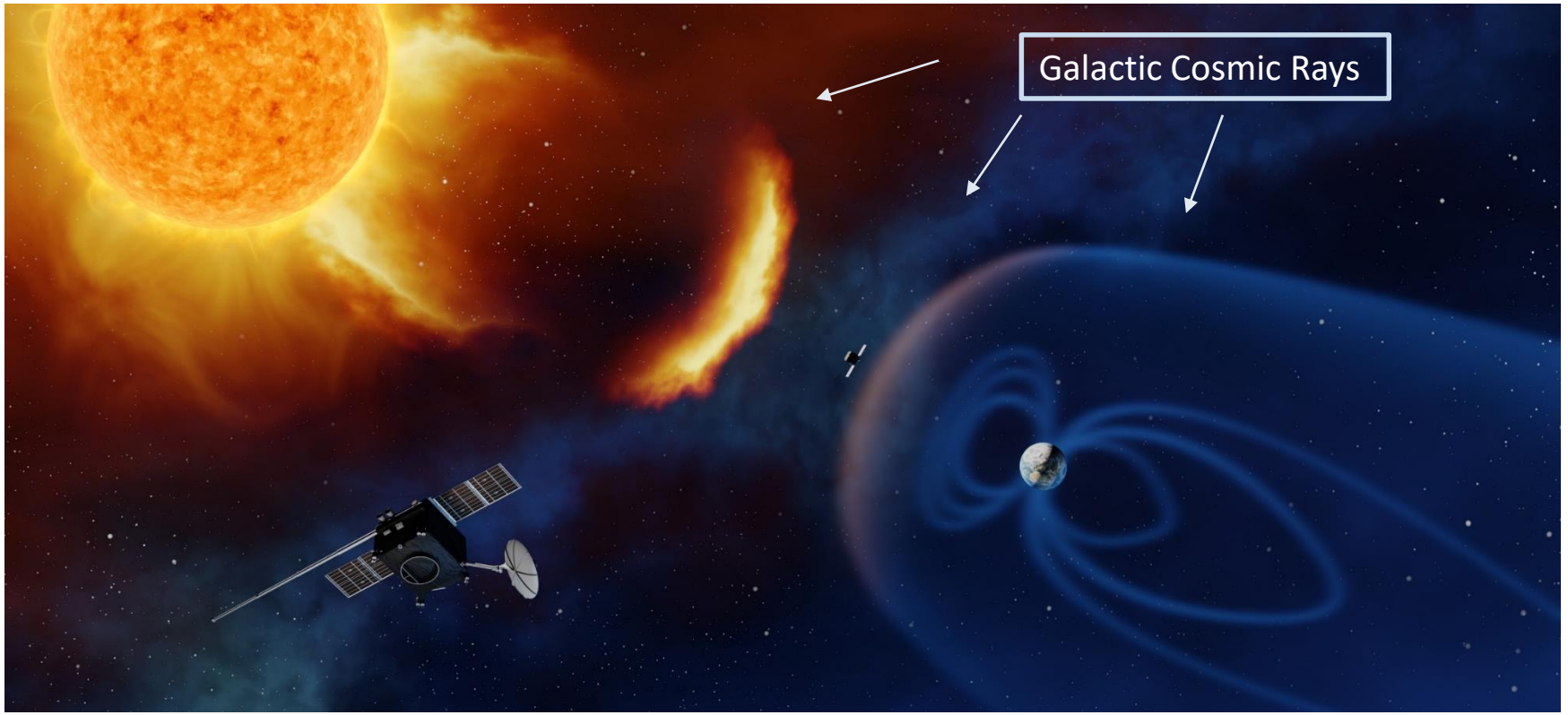




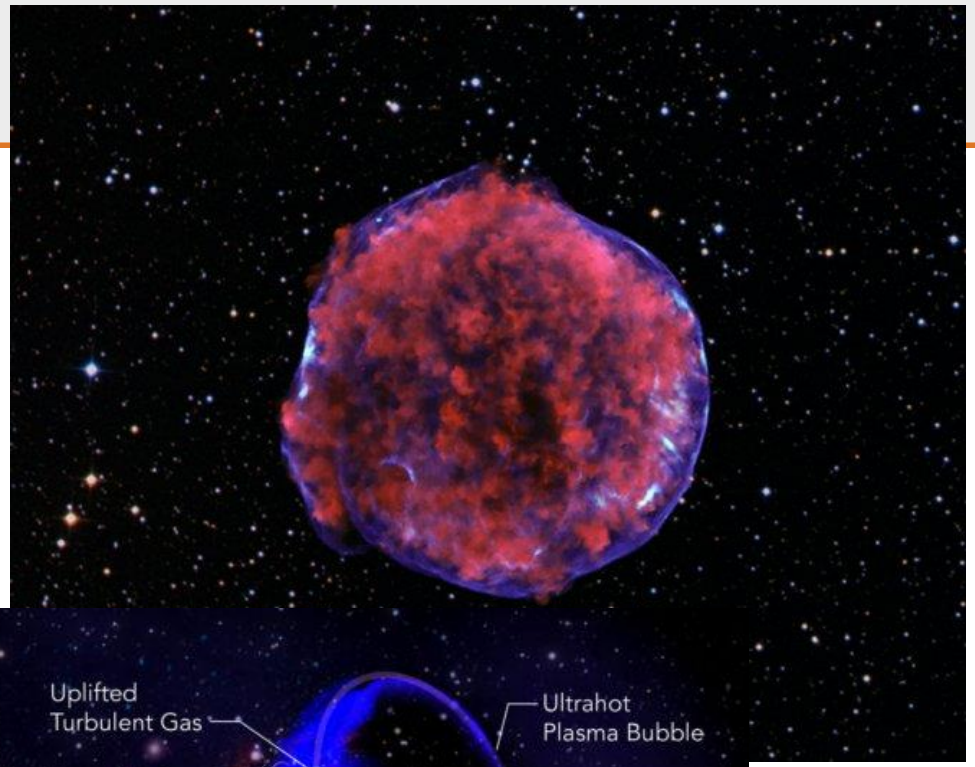
NASA/JPL-Caltech/GSFC

Galactic Cosmic Rays

- High-energy particles produced outside of the Solar system
  - ~83% protons
  - ~ 13% He ions
  - ~ 3% electrons
  - ~ 1% heavier nuclei

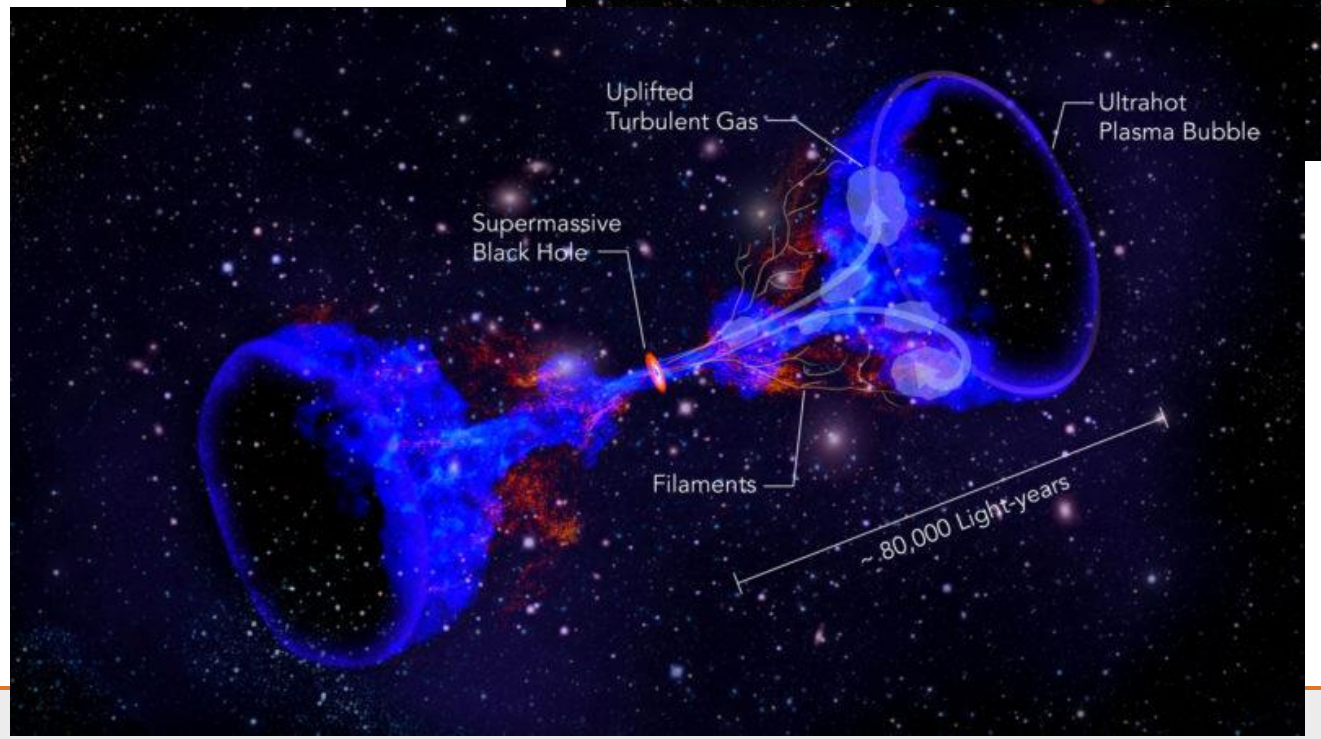


Galactic Cosmic Rays



X-ray:
NASA/CXC/Rutgers/
K.Eriksen et al.;
Optical: DSS

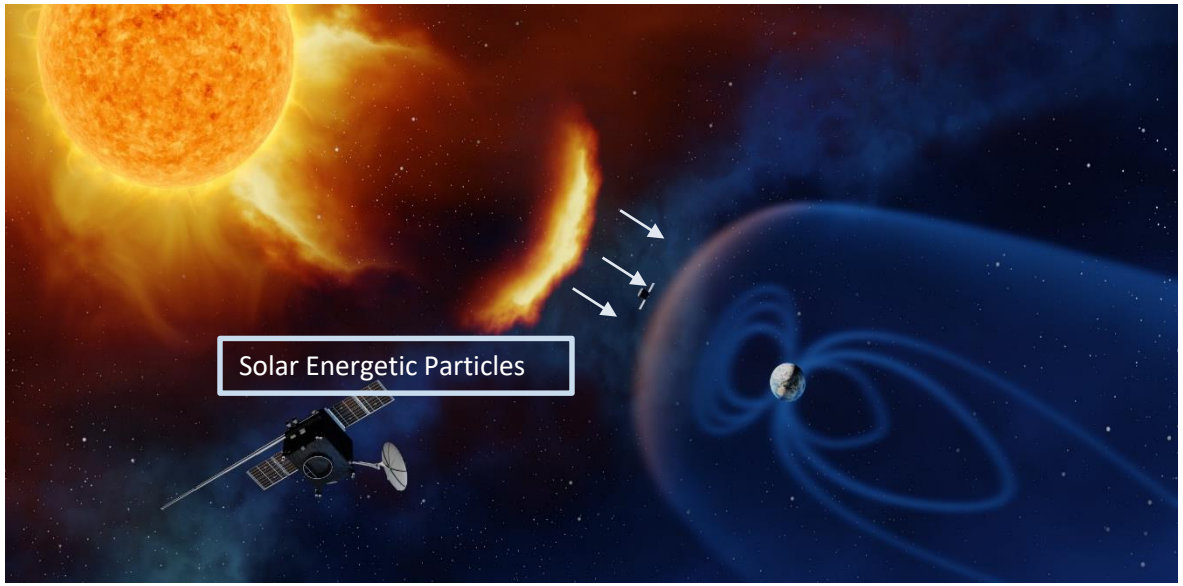
- High-energy particles produced outside of the Solar system
  - ~83% protons
  - ~ 13% He ions
  - ~ 3% electrons
  - ~ 1% heavier nuclei
- Energy ranges:
  - MeV – GeV (galactic source)
  - >TeV (extra-galactic)

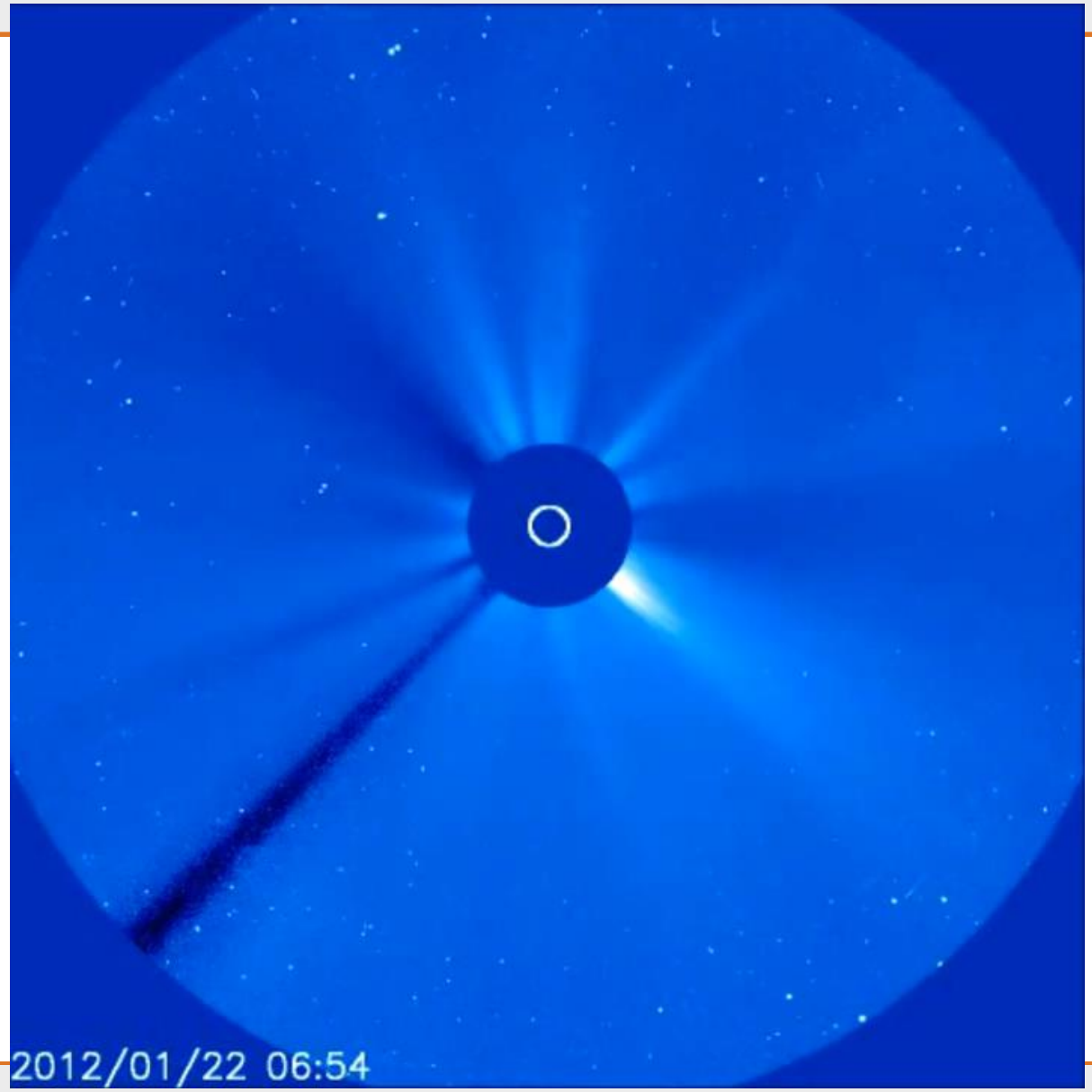


SLAC
National
Accelerator
Laboratory

Solar Energetic Particles

- Produced in solar flares and by coronal mass ejections
  - → SEP events

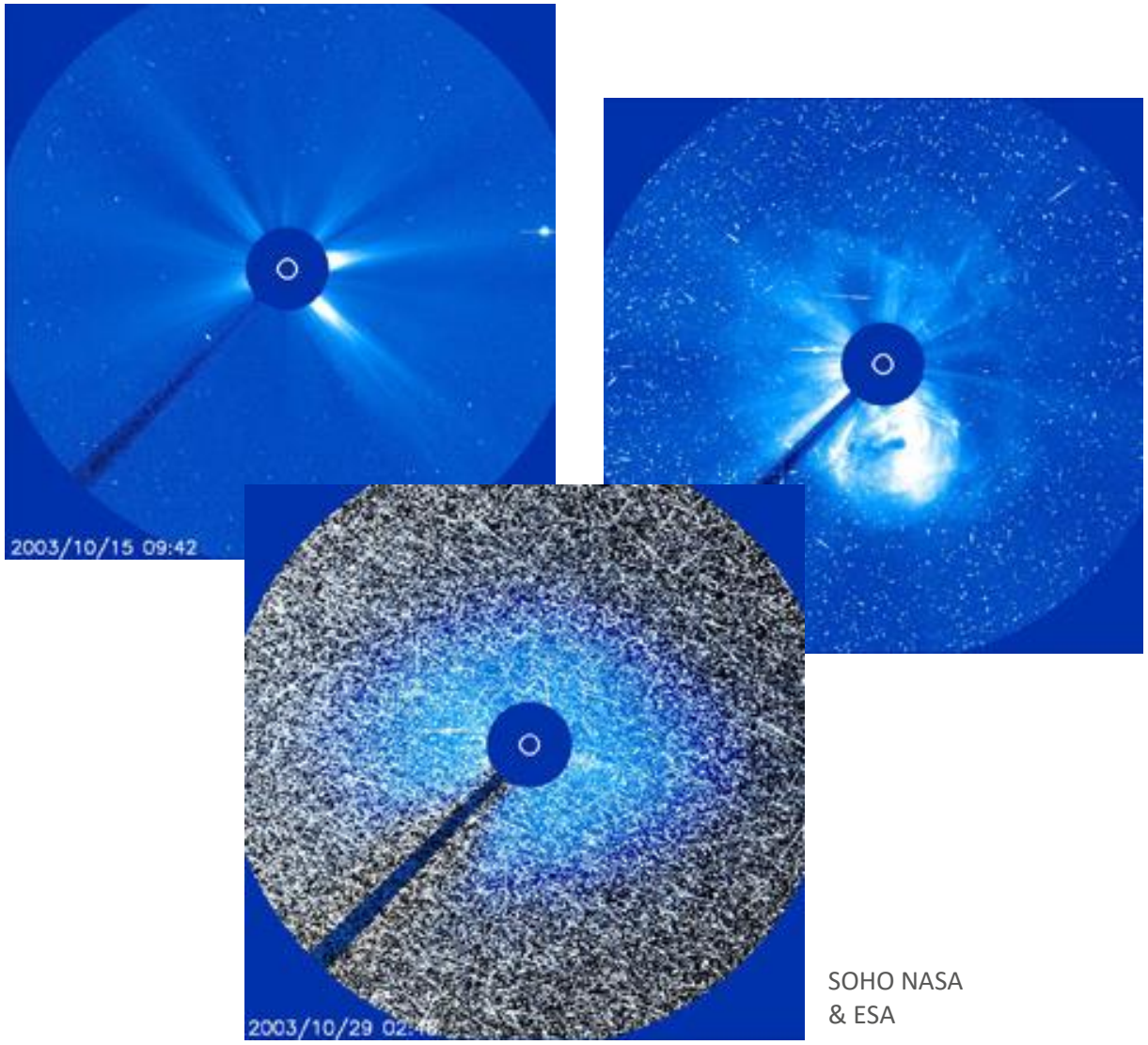




SOHO NASA & ESA

Solar Energetic Particles

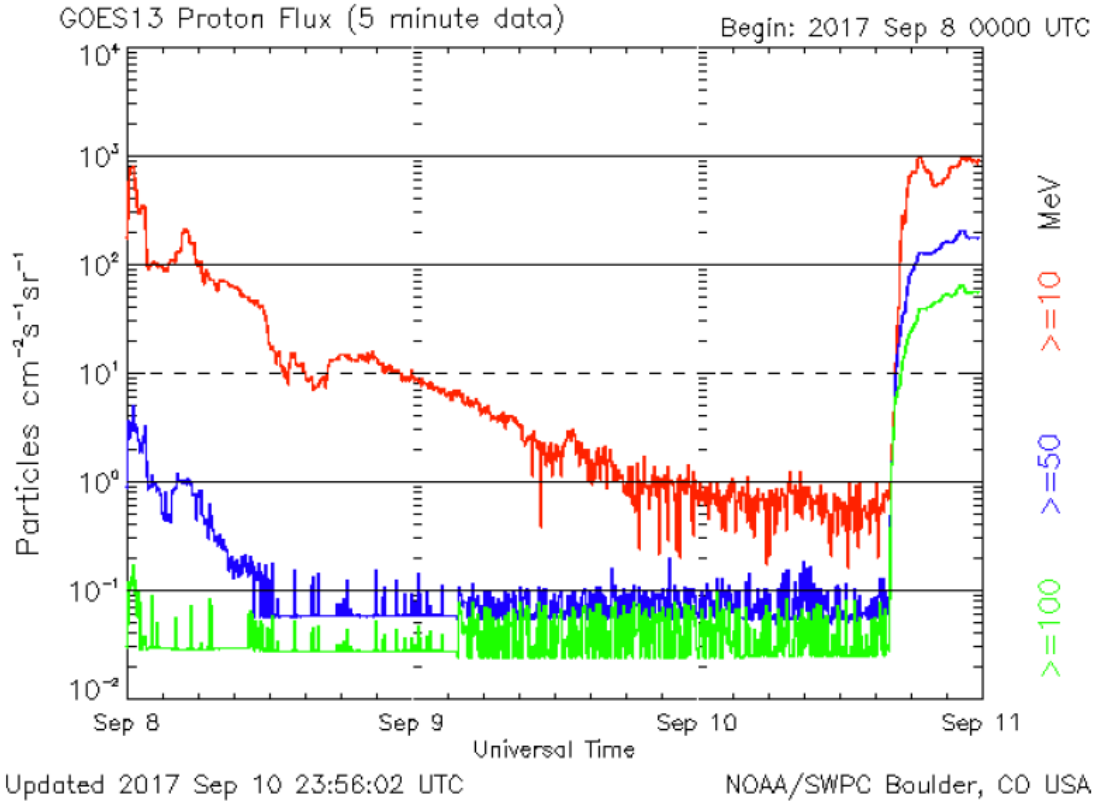
- Produced in solar flares and by coronal mass ejections
  - → SEP events
- > 90% protons, electrons, heavy ions
- E: keV-GeV



SOHO NASA & ESA

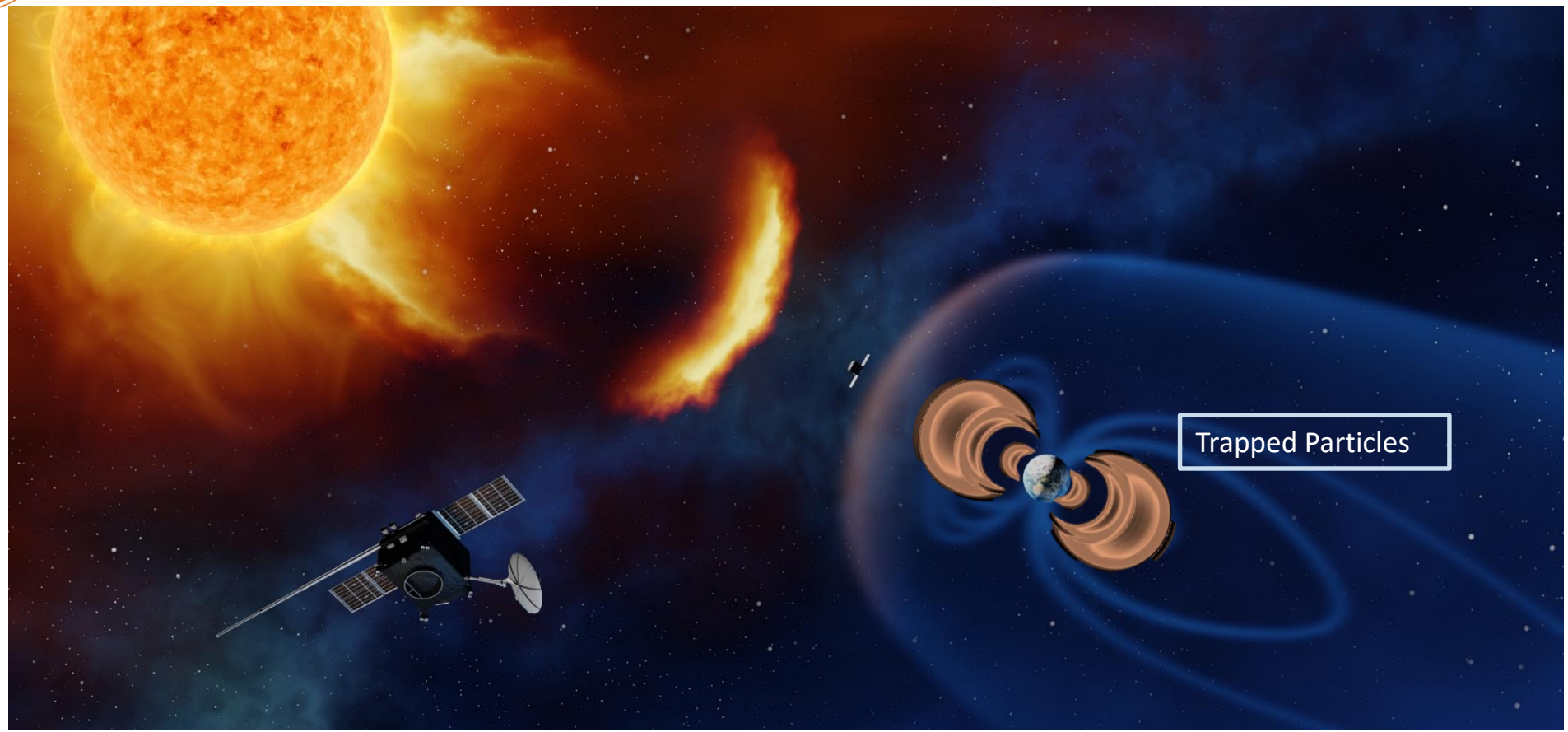
Solar Energetic Particles

- Produced in solar flares and by coronal mass ejections
  - → SEP events
- > 90% protons, electrons, heavy ions
- E: keV-GeV
- Solar Proton Event: >10 pfu at >10 MeV



1 proton/cm²/sr/s = 1 pfu

Trapped particles – Van Allen radiation belts



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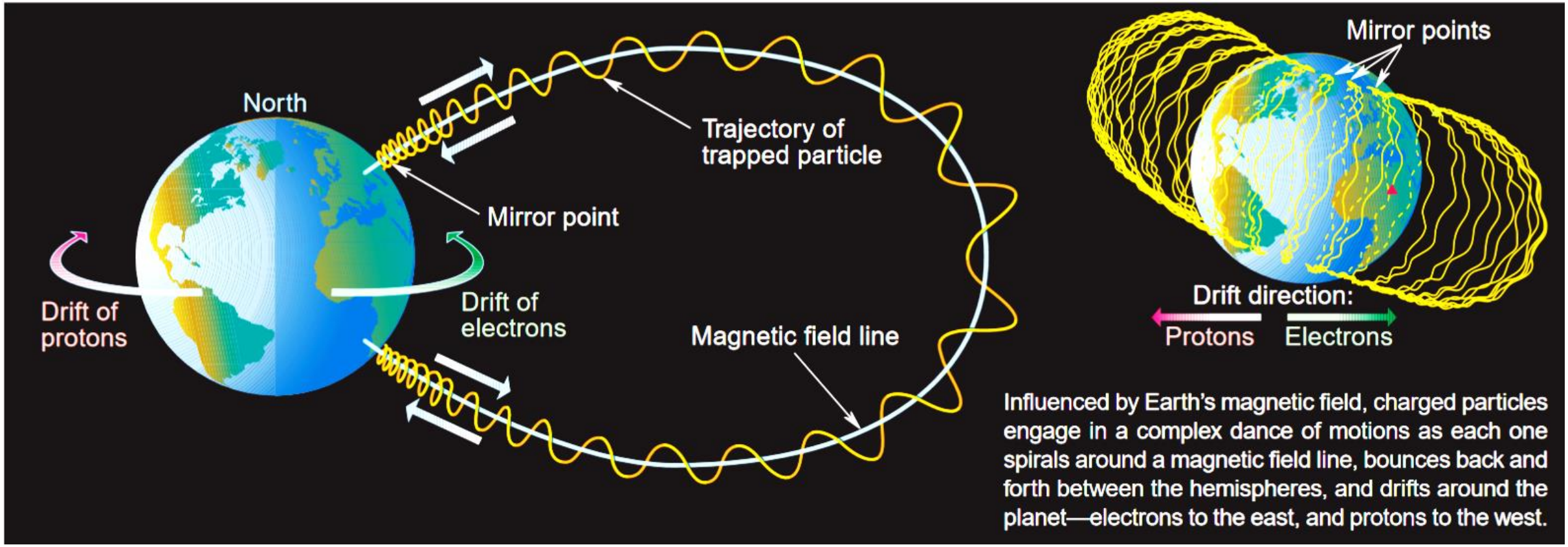
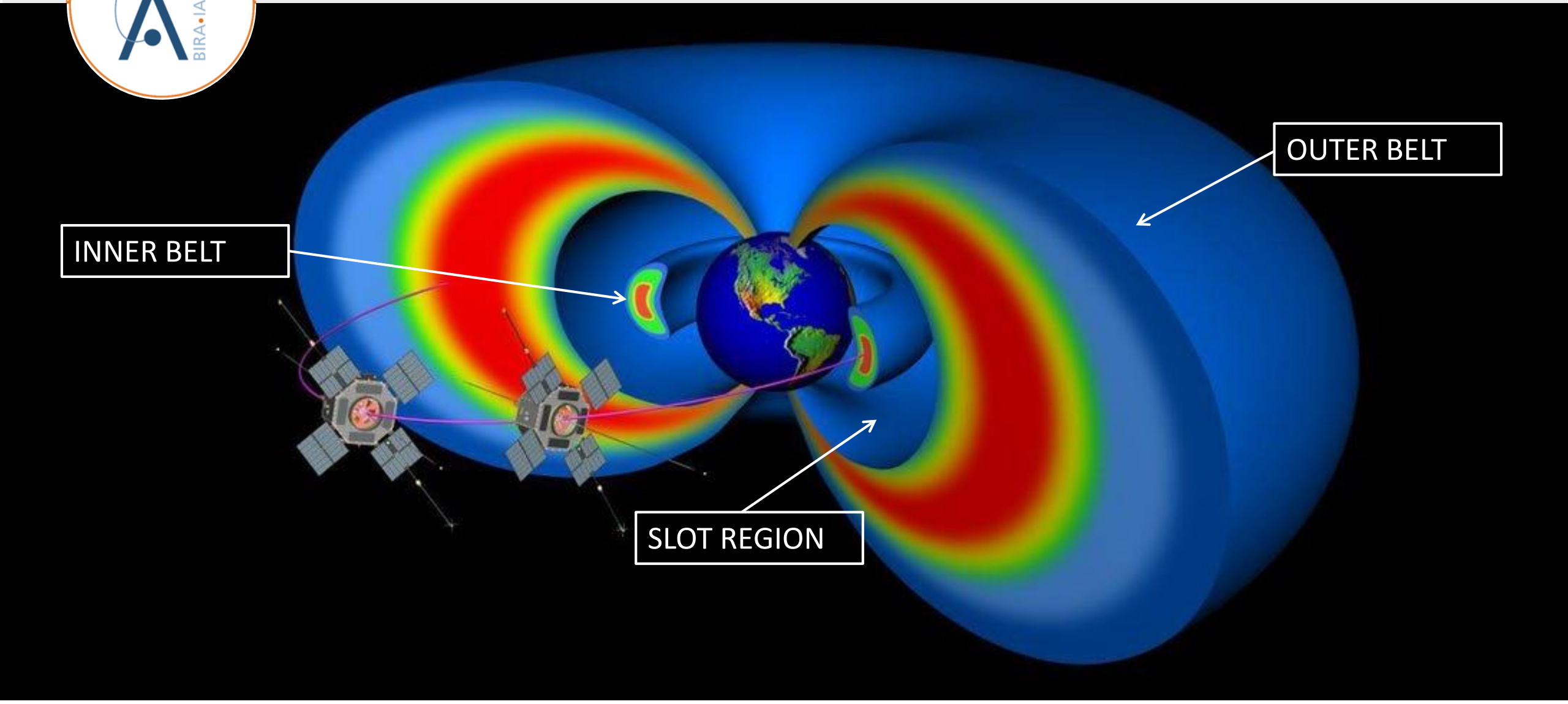


Ref. An overview of the Space Radiation Environment, E.J. Mazure, Crosslink, the Aerospace Corporation Magazine, Vol. 4, No.2, 2003

Trapped particles – Van Allen radiation belts



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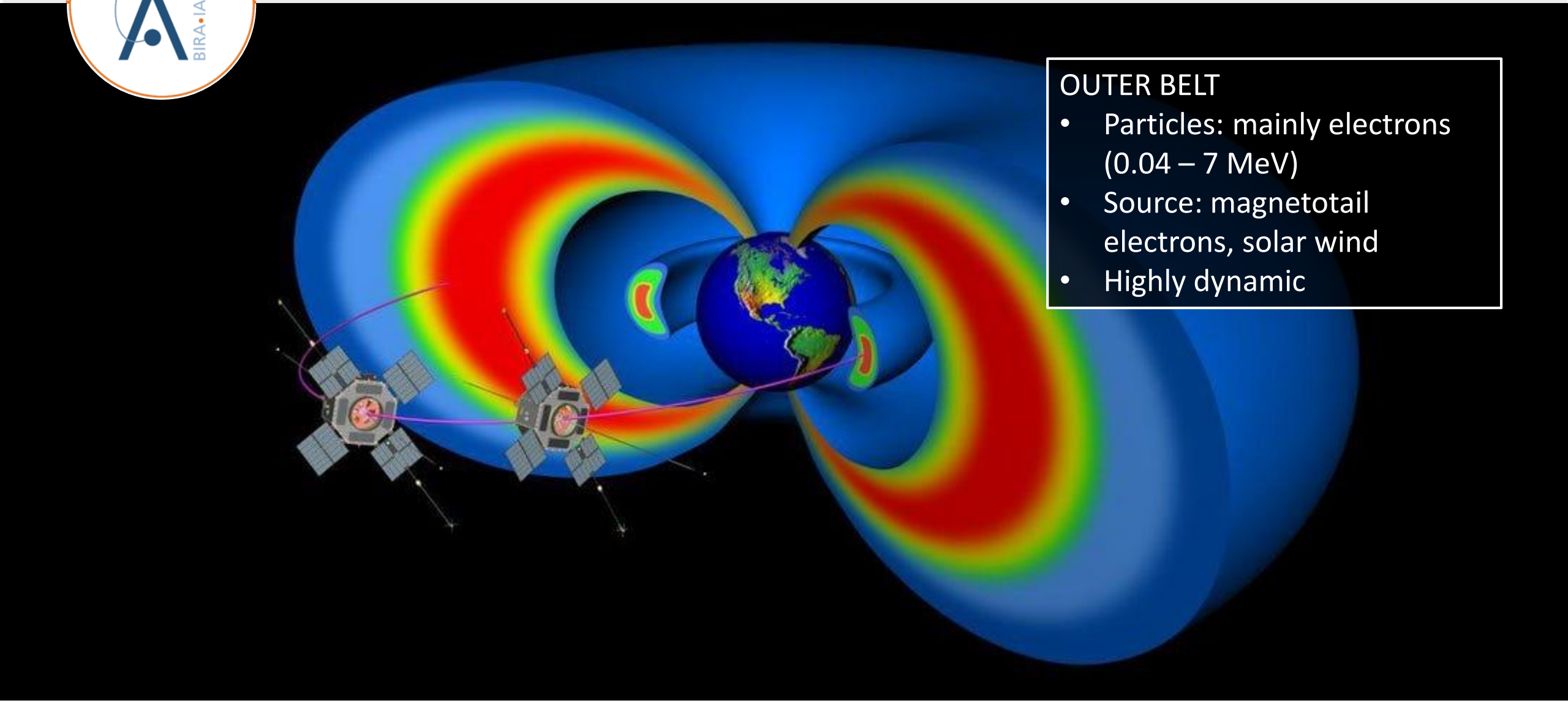
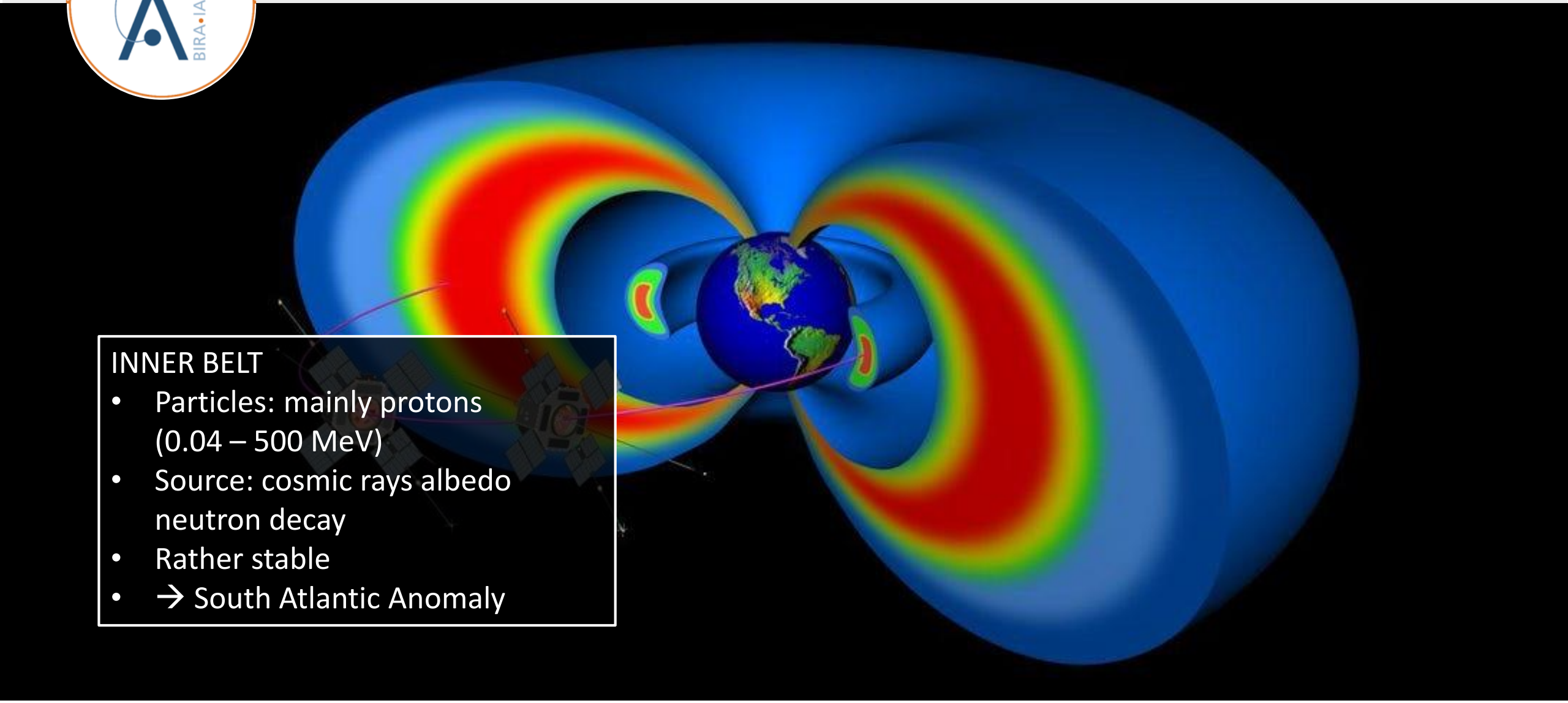


OUTER BELT

- Particles: mainly electrons (0.04 – 7 MeV)
- Source: magnetotail electrons, solar wind
- Highly dynamic

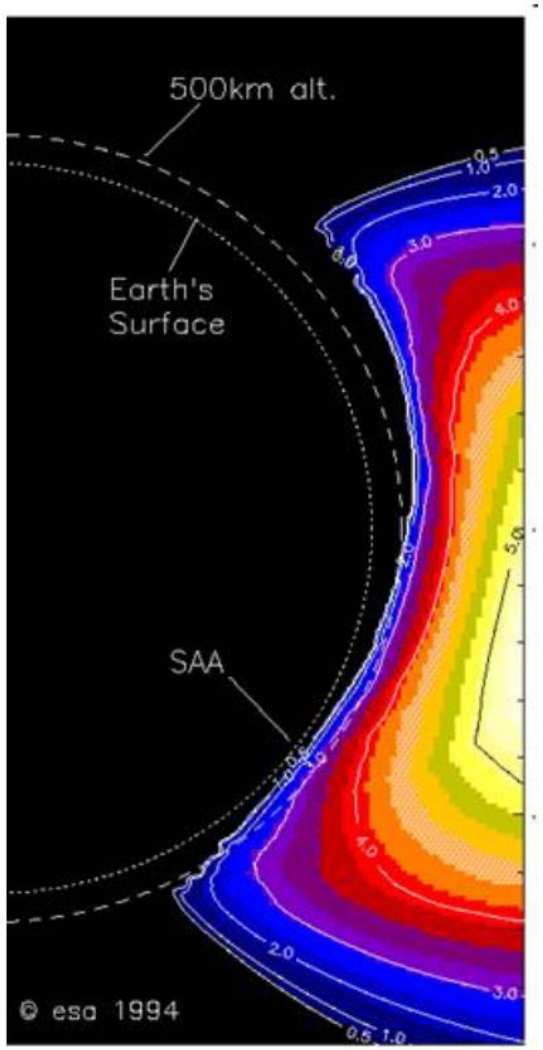
Trapped particles – Van Allen radiation belts

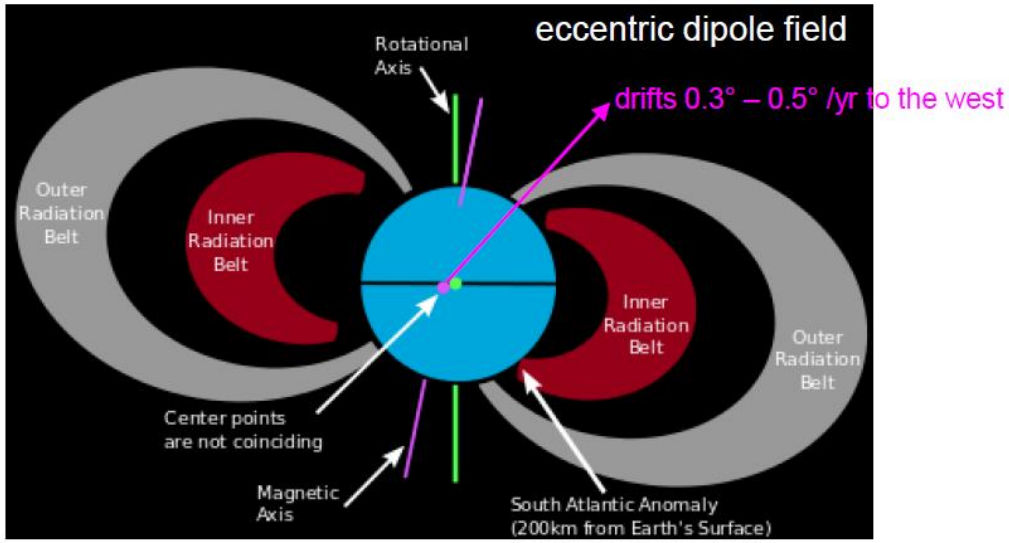


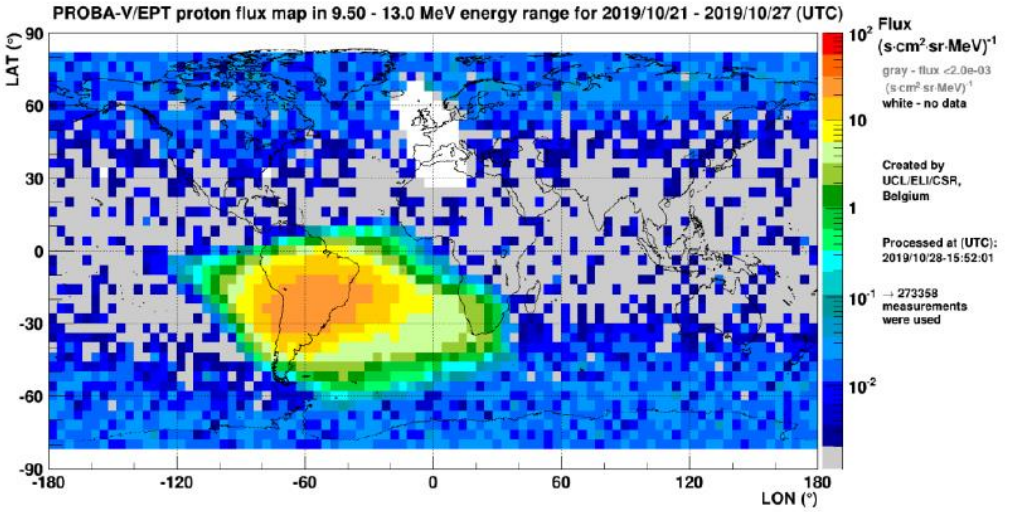
INNER BELT

- Particles: mainly protons (0.04 – 500 MeV)
- Source: cosmic rays albedo neutron decay
- Rather stable
- → South Atlantic Anomaly

South Atlantic Anomaly (SAA)

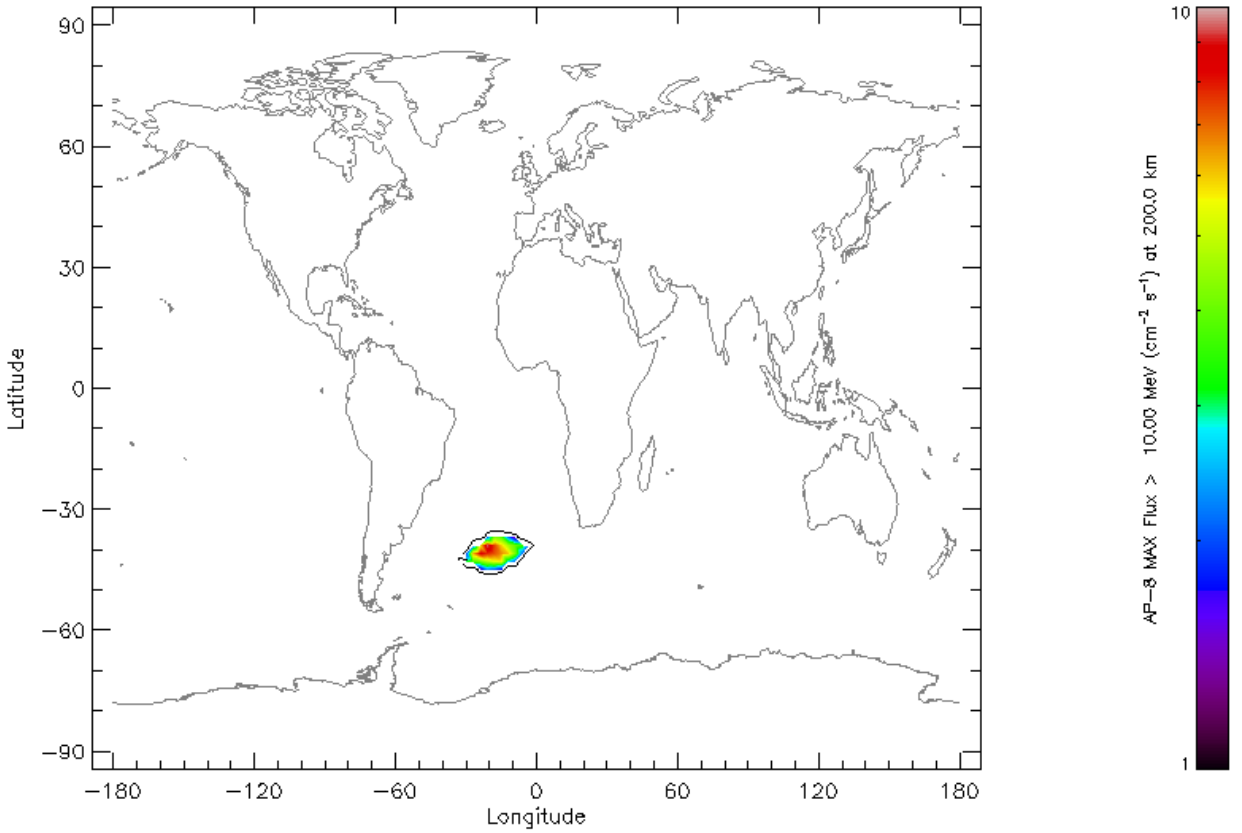


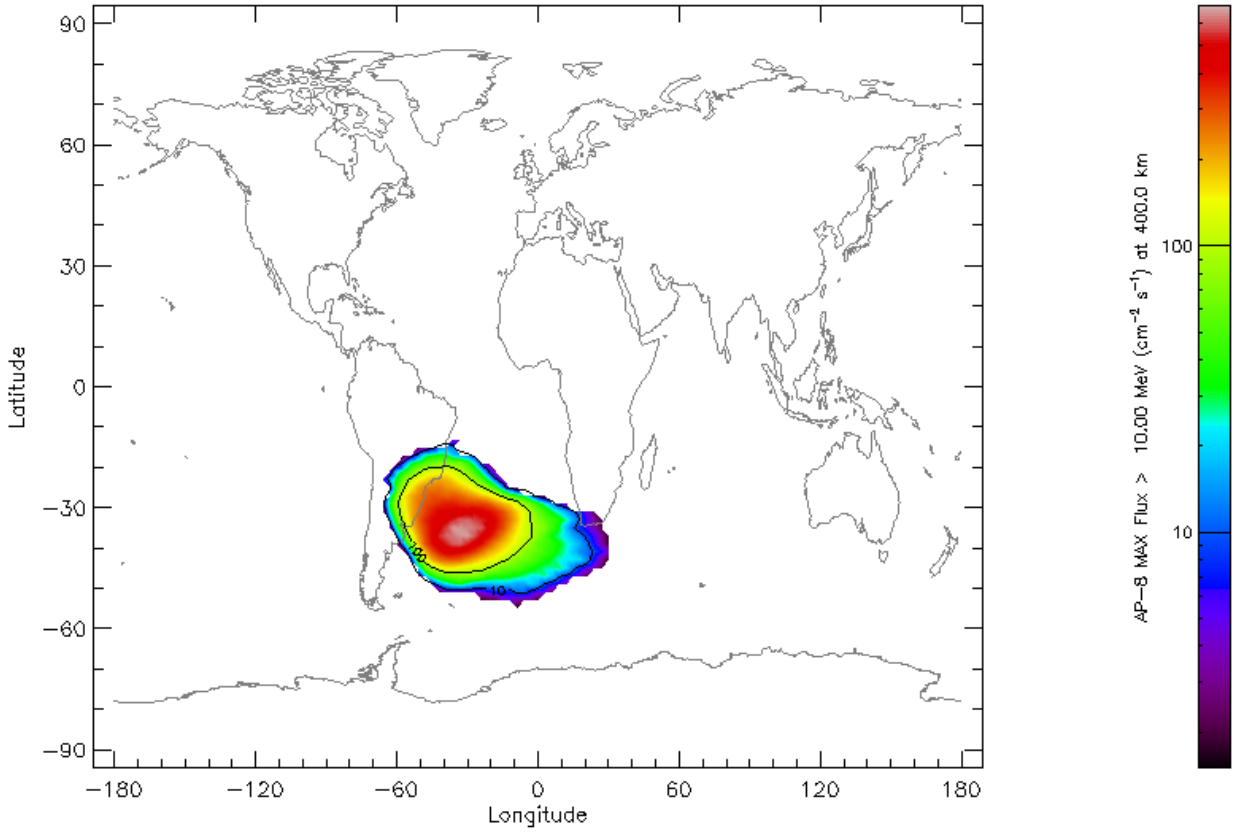




South Atlantic Anomaly (SAA)

SPENVIS simulation (at 200 km, at ISS altitude)





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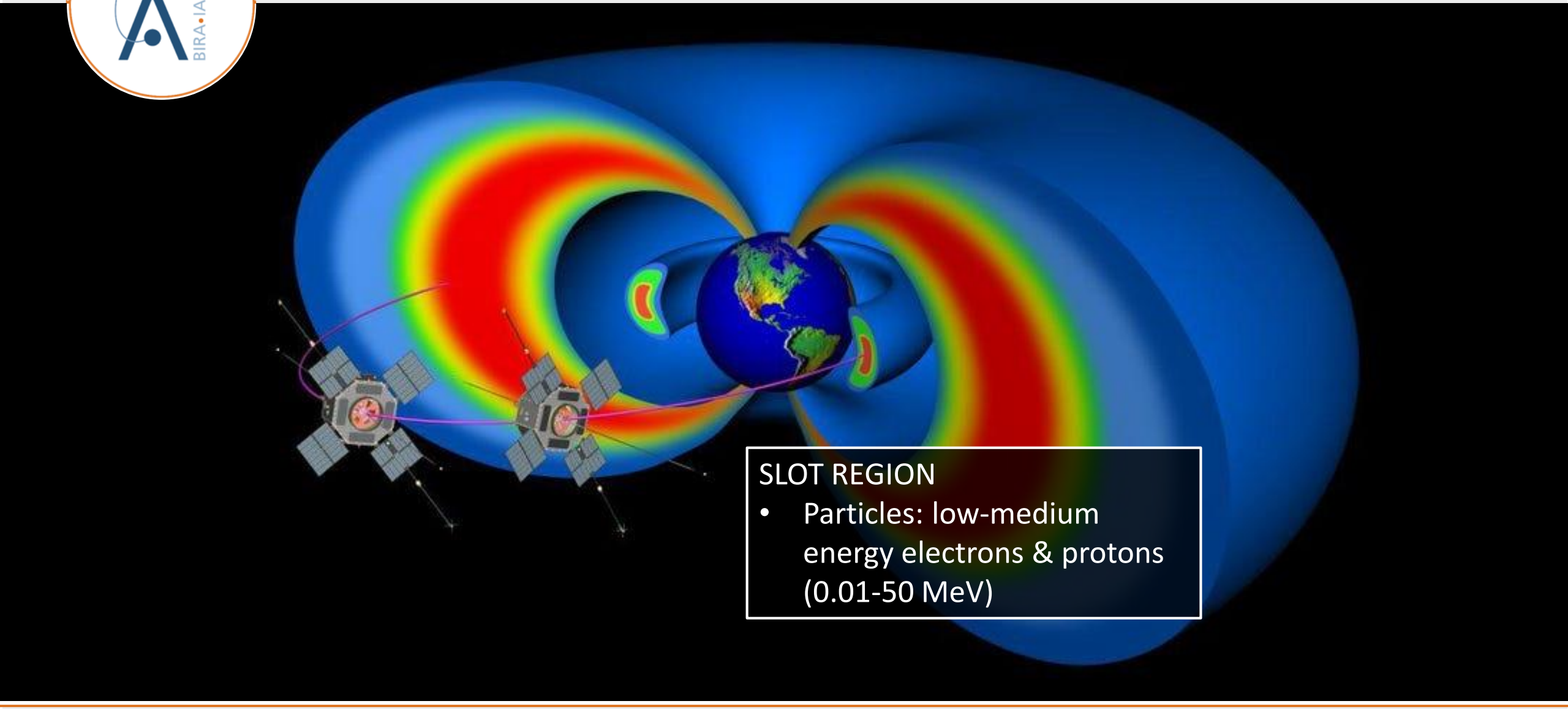


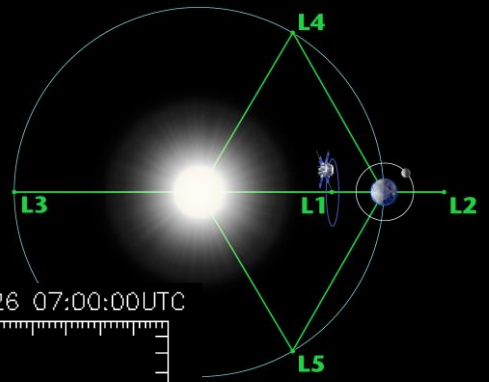
SLOT REGION

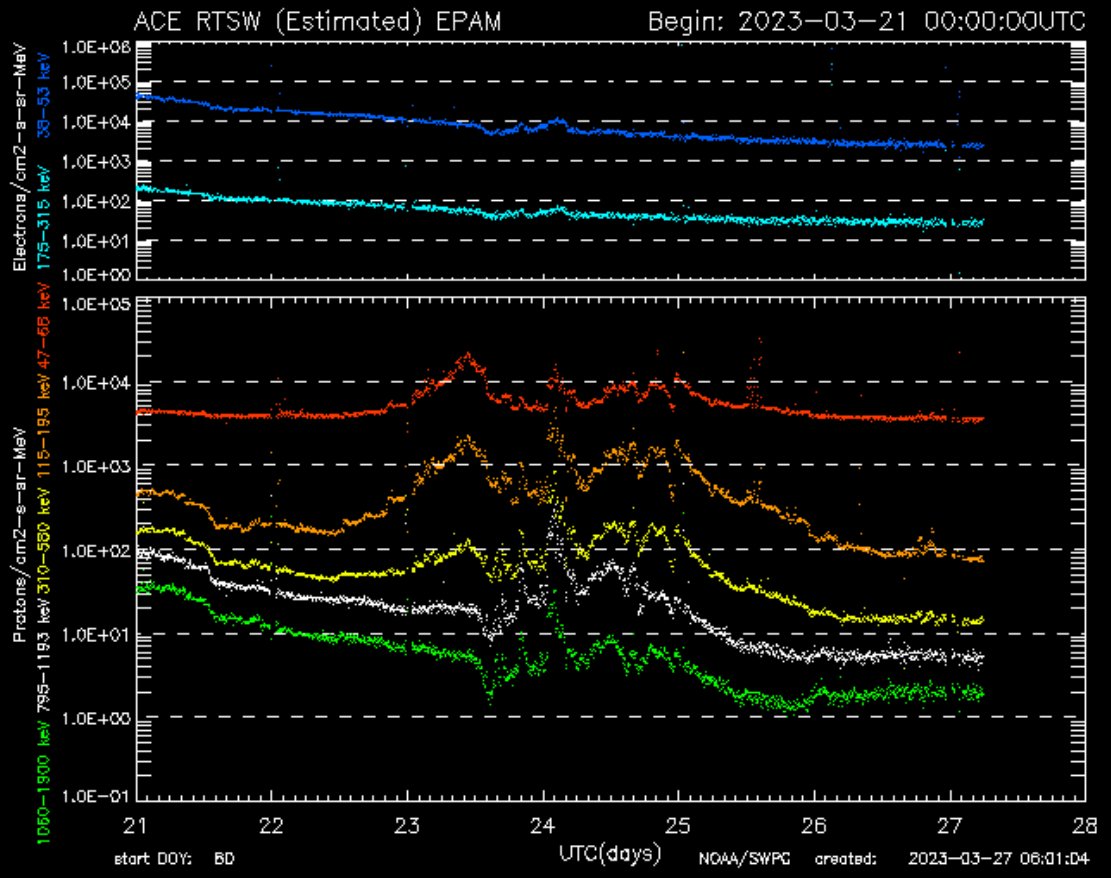
- Particles: low-medium energy electrons & protons (0.01-50 MeV)

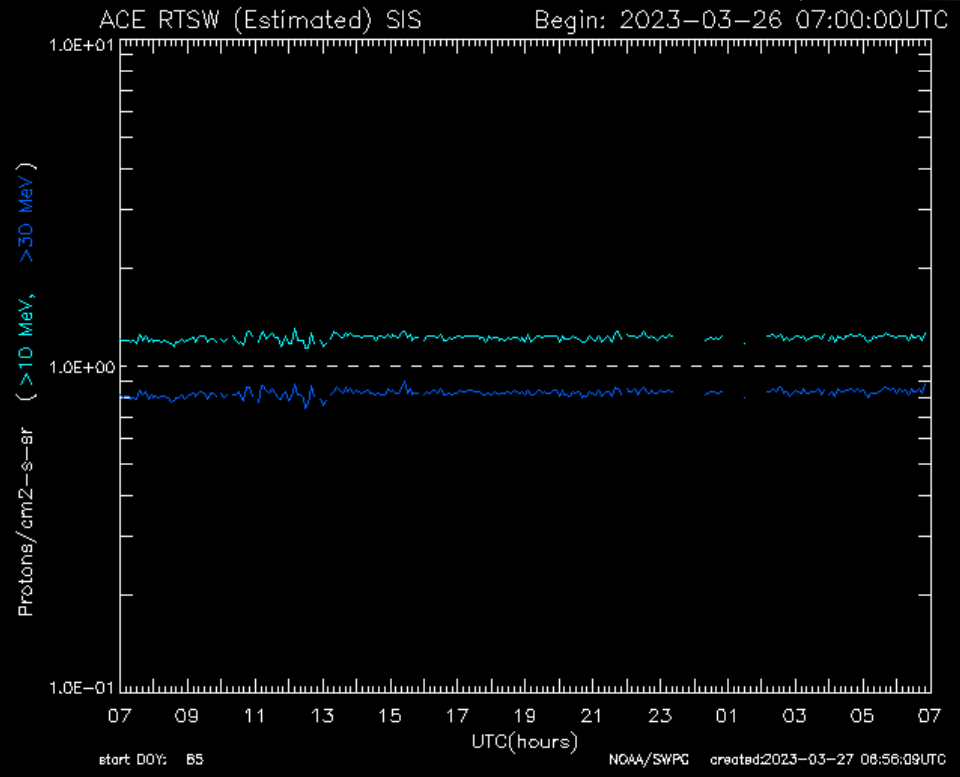
OBSERVATIONS

Observation of high & low energy particles

ACE satellite

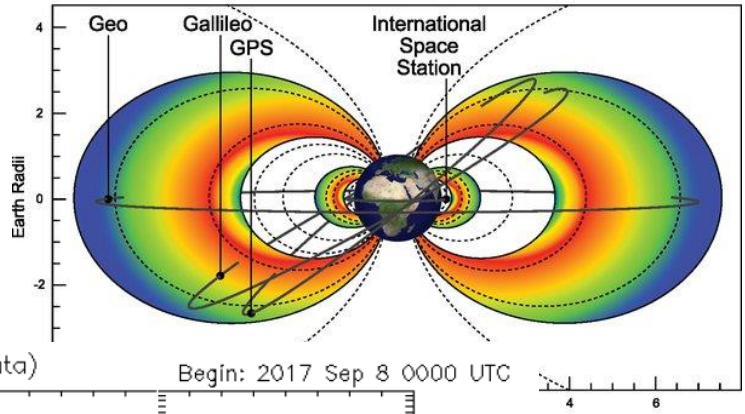


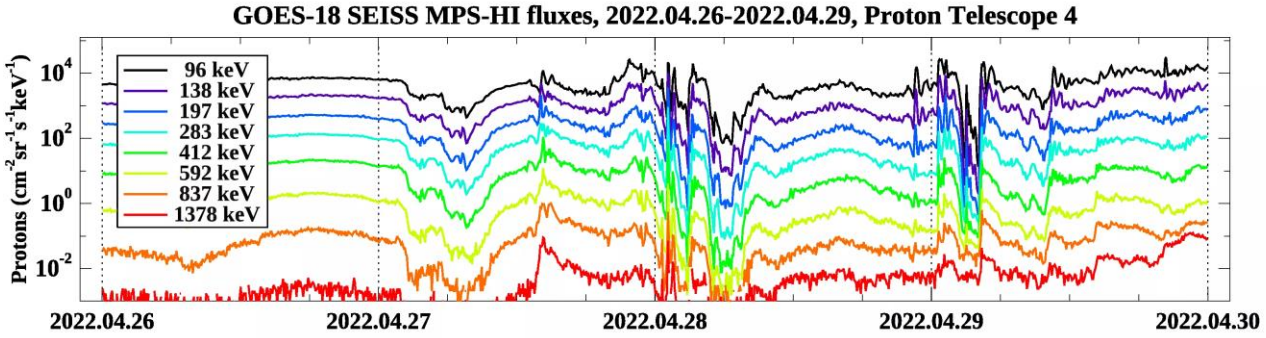


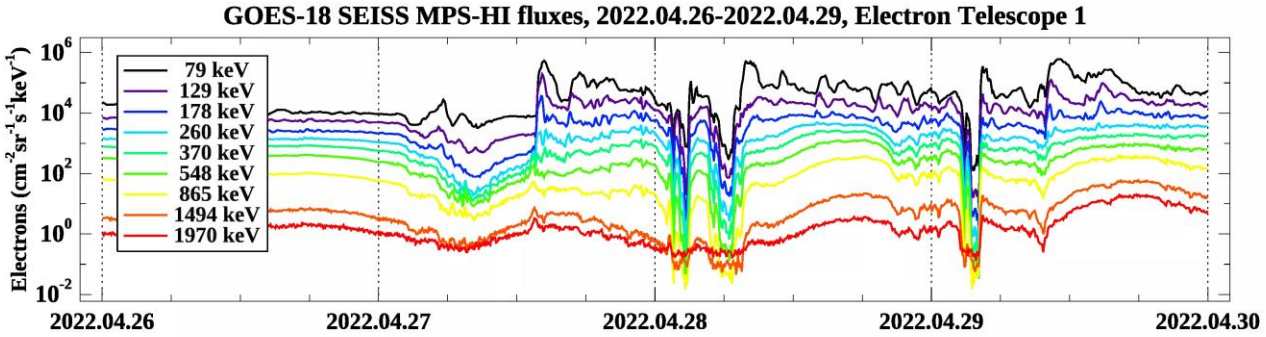


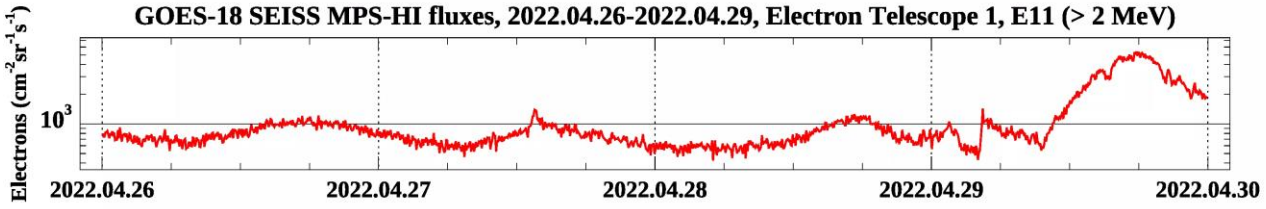
Observation of high & low energy particles

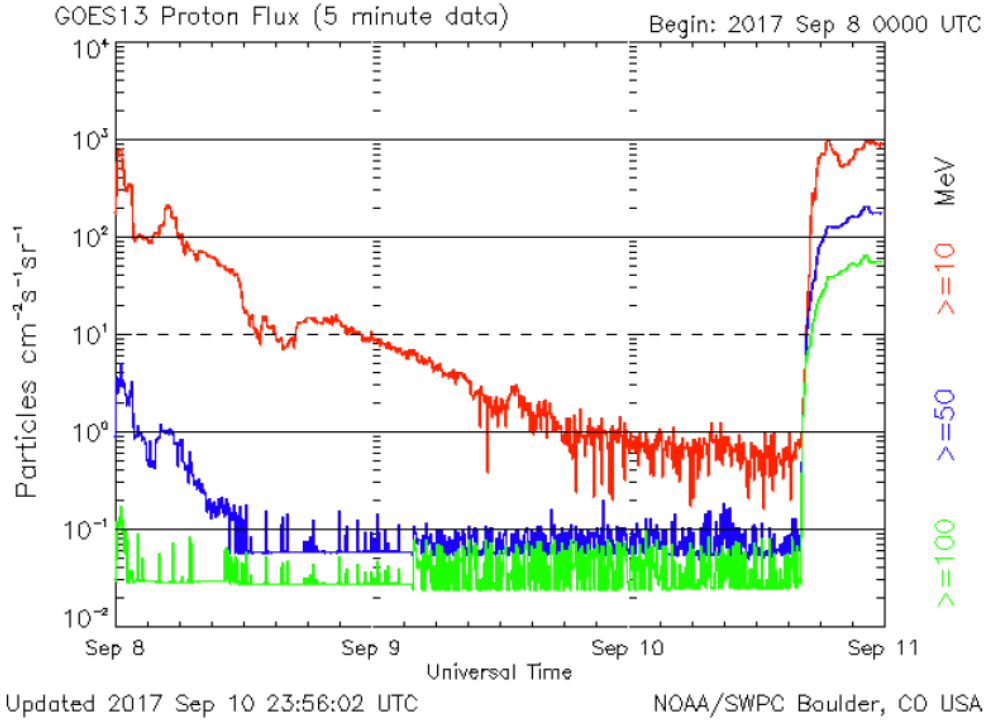
GOES satellites











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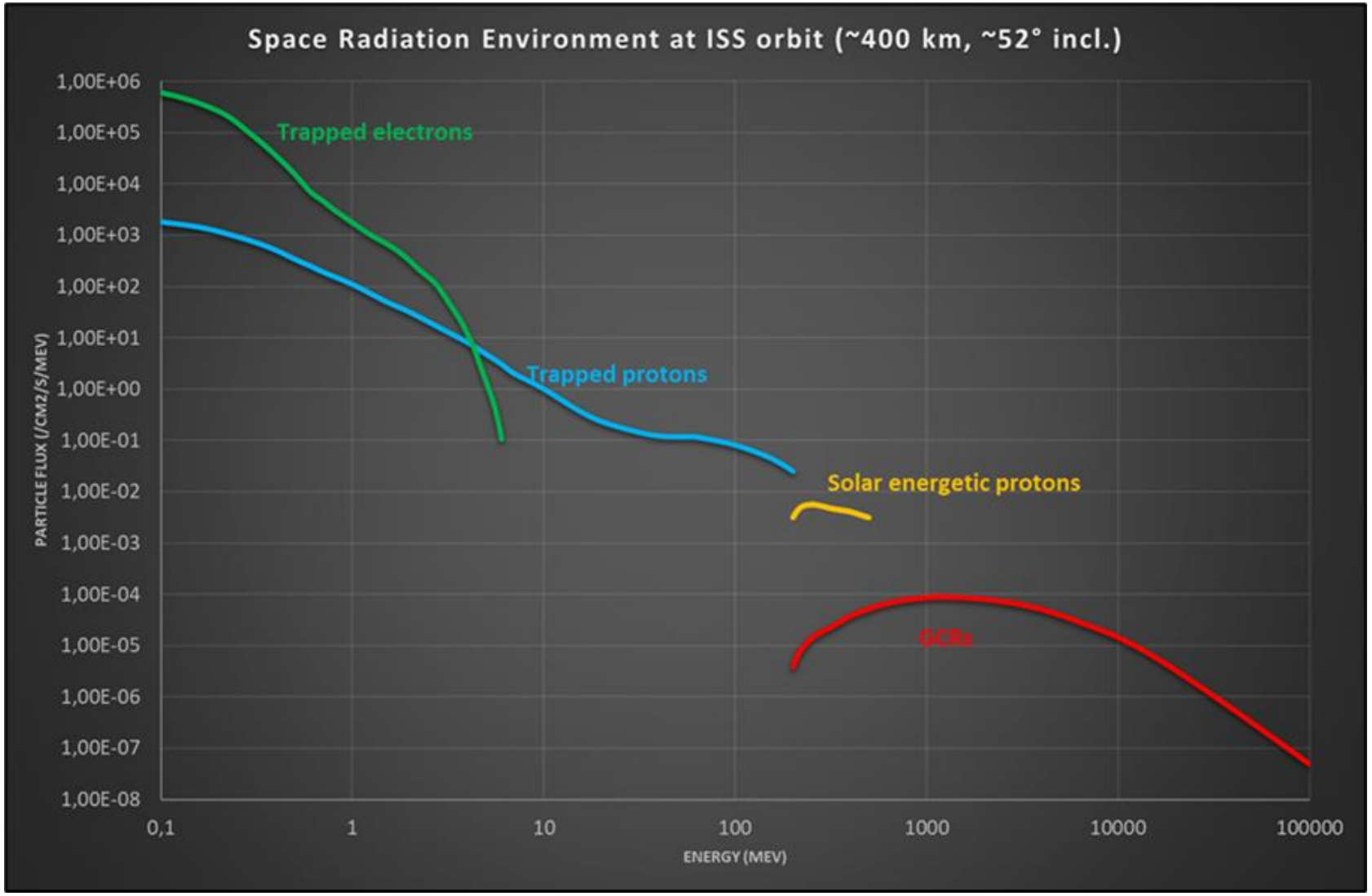


RADIATION EFFECTS IN ORBIT

Radiation effects in orbit

- Spacecraft charging
- Single event effects
- Total radiation dose

Space hazard	Spacecraft charging		Single-event effects			Total radiation dose		Surface degradation		Plasma interference with communications	
Specific cause	Surface	Internal	Cosmic rays	Trapped radiation	Solar particle	Trapped radiation	Solar particle	Ion sputtering	O^+ erosion	Scintillation	Wave refraction
LEO <60°											
LEO >60°											
MEO											
GPS											
GTO											
GEO											
HEO											
Inter-planetary											

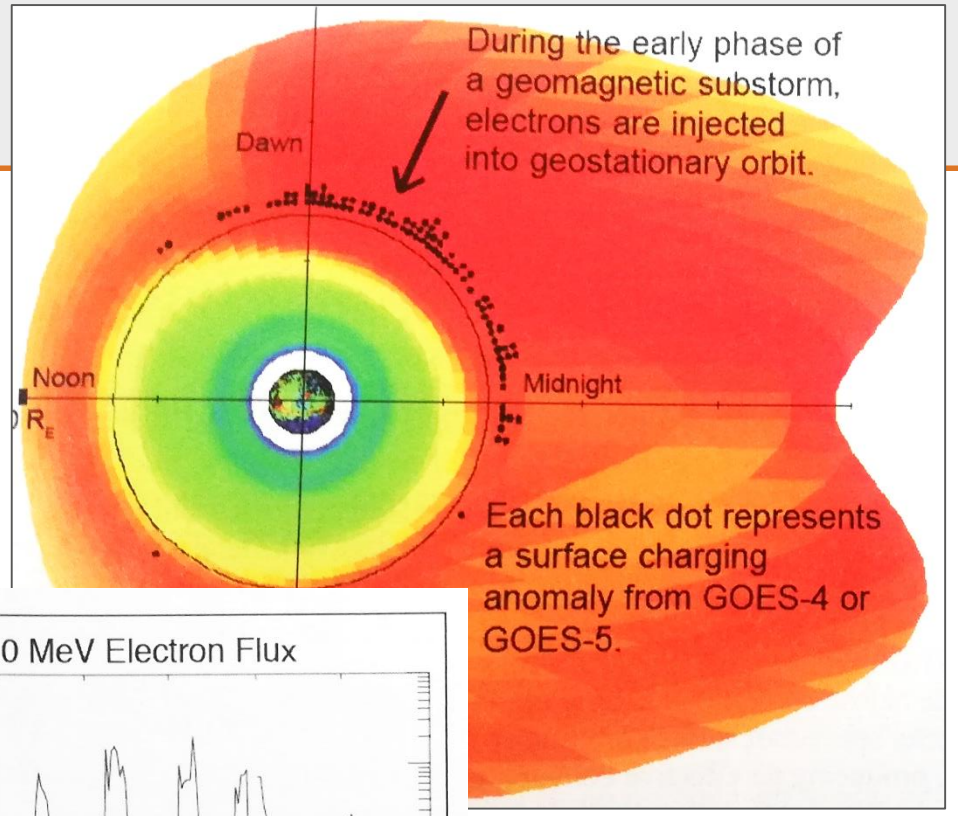
Important Relevant Not applicable

Space environment hazards for typical orbits. Key: LEO <60°—low Earth orbit, less than 60 degrees inclination; LEO >60°—low Earth orbit, more than 60 degrees inclination; MEO—medium Earth orbit; GPS—Global Positioning System satellite orbit; GTO—geosynchronous transfer orbit; GEO—geosynchronous orbit; HEO—highly elliptical orbit; O^+—atomic oxygen.

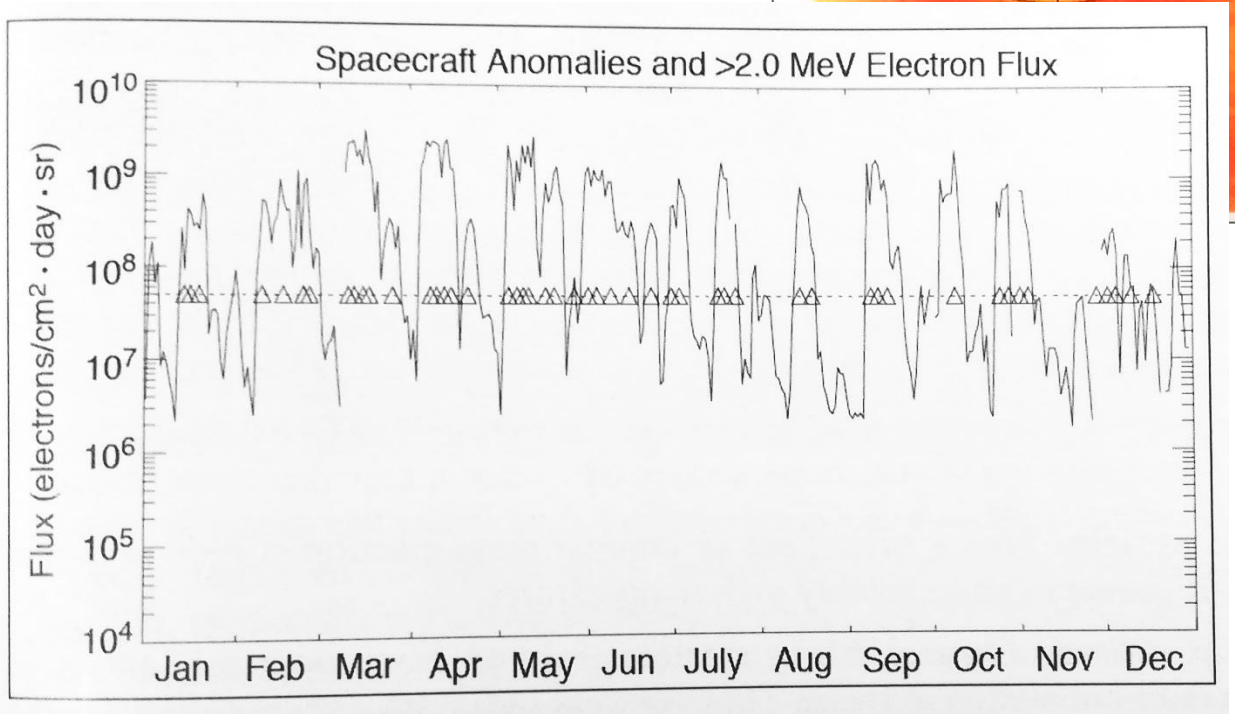
Ref. An overview of the Space Radiation Environment, E.J. Mazure, Crosslink, the Aerospace Corporation Magazine, Vol. 4, No.2, 2003

Radiation effects in orbit

- Spacecraft charging
  - Internal charging
  - Surface charging
- Single event effects
- Total radiation dose



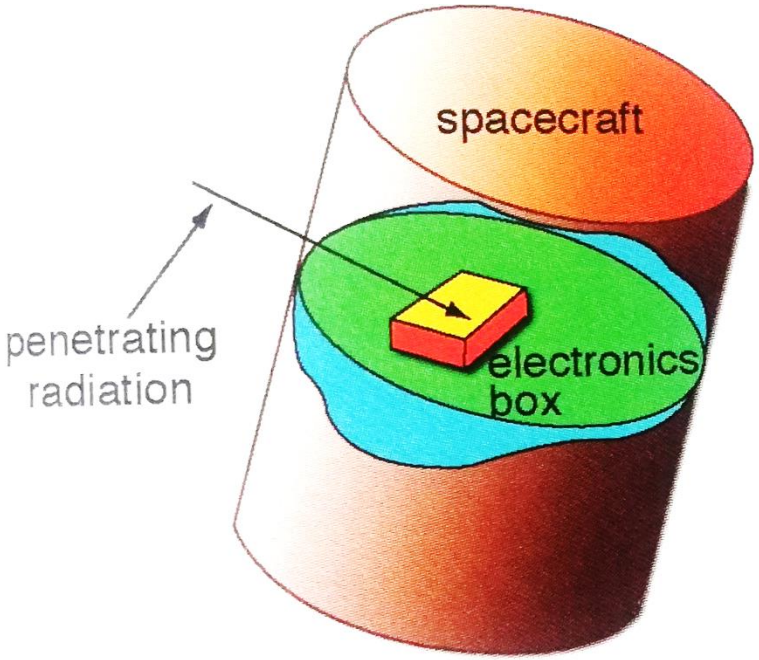
National Geophysical Data Center and John Freeman of Rice University

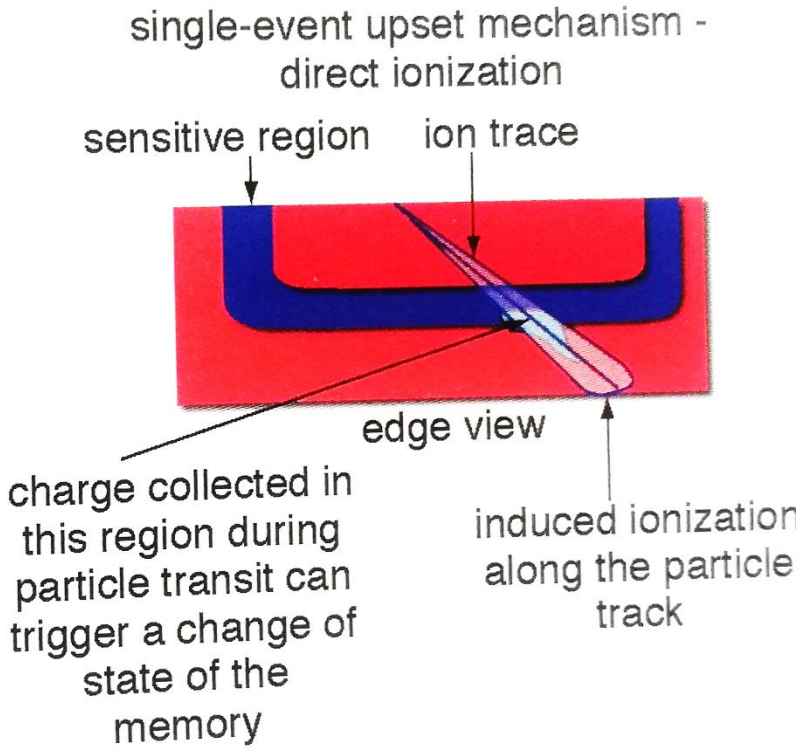


Wrenn and Smith, 1996

Radiation effects in orbit

- Spacecraft charging
- Single event effects
- Total radiation dose





After Baker, 2002

Radiation effects in orbit

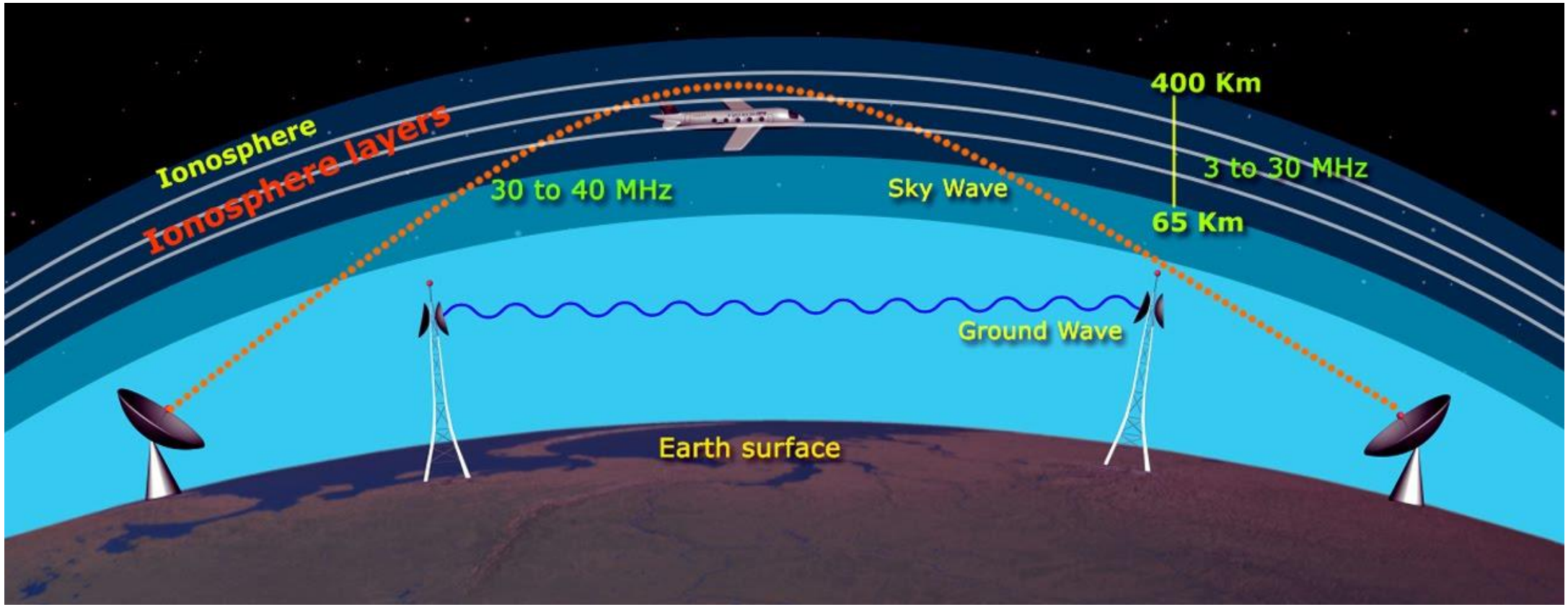
- Spacecraft charging
- Single event effects
- Total radiation dose

NASA

RADIATION EFFECTS IN ATMOSPHERE

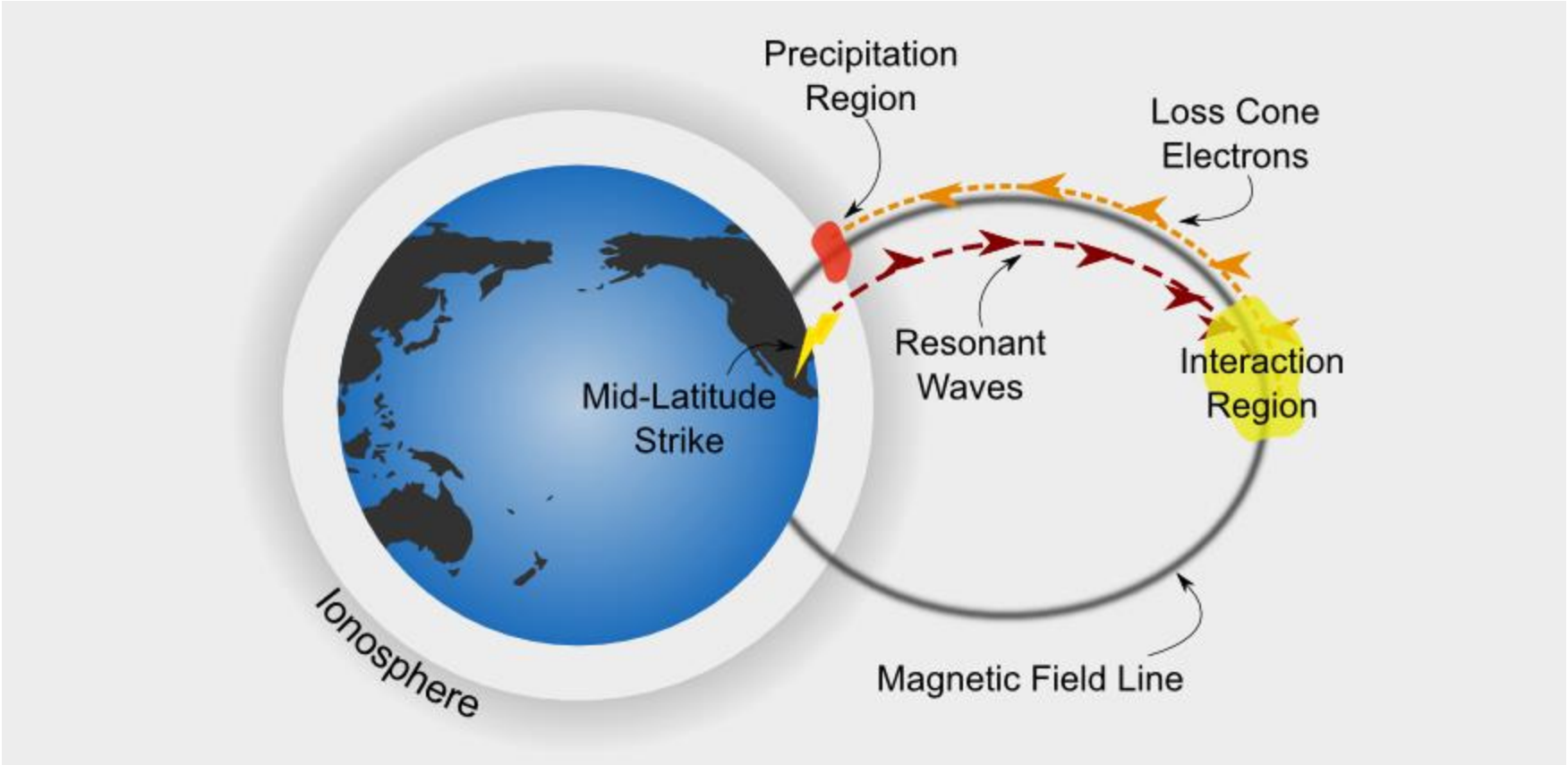
Radiation effects in ionosphere/atmosphere

- Polar Cap Absorption



Radiation effects in ionosphere/atmosphere

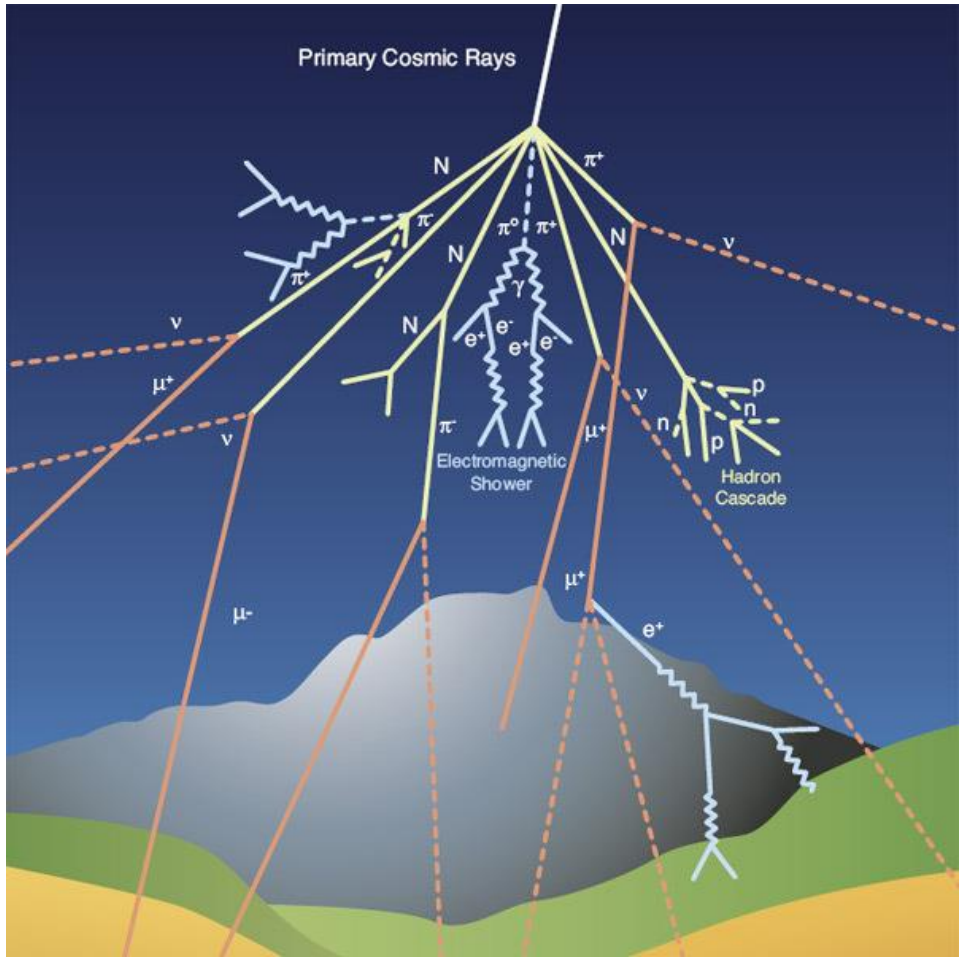
- Trapped Electron Precipitation



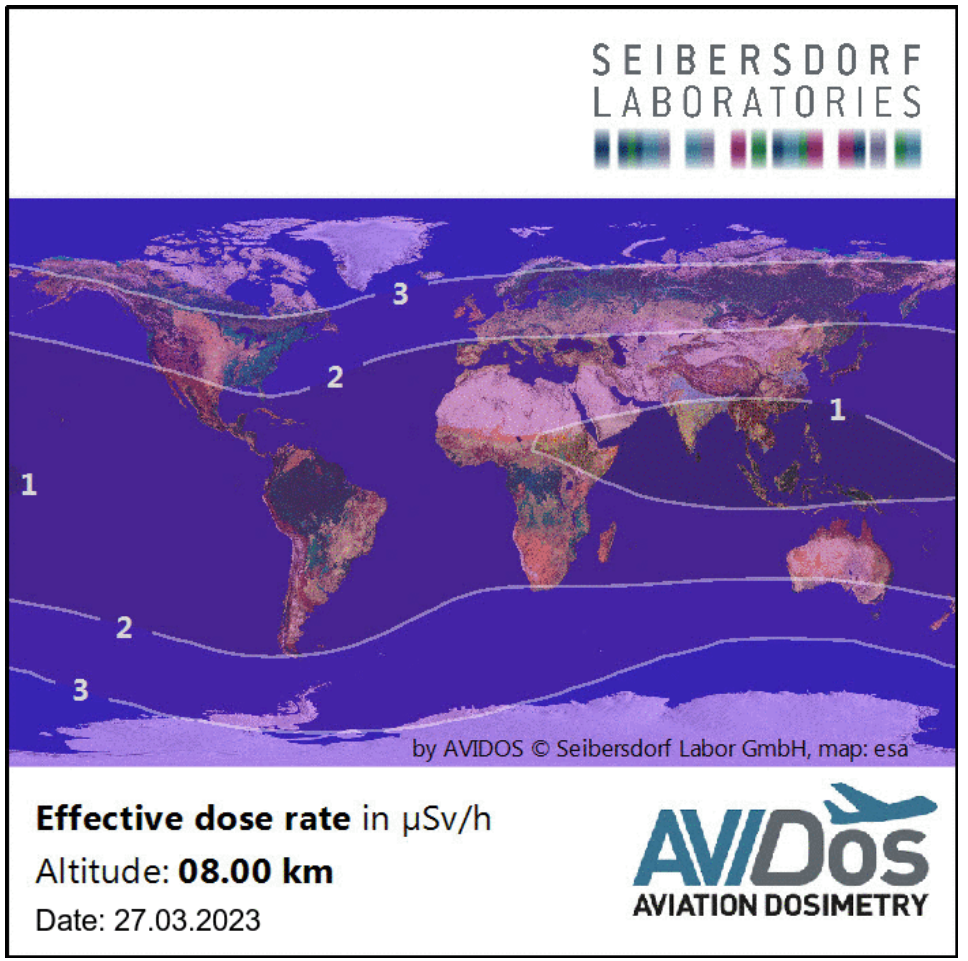
Standford VLF Group

Radiation effects in ionosphere/atmosphere

- Radiation dose



CERN



Seiberdorf Laboratories

THANK YOU!

www.aeronomie.be

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