From Particle Physics to Space

… and health

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Radiation Environment in the Solar System

Galactic Cosmic Rays

low flux but highly penetrating

Protons & ions

Solar Particle Events

sporadic, intense & dangerous

Electrons, protons & ions

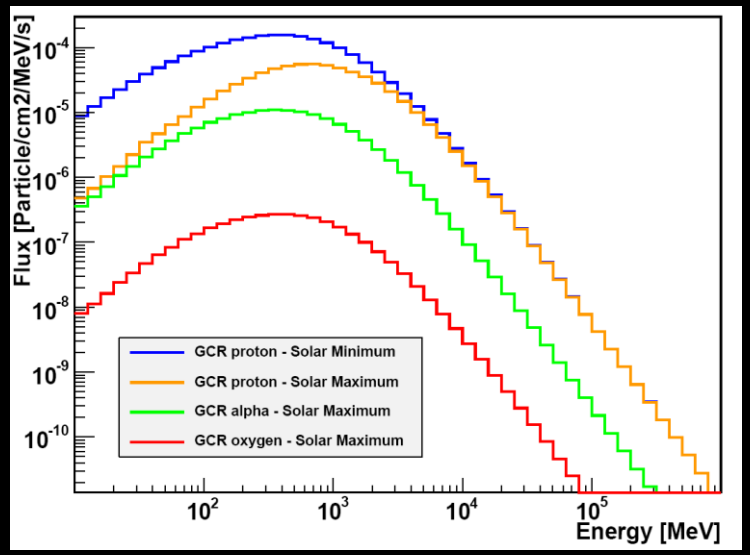
Radiation Belts

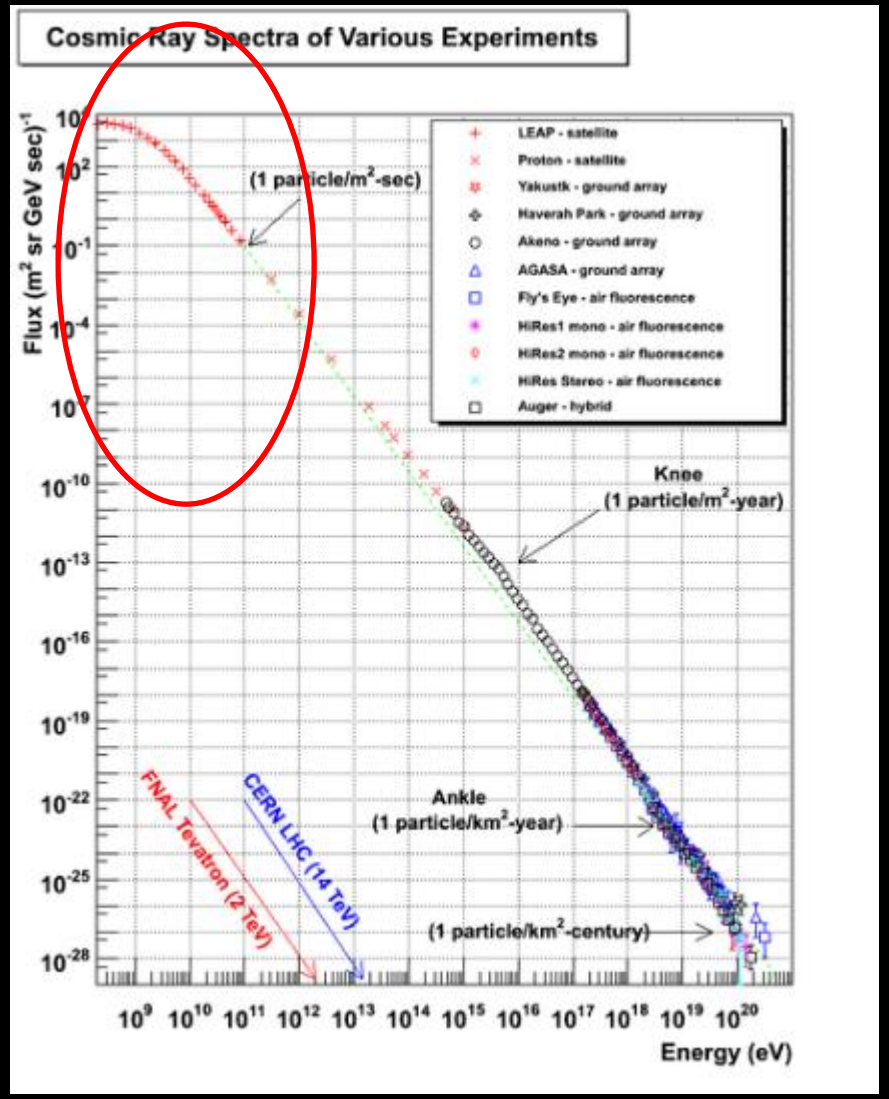
high radiation dose

Electrons & protons

Supernova in Crab nebula seen in X-ray by the Chandra mission

“Galactic” Cosmic Rays (GCR)

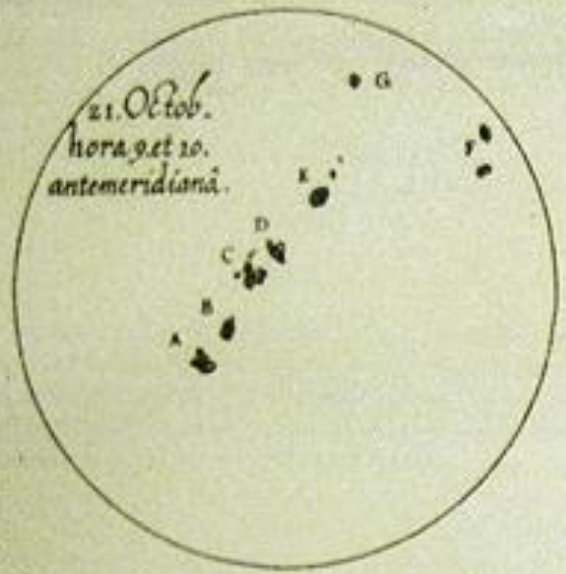


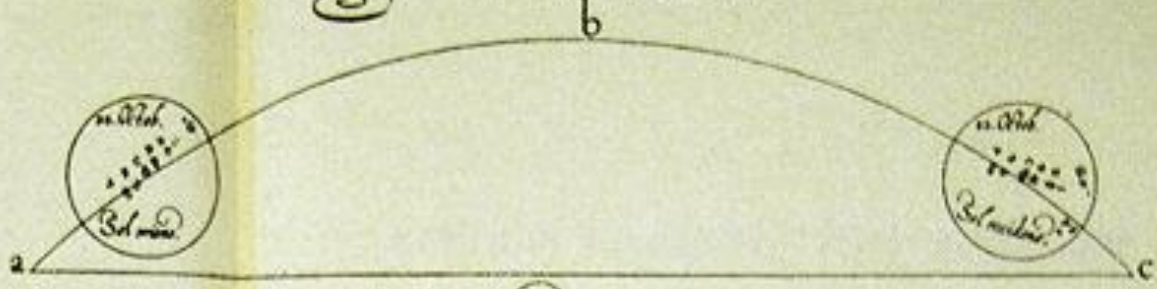


Low flux but highly penetrant

- Protons and nuclei: energy spectra peak at ~1 GeV/n
- Solar cycle modulated flux inversely proportional to the Sun’s activity
- E < 1 GeV/n: highly affected by solar activity

MACVLAE IN SOLE APPARENTES, OBSERVATAE anno 1611. ad latitudinem grad. 48. min. 40.



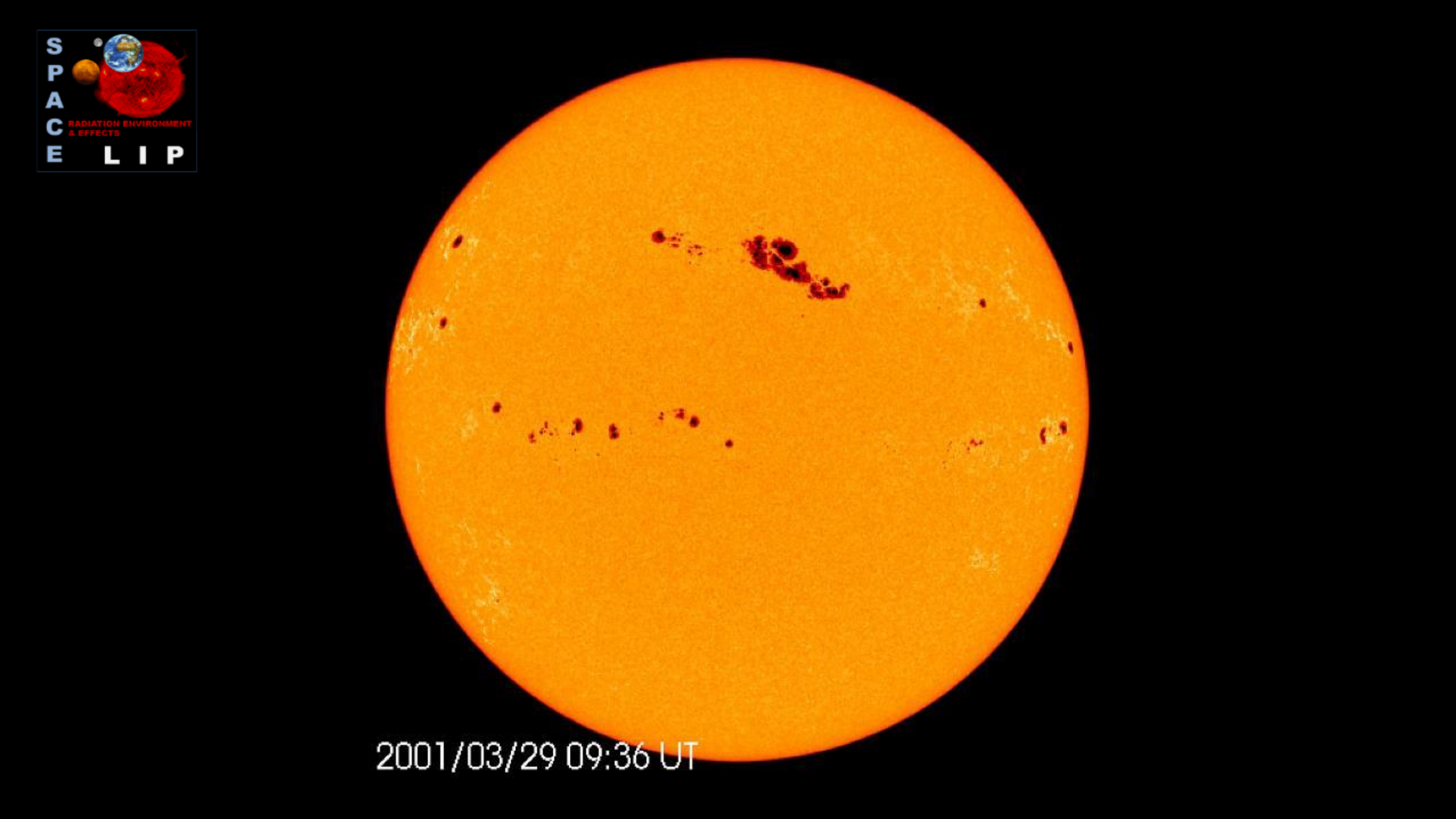


a c, horizon. a b c, arcus solis diurnus. Soloriens ex parte a, maculas exhibet quas vides, occidens verò c, easdem ratione primj motus, nonnihil inuertit. Et hanc matutinam vespertinamq; mutationem, omnes maculæ quotidie subeunt. Quod semel exhibuisse et monuisse, sufficiat.

Macula M, est hactenus visarum maxima, nullique prima magnitudinis sideri fixo cedit.

Macula I fuit valde conspicua, propter notabilem pra reliquis magnitudinem.

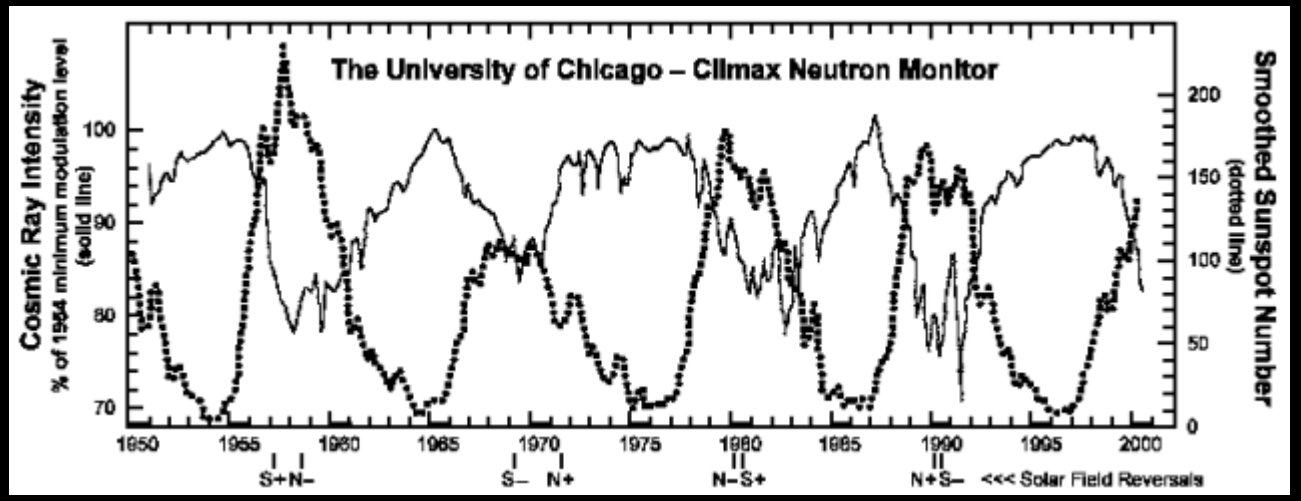
Figura qua habet annexum signum X, et Olittera.

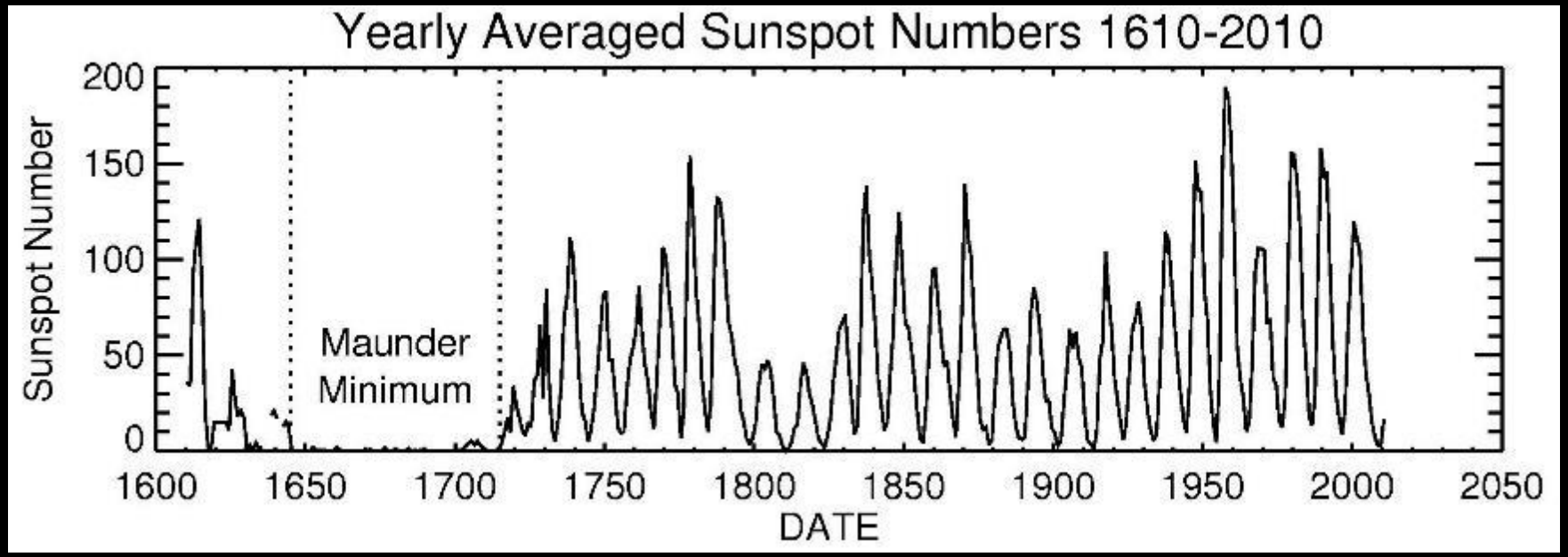

SPACE
RADIATION ENVIRONMENT & EFFECTS
LIP
2001/03/29 09:36 UT

11 year Solar Cycle

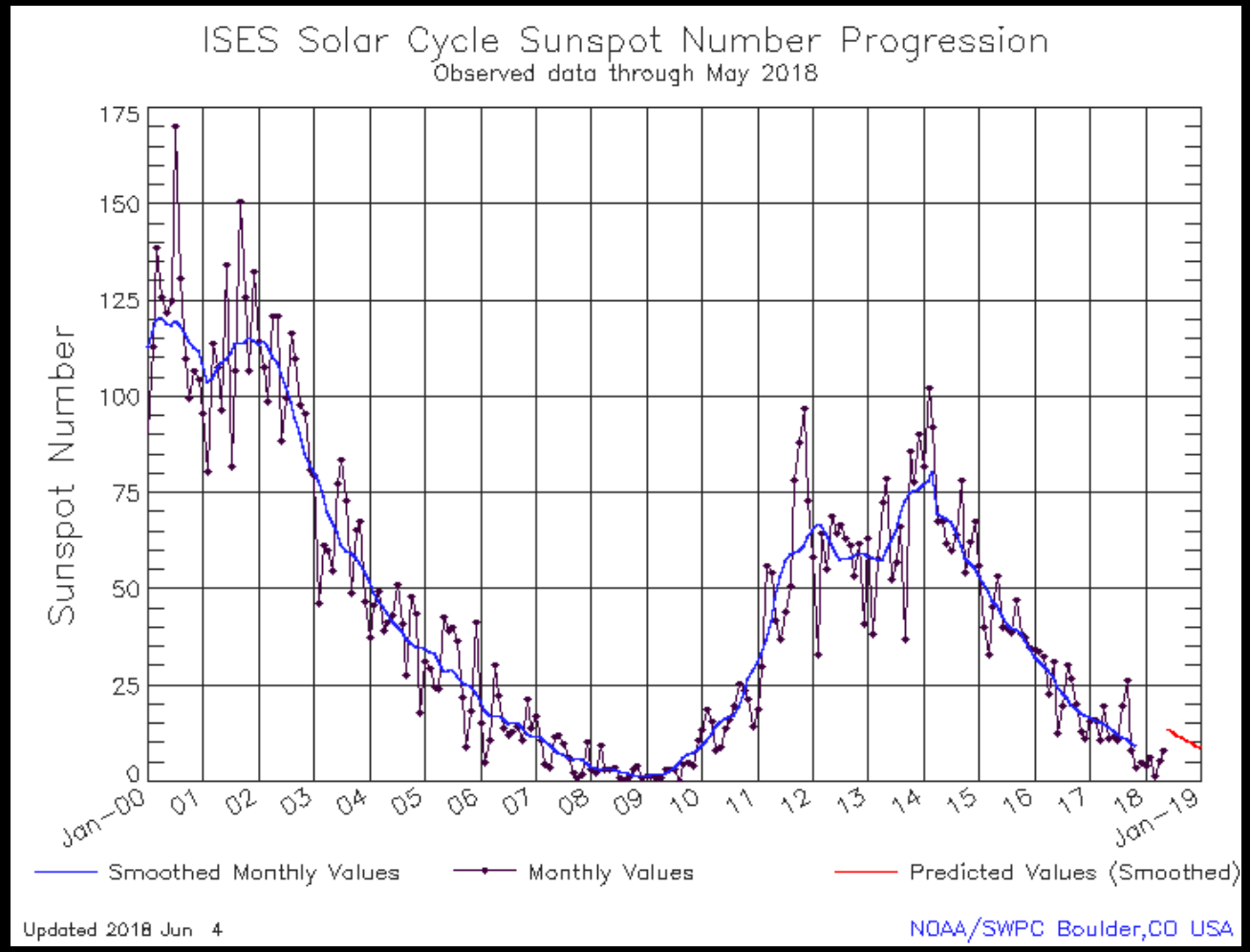
Modulation with solar activity

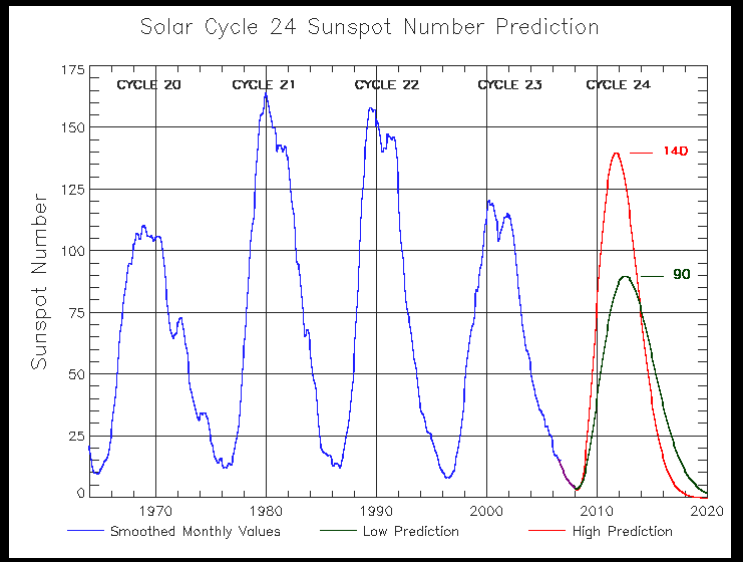
- ★ Solar Maximum: solar storms and SEP
- ★ Solar Minimum: more GCR





Solar Cycle 24



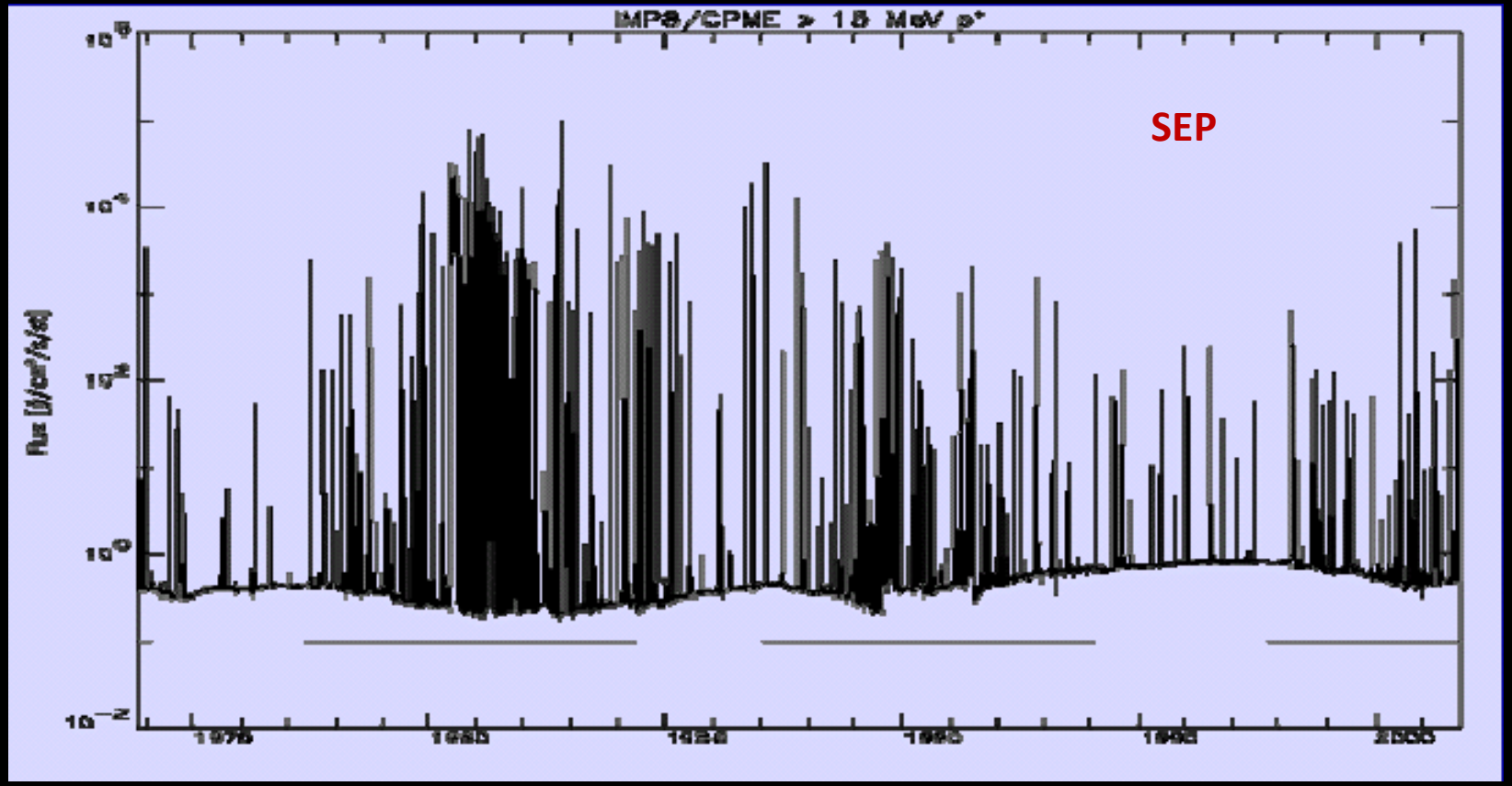


Solar Energetic Particle events

★More frequent in “maximum” solar activity years

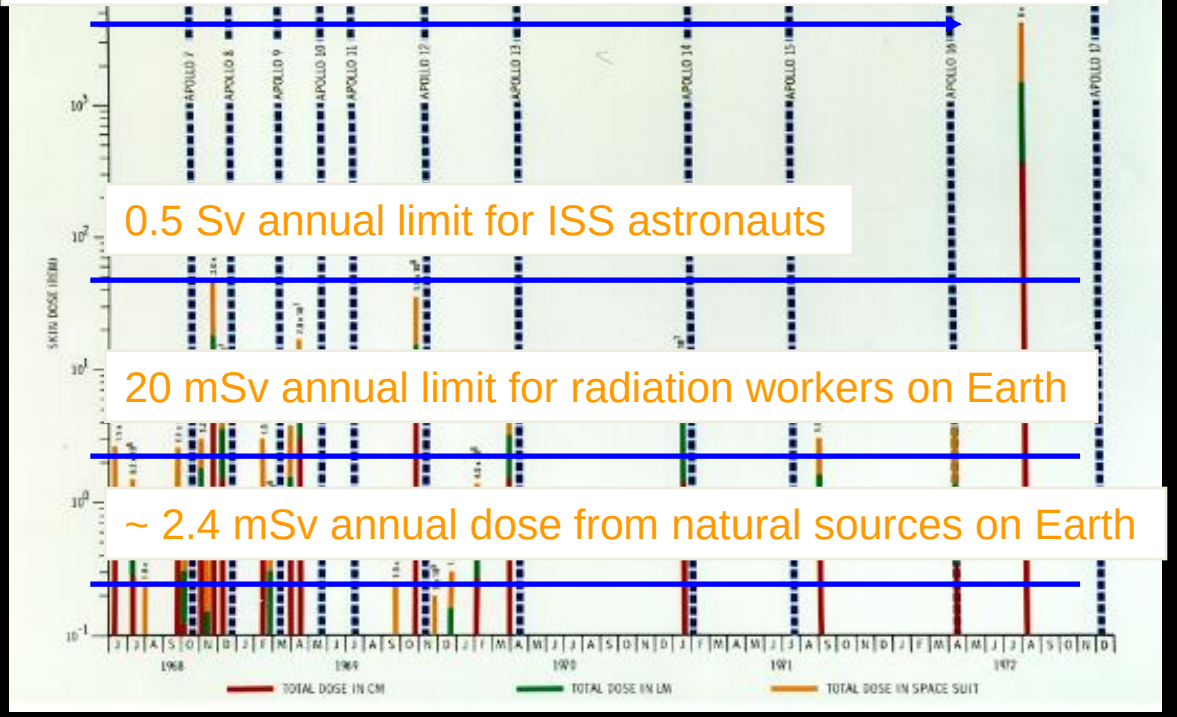
★Highly unpredictable

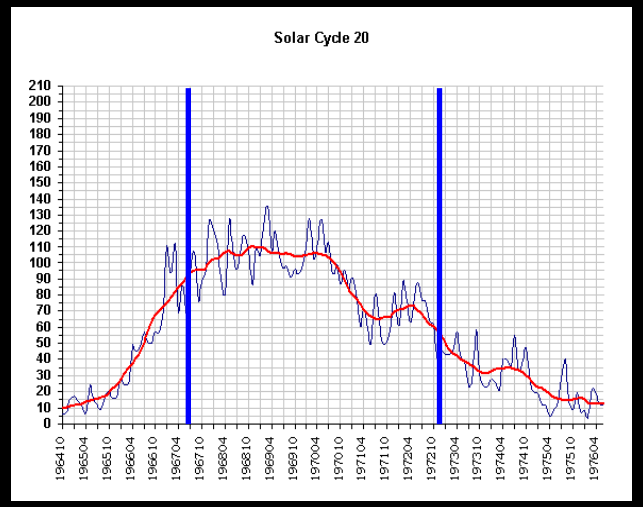
★ Design for by making statistical assessment

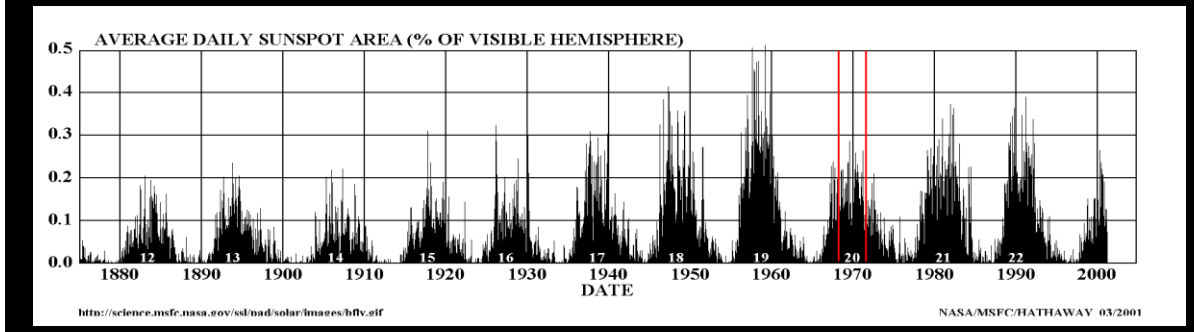


Apollo missions: Solar maximum

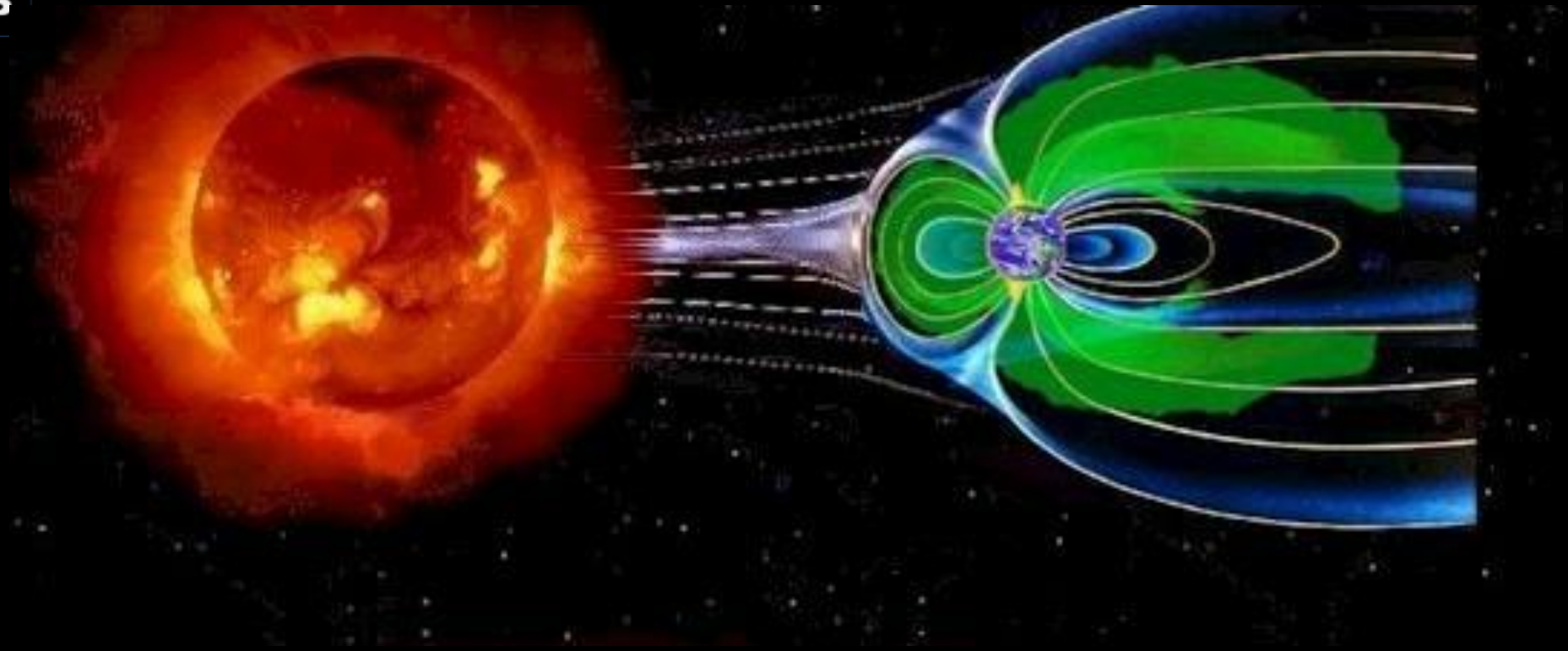
~ 40 Sv acute skin dose (without shielding) from August –72 SPE. Potentially very serious for the lander/EVA



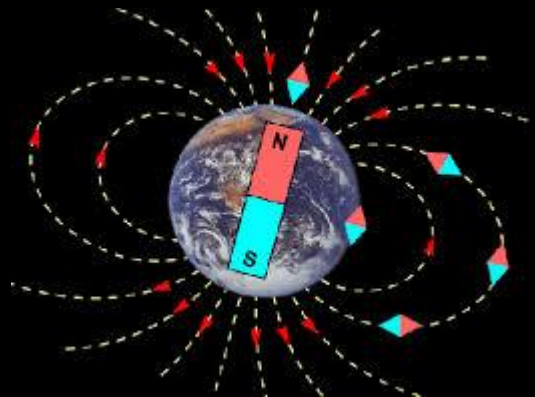




The Magnetosphere: an invisible shield

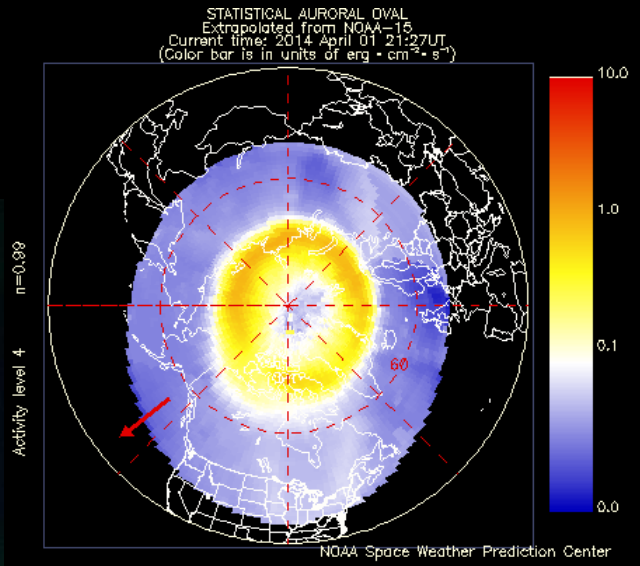


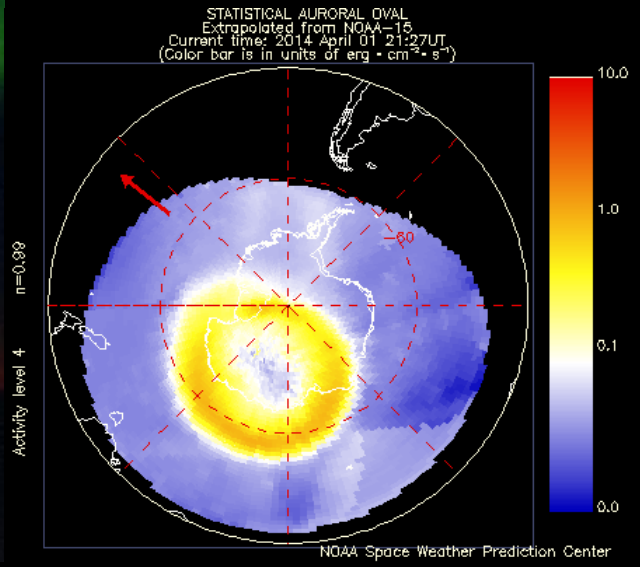
In Earth orbits the radiation belts containing trapped electrons and protons constitute the major radiation source.



Auroras

Charged particles captured in the radiation belts excite N2 and O2 molecules that emit visible light while returning to the fundamental state.





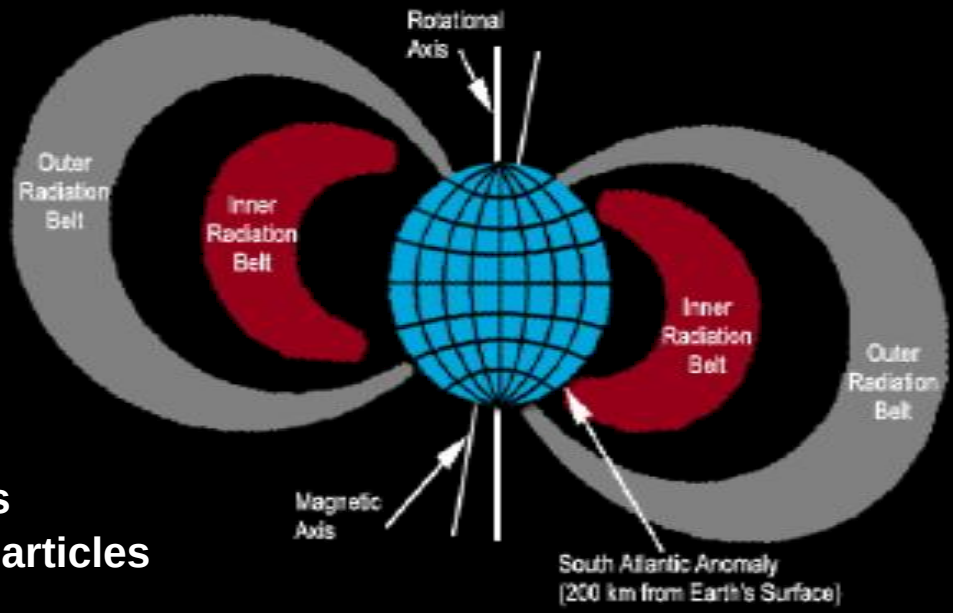
Earth Radiation Belt Regions

High radiation dose, electrons (<10 MeV) & protons (<250 MeV)

- **Inner belt (700-10000 km)**
  - dominated by **protons**
  - CRAND = Cosmic Ray Albedo Neutron Decay
  - ~static
  - E~100's MeV

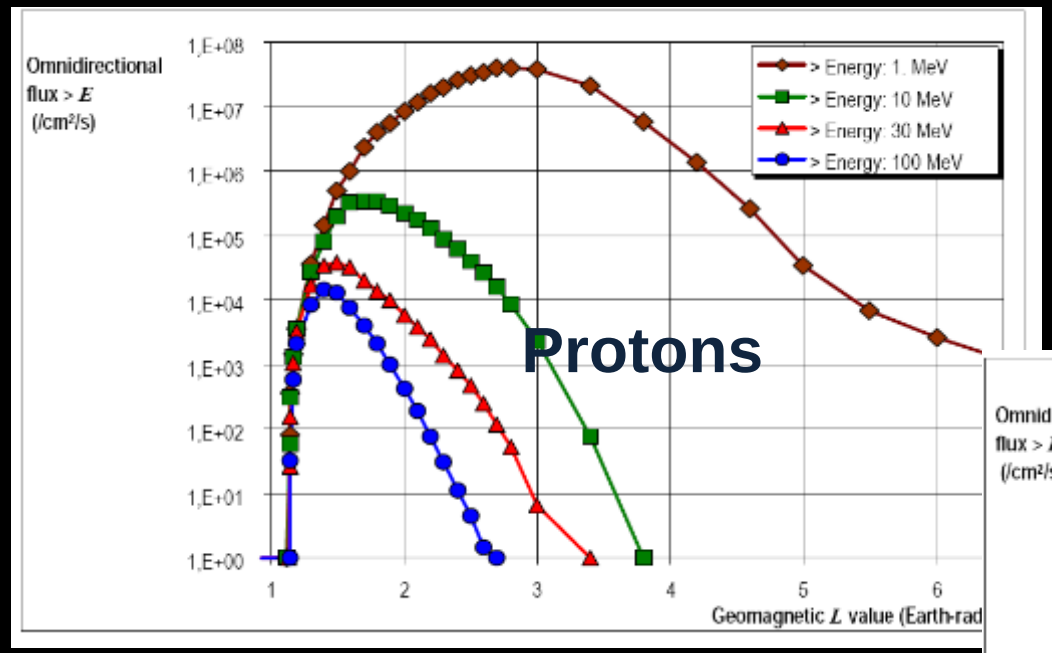
- **Outer belt (~20000-70000 km)**
  - dominated by **electrons**
  - Controlled by "storms"
  - Very dynamic
  - E~ MeV

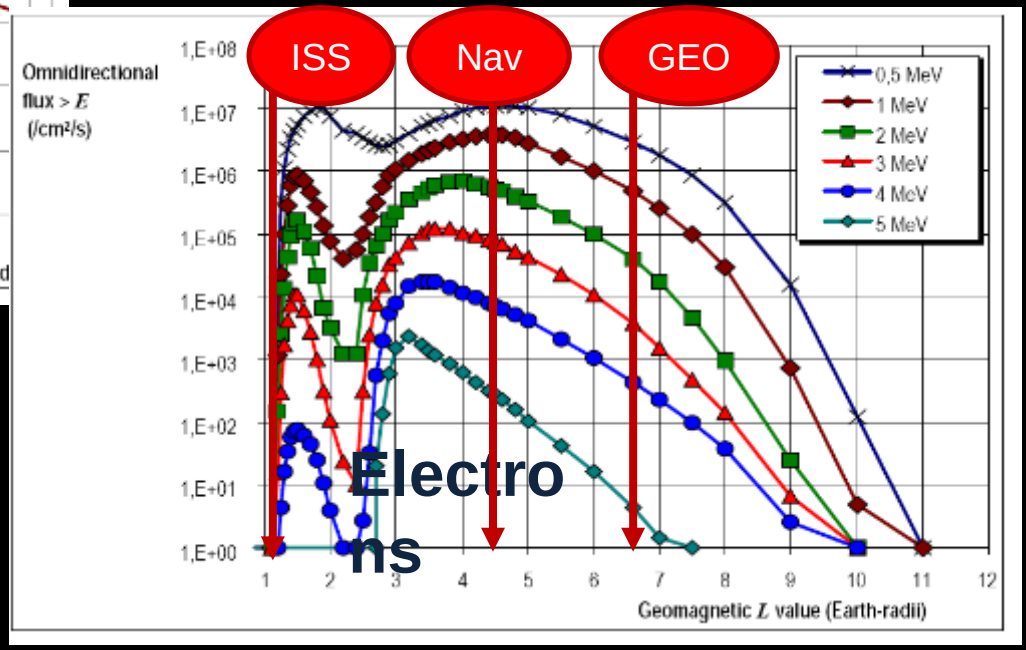
- **Slot**
  - low intensities of MeV electrons
  - occasional injections of more particles



Earth Radiation Belt Models

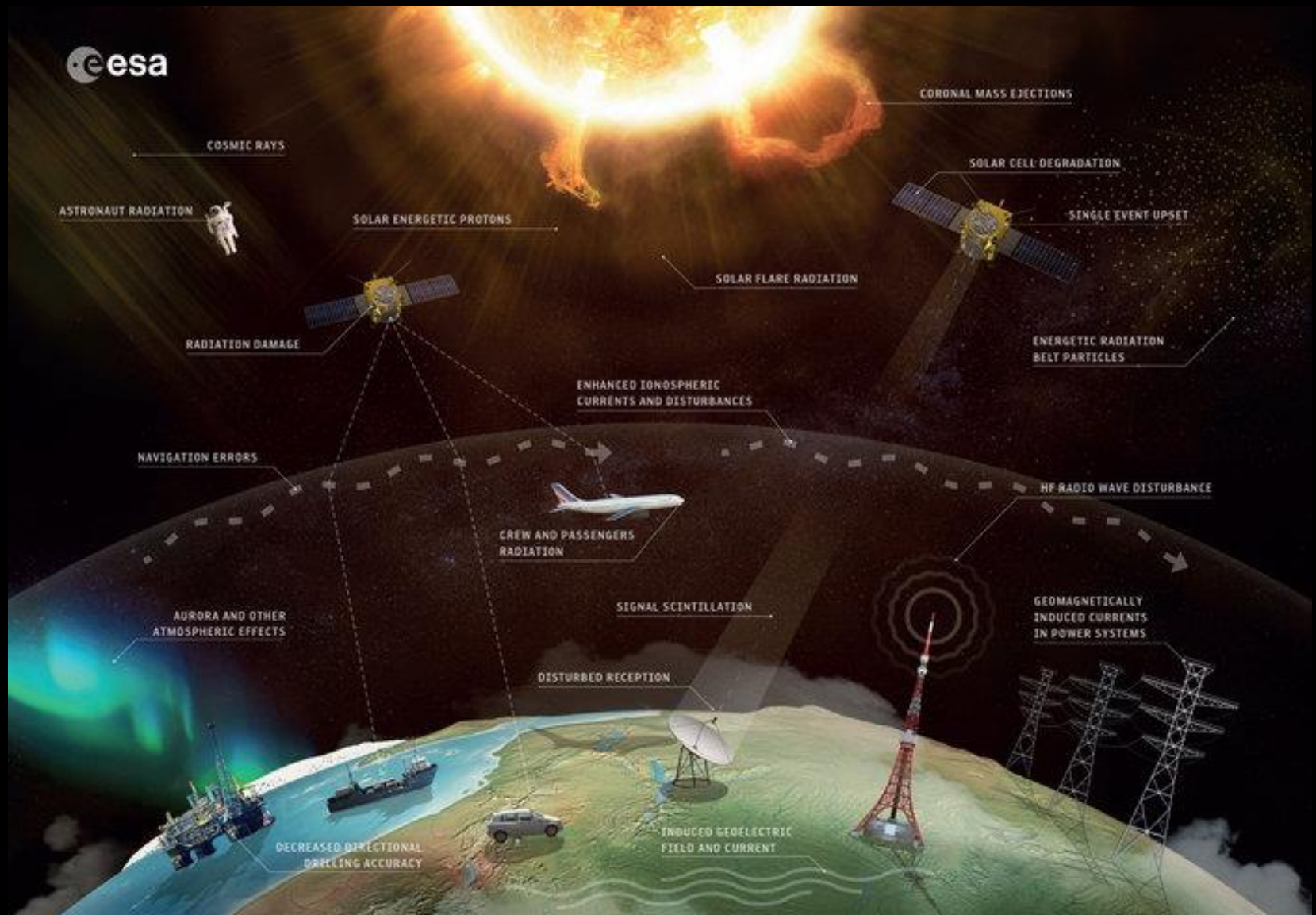
Models AP8,AE8





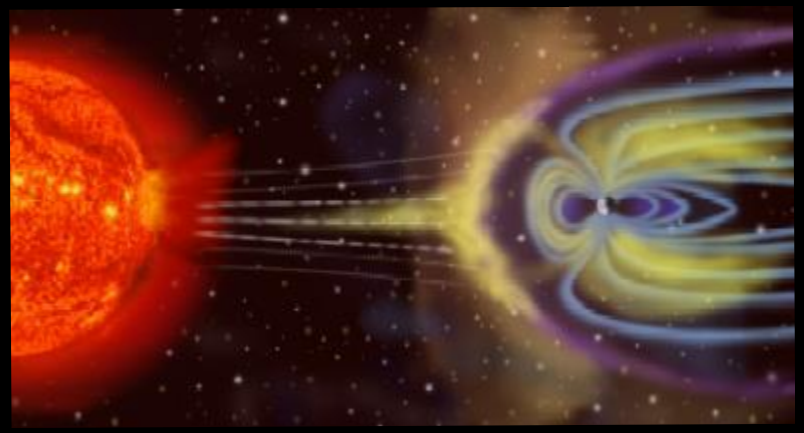
- Based on data from 1960-1970
- Long term averages
  but : outer belt is very stormy
- ongoing work to update models

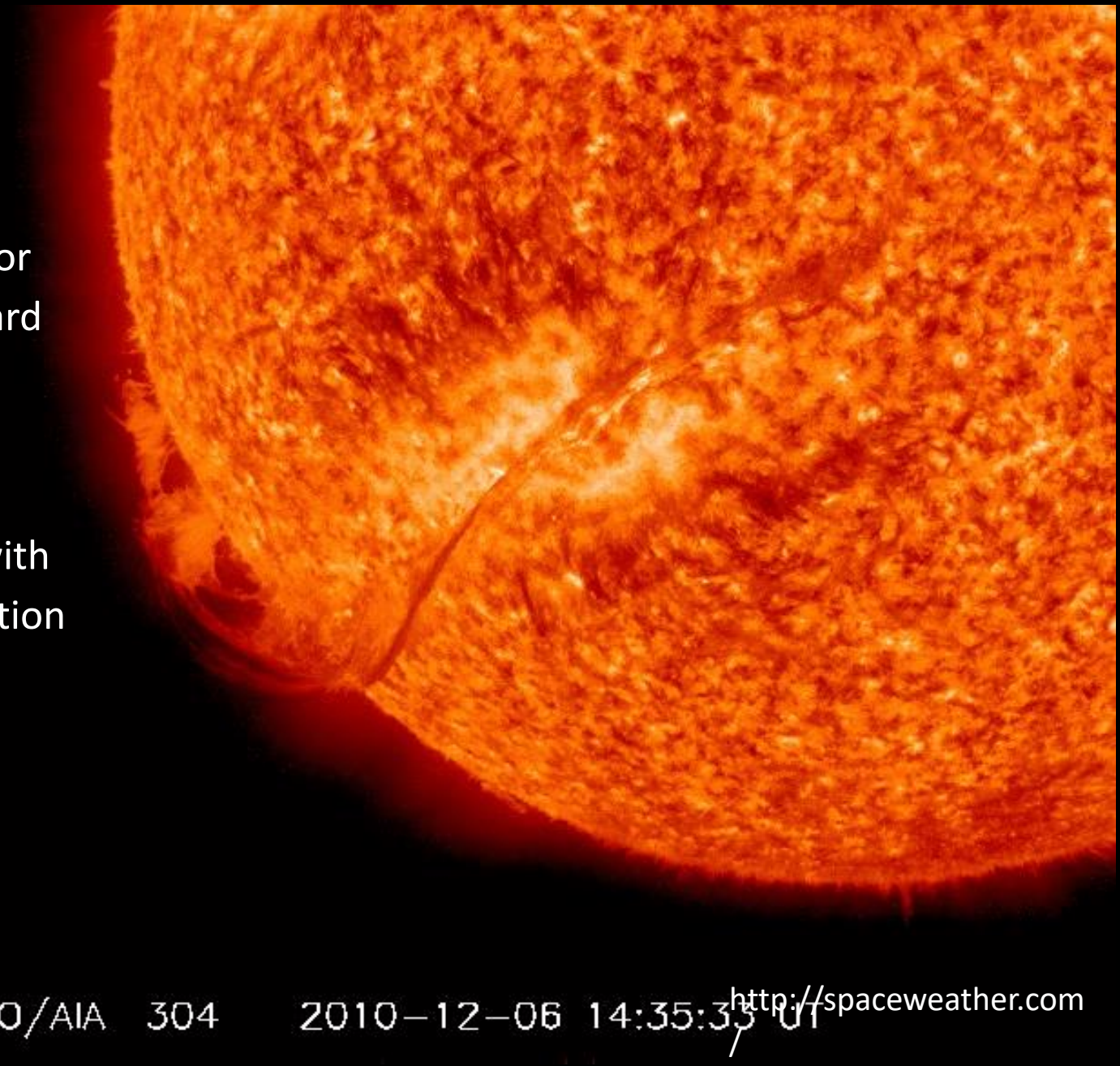
Radiation effects on Earth and in orbit



In space, the radiation environment is responsible for spacecraft system, sub-system and component hazard and damage and it is also responsible by strict constrains on human space exploration.

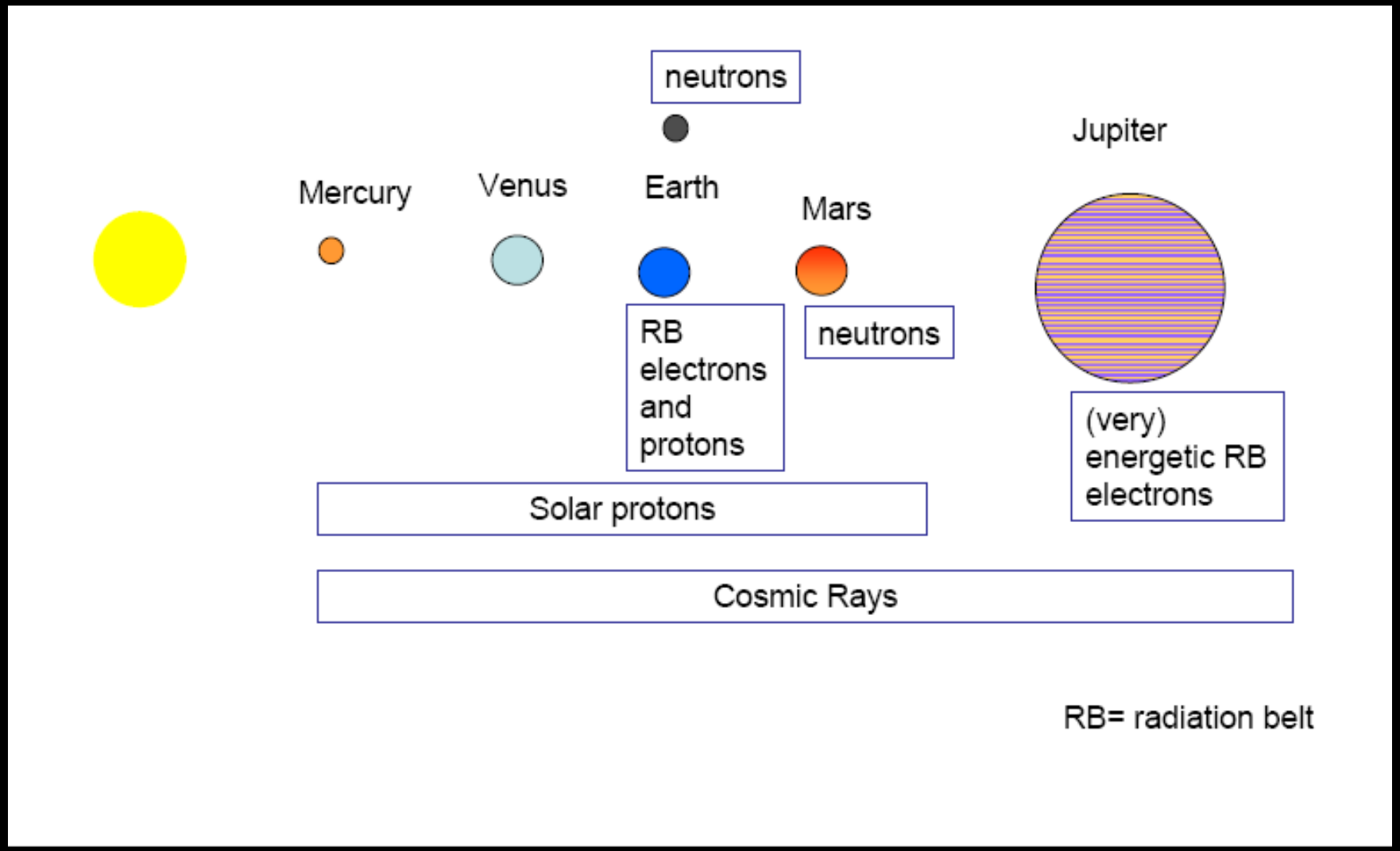
At Earth's surface, the atmosphere in conjunction with the geomagnetic field provides considerable protection against cosmic rays and solar particle events.





http://spaceweather.com

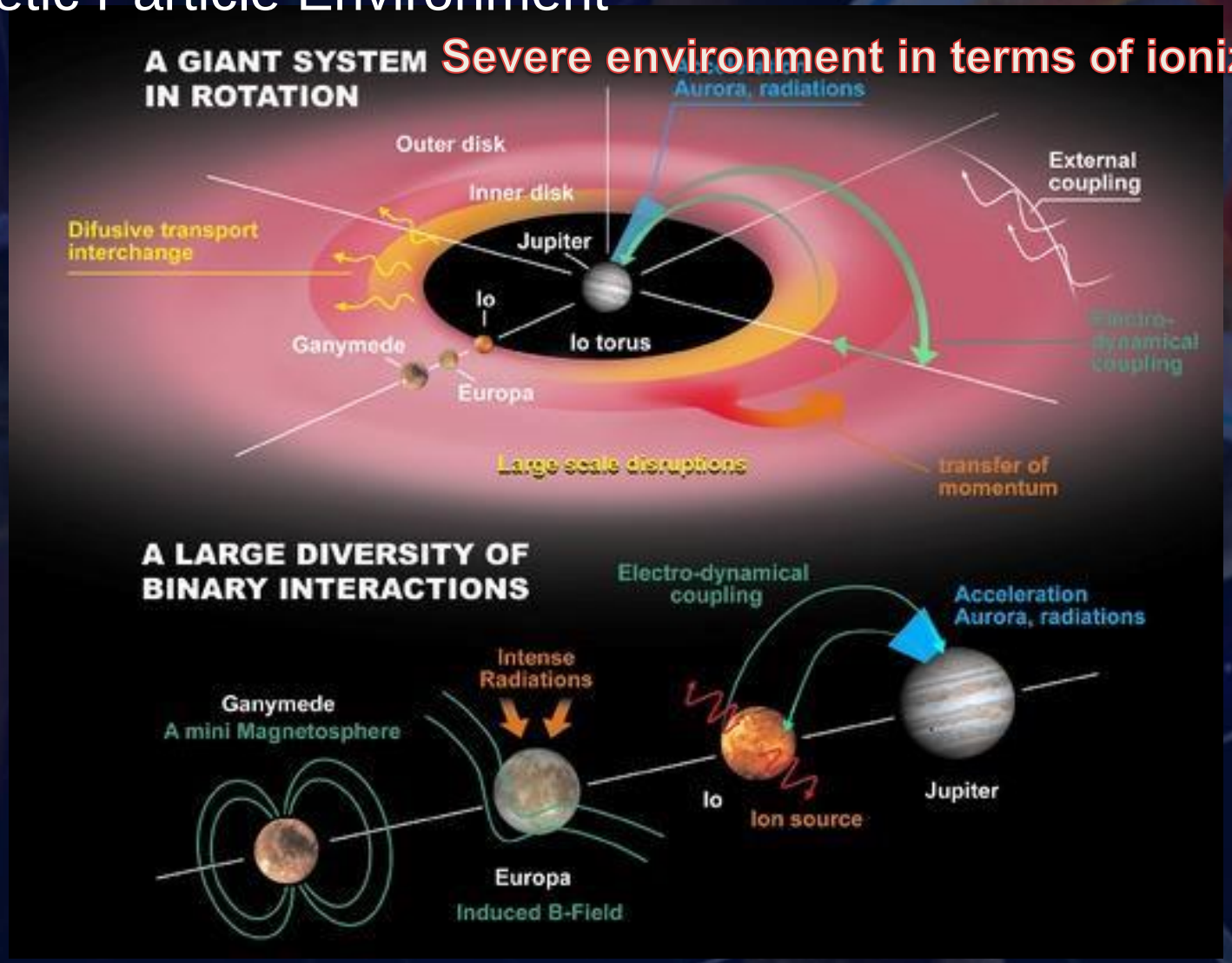
Radiation Environment in Space



Jovian System

Energetic Particle Environment

Severe environment in terms of ionizing particles



Juice Mission Objectives

Study the emergence of habitable worlds around gas giants

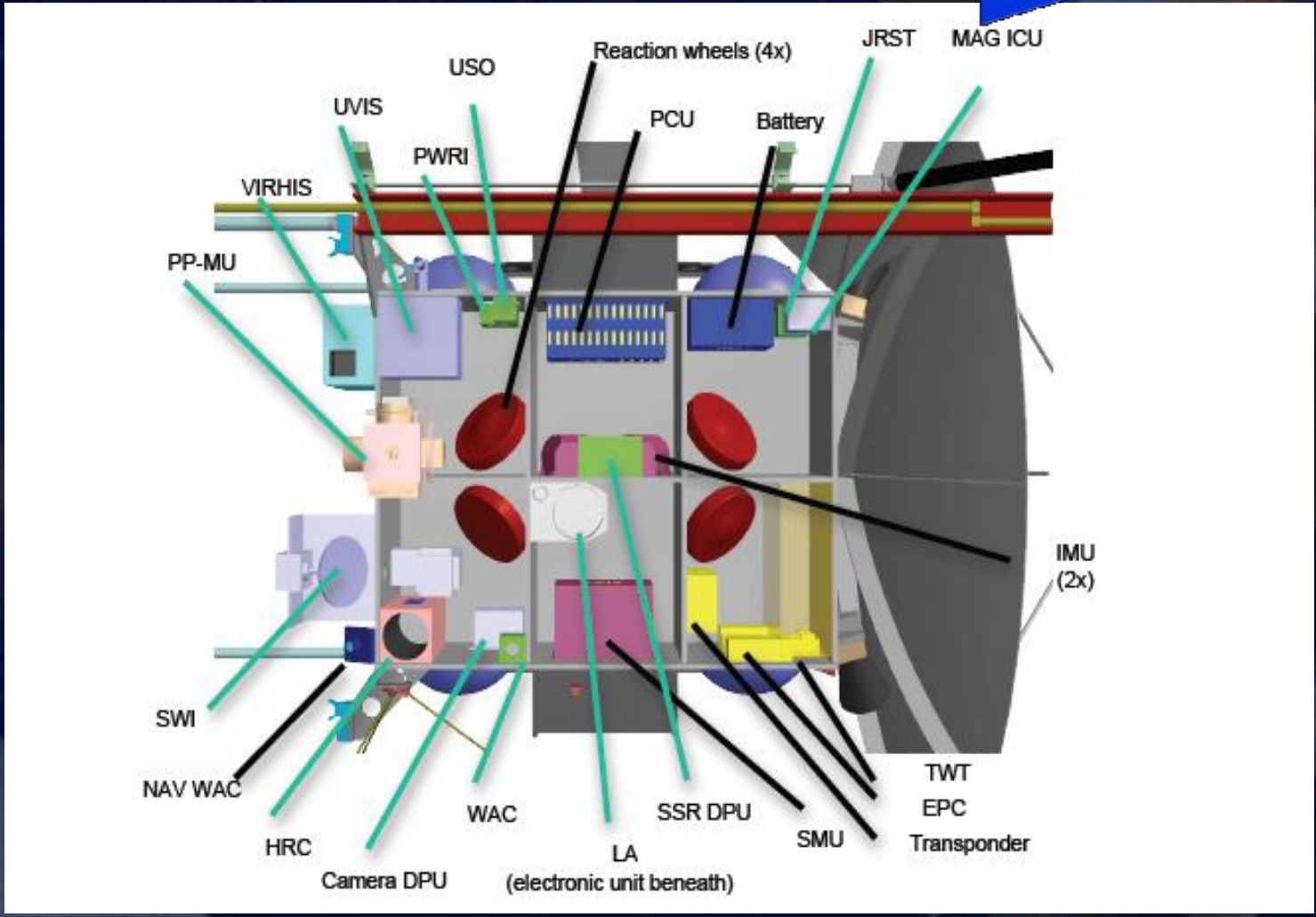
- Characterise the Jupiter Icy Moons: Ganymede, Europa and Callisto as planetary objects and potential habitats
- Explore the Jovian system as an archetype for gas giants

Juice mission

Implications for Astrophysics & Planetary Physics

Juice Scientific Payload

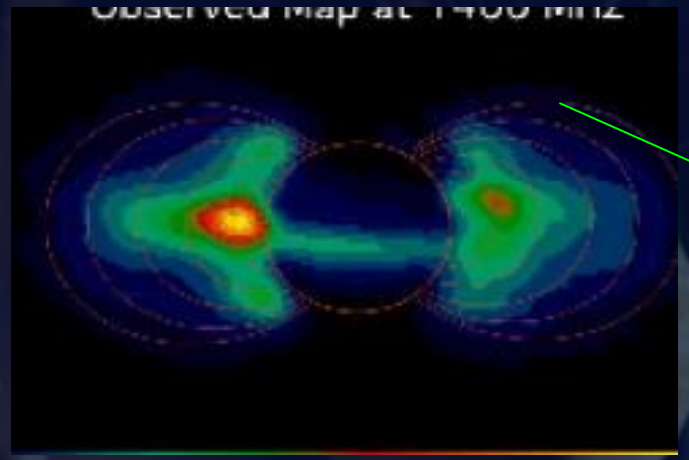
11 instruments with total mass of ~100 kg



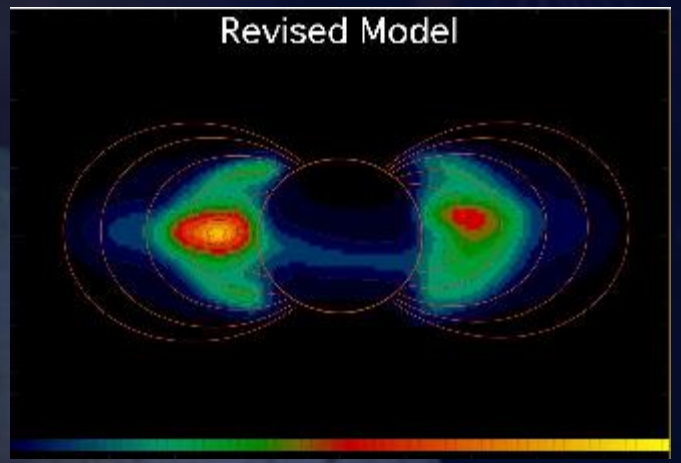
Possible configuration for Scientific Payload accomodation

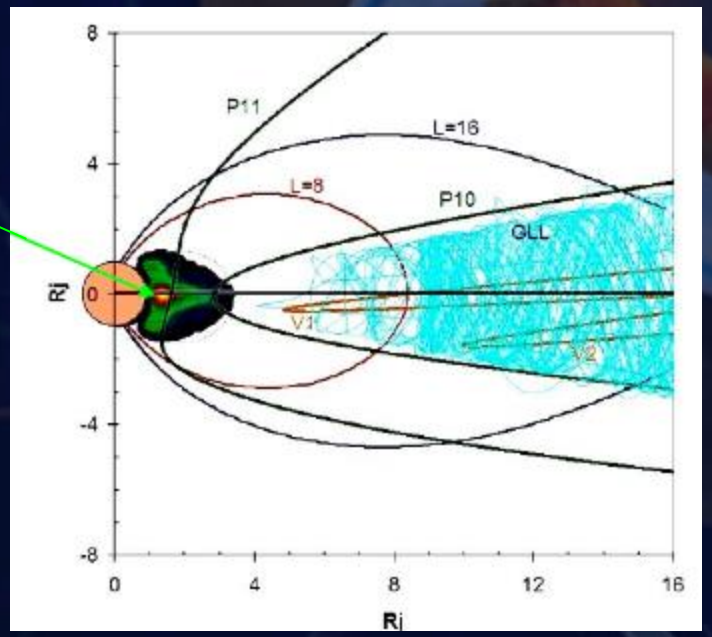
Data and models

Synchrotron emission observations



Synchrotron emission predictions from Divine model





Courtesy of H.B.Garret, Jet Prop.Lab

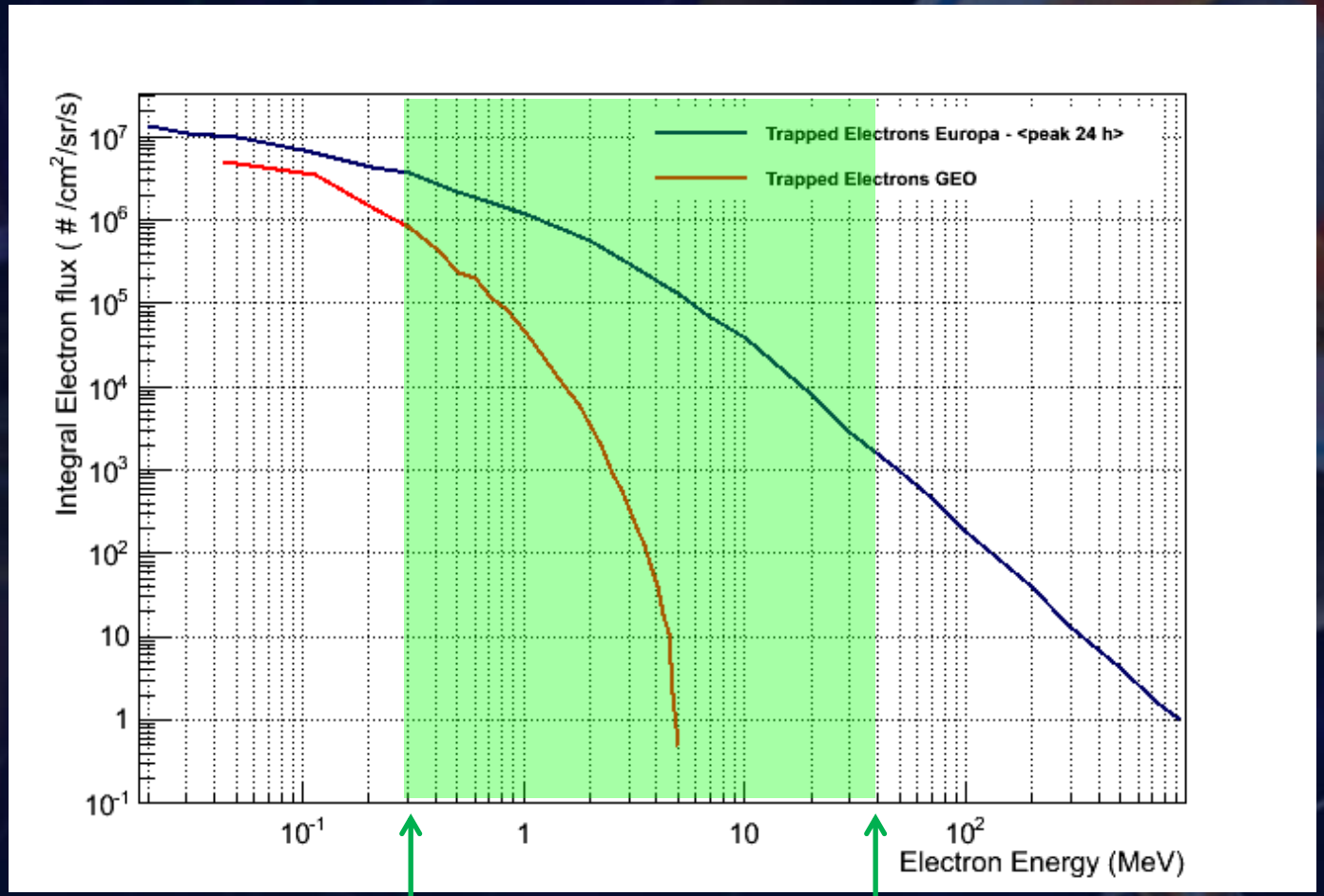
Limited data from Missions

- Pioneer 10-11 (1973, 1974)
- Voyager 1-2 (1979)
- Galileo (1989)
- Juno (NASA) 2017

Models

-Divine e- and proton models
- GIRE (Galileo Interim Radiation Environment Model)
- Salammbô(e-belt model from Jupiter surface to Europa)
- JOSE (based on Divine+GIRE+Salammbô+data)

Very Hard Electron Spectrum



Radiation Monitors

1. Radiation Housekeeping
2. Alert and safeguarding
3. Support to platform and payload
4. Future mission preparation & provision of science data

Particle detectors in Space

Mass ~ 1 kg
Power ~ 1 Watt
Volume - 1 lt

RADIATION ENVIRONMENT MEASUREMENT

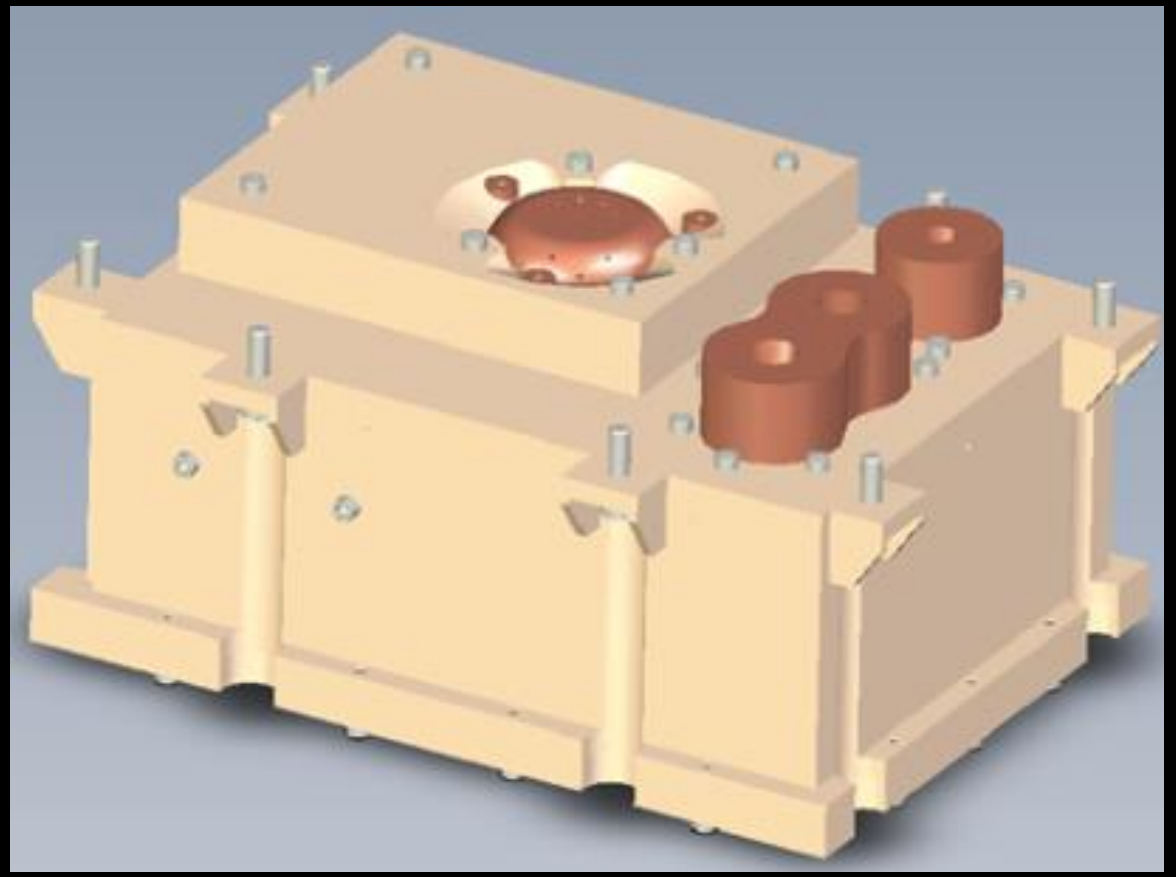
RADEM

Main Objectives

- Ensure mission safety
- Provide valuable scientific data

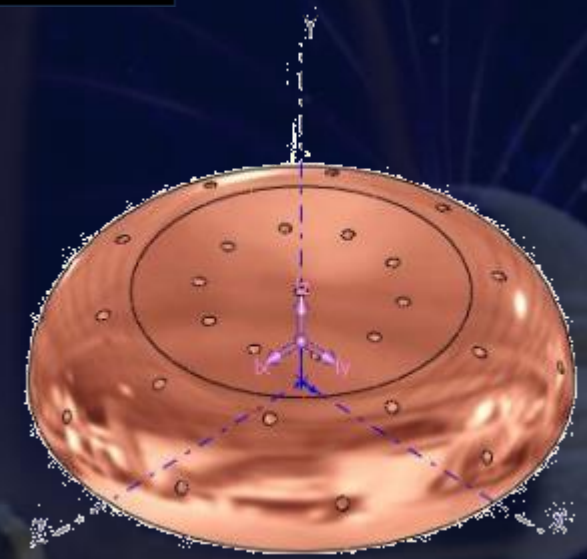
Requirements

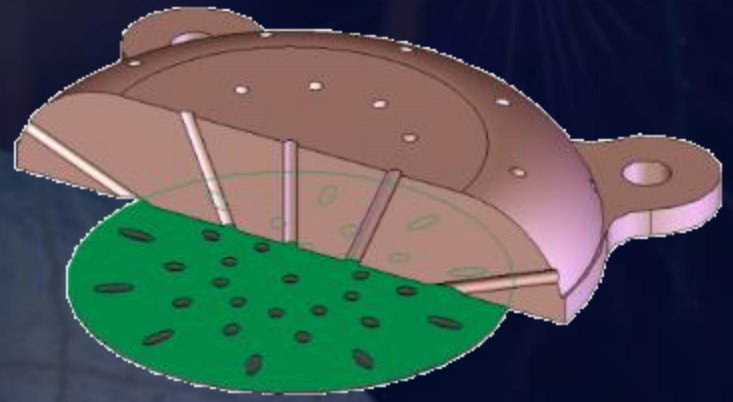
- Electron detector
  - Spectral range 300 keV – 40 MeV
  - Peak Flux 10^9 e/cm^2/s
- Proton Detector
  - Spectral range 5 MeV– 250 MeV
  - Peak Flux 10^9 e/cm^2/s
- Particle Separation
  - From Helium to Oxygen
- Dose determination
- Low mass
- Low power consumption



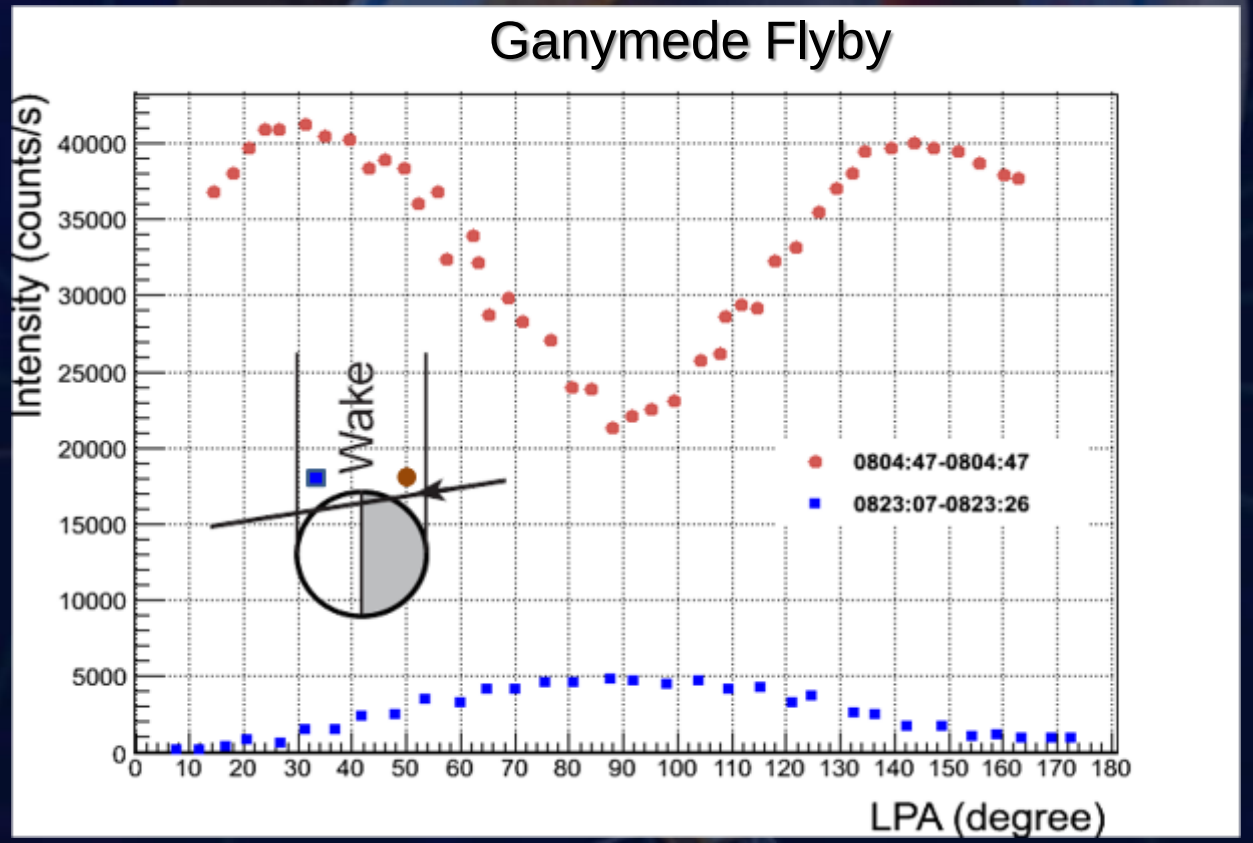
Electron Directionality Detector

JOVIAN RAD-HARD ELECTRON MONITOR PROTO-FLIGHT MODEL
ESA/ESTEC CONTRACT 1-7560/13/NL/HB EFACEC,LIP, RUAG,PSI,IDEAS





304–527 keV electrons

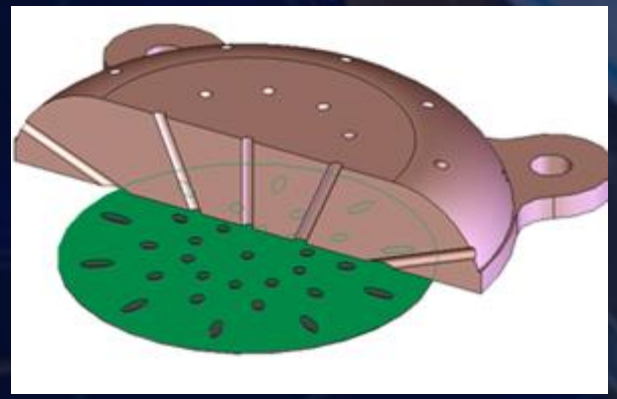


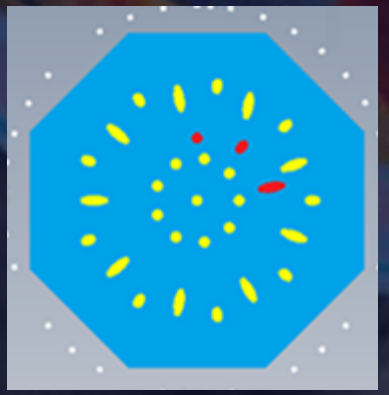
DATA: EPD measurements
Galileo G29 encounter with Ganymede in December 2000

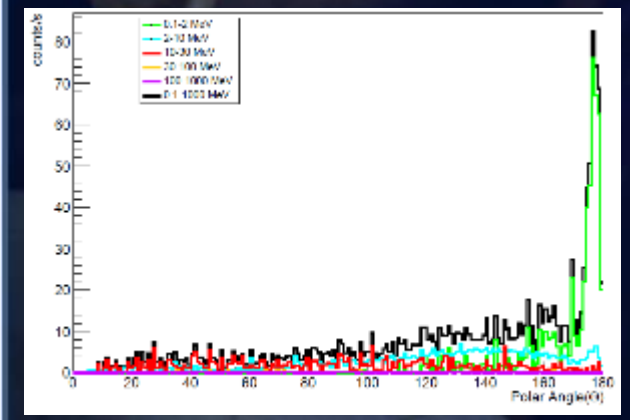
DD- THE RADEM DIRECTIONALITY DETECTOR

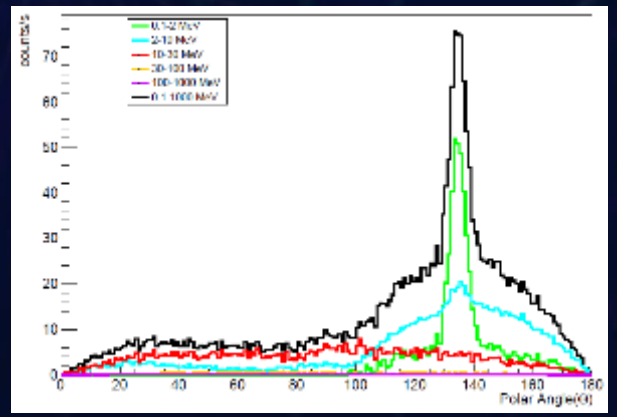
Design, testing and performance:

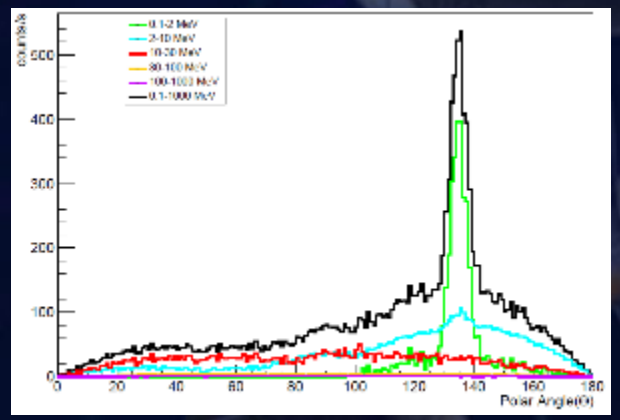
- Copper Collimator - 28 directions
- Single 505μm Kapton Absorber
- Single Detection Plane
- 28 Si Diodes
- 3 Blind Sensors

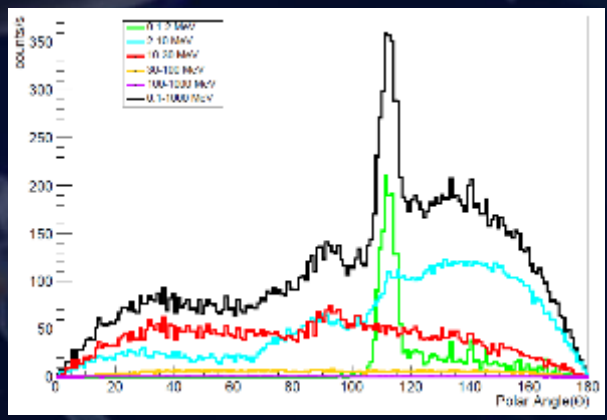










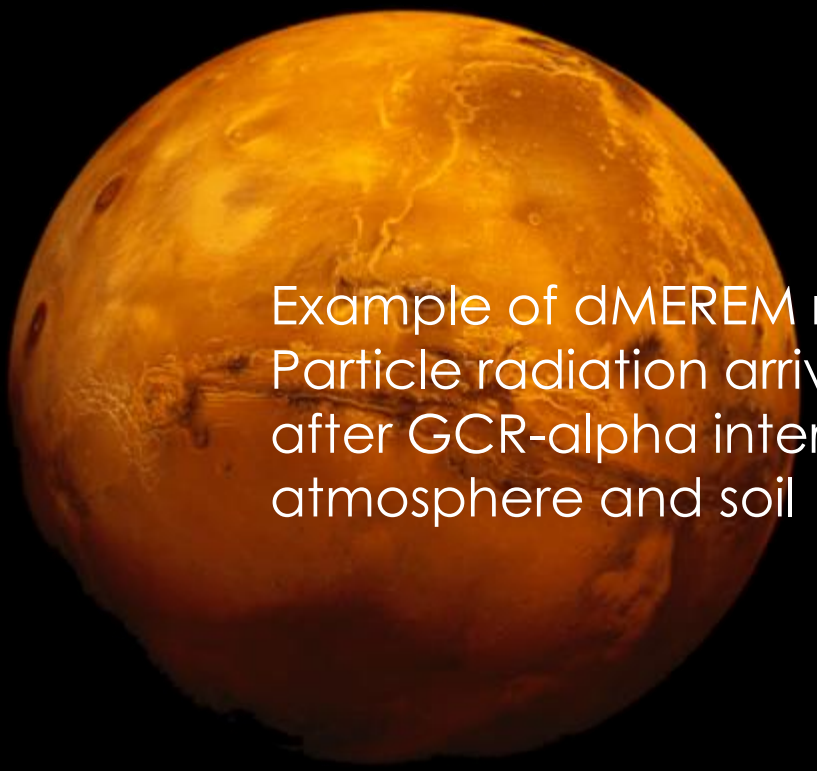


RADIATION ENVIRONMENT MODELING

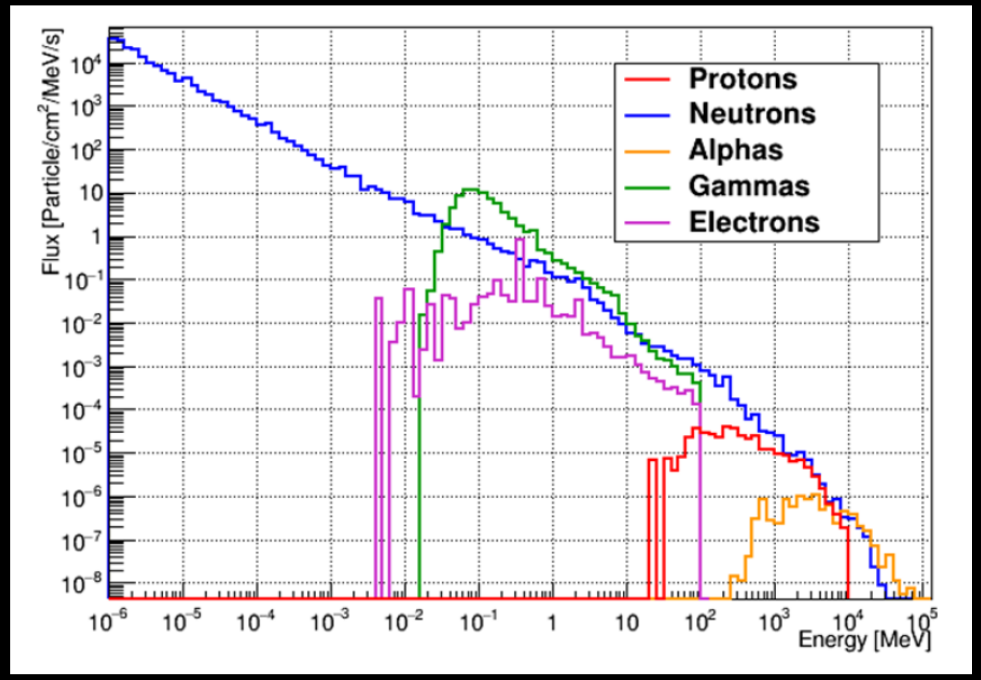
MARSREM: THE MARS ENERGETIC RADIATION ENVIRONMENT MODELS

LIP developed **dMEREM**, a **Geant4 based model for the radiation environment on Mars, Phobos and Deimos**, including local treatment of surface topography and composition,

Inputs given as a function of latitude, longitude, in a 5 x 5 degree grid, and season.



Example of dMEREM results:
Particle radiation arriving on Mars surface after GCR-alpha interaction with atmosphere and soil



...IT IS POSSIBLE !

LIP ESA contracts

ESA JUICE mission

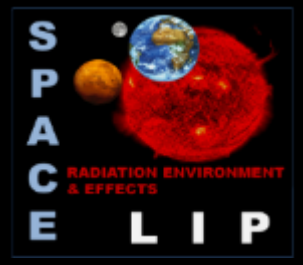
- RADEM – Radiation Hard Electron Monitor
- EEE component testing for Jovian environment

ESA Mars Energetic Radiation Environment Models

Expert support to BERM and RADEM radiation monitors
From Mercury to Jupiter

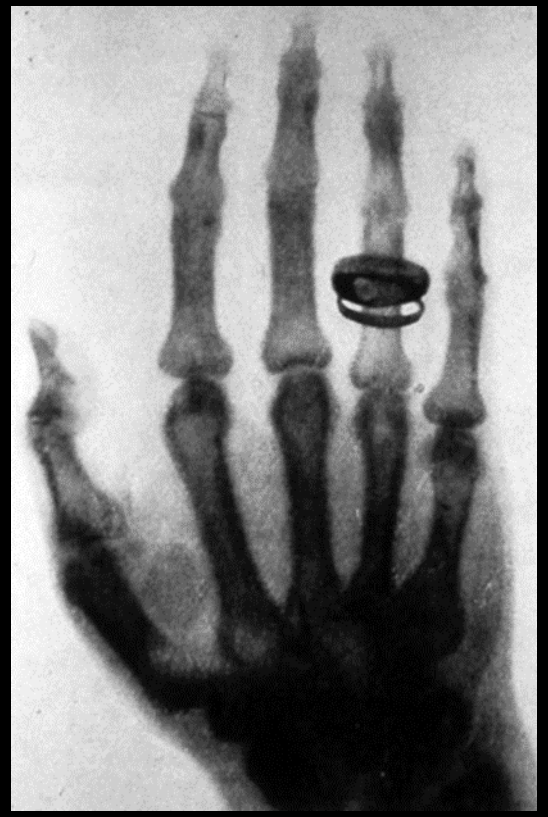
GEO Radiation Environment:

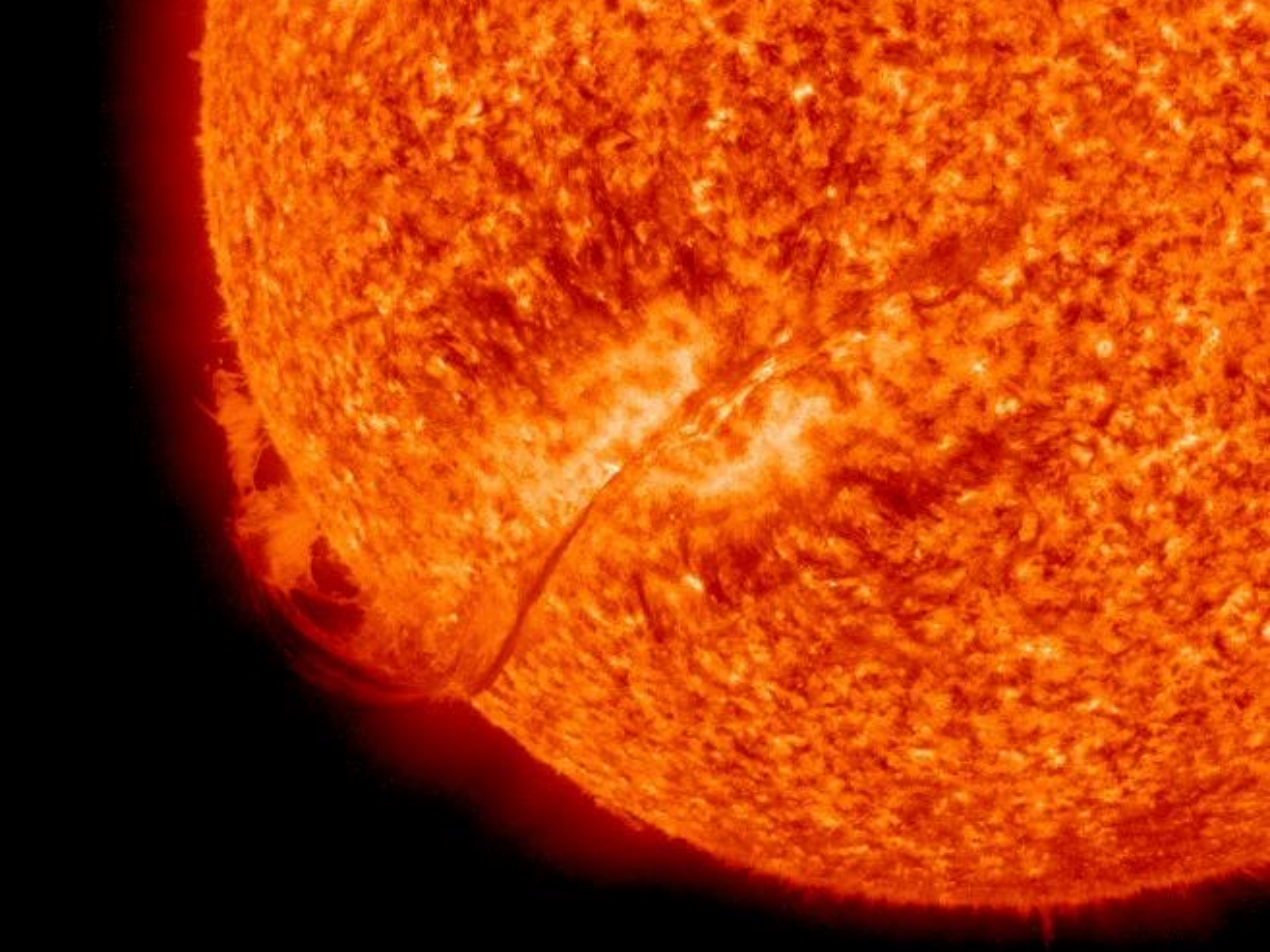
- Radiation Environment Measurement (MFS)
- EEE component test bed (CTTB)



What can Space & Biomedical applications have in common?

RADIATION





SDO/AIA 304 2010-12-06 14:35:33 UT

http://spaceweather.com/

The interplanetary travel

The most dangerous phase while travelling to Mars , from the point of view of the radiation hazard, is the interplanetary travel !

The biggest danger is the possibility of a SEP reaching the mission..

<u>Mitigation Strategies:</u>

- Shelters inside water compartments or other
- Faster propulsion system
- SEP Forecasting tools and alarms
- Radiopharmaceuticals …

What is cancer?

Cancer is a group of diseases in which there is an abnormal and uncontrolled proliferation of cells that originated from a "normal" cell that mutated, giving rise to cells that have the ability to continue to multiply, spreading to other tissues and organs beyond those to which the original cell belonged.

Radiotherapy

Radiotherapy with radioactive sources or internal radiotherapy

- Brachytherapy:

  Photons and electrons released from sources - “seeds” - placed close to the tissue to treat

Radiotherapy

Radiotherapy with external beams

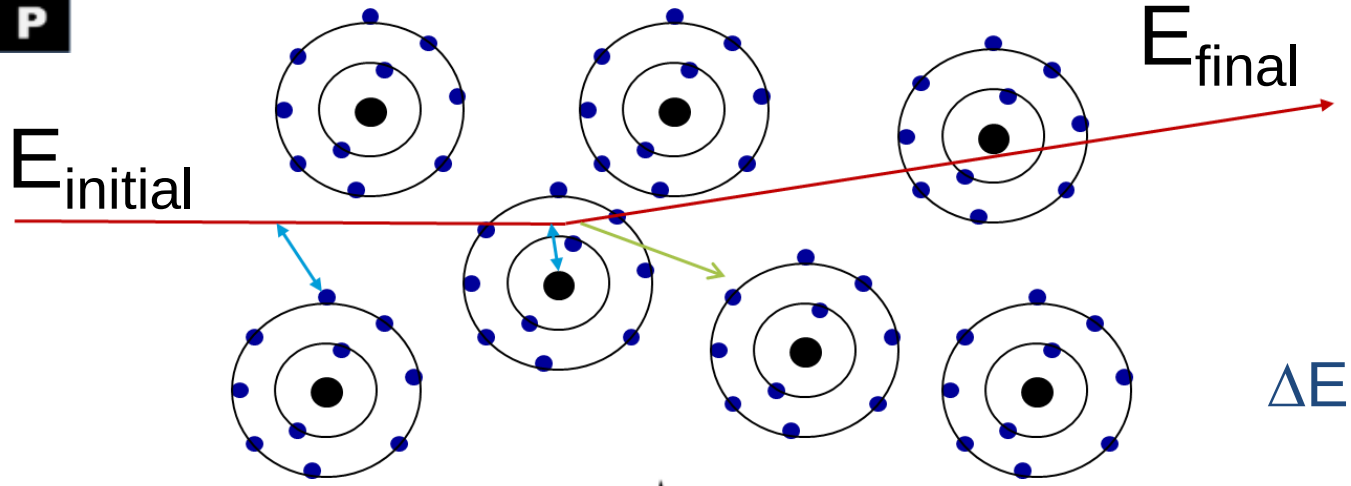
- LINACs

electrons and photons

- Cyclotrons and synchrotrons

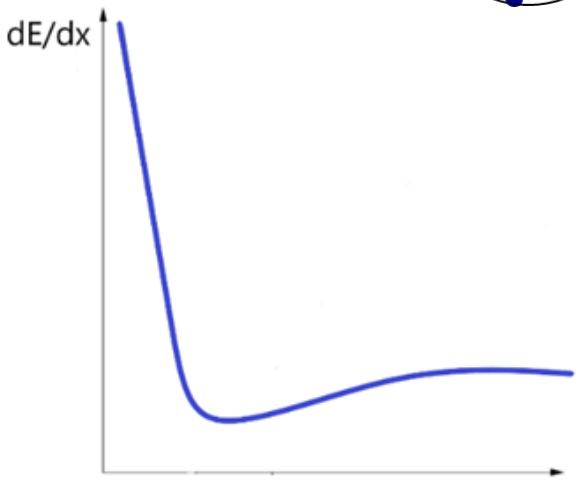
protons and carbon ions

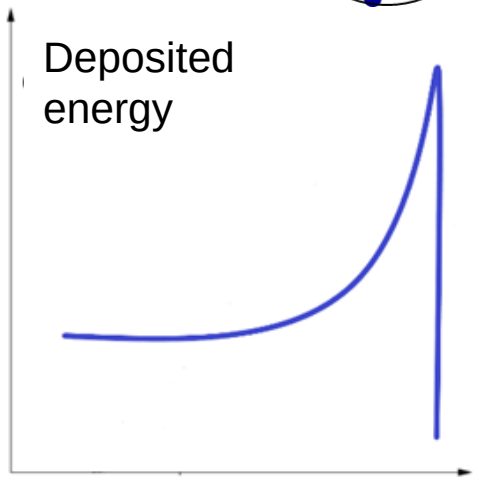
Charged particles



$$E_{final} = E_{initial} - \Delta E$$

ΔE - transferred energy





In charged particle therapy the kinetic energy lost by the particles is transferred on to the tissues!

Therapy with hadrons

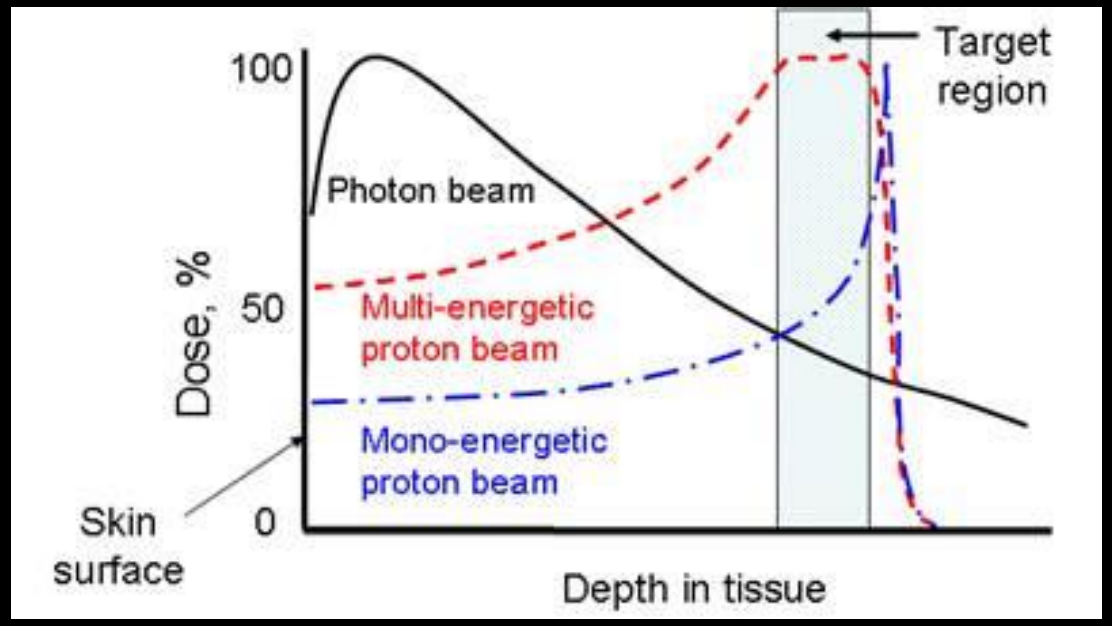
Proton/ion therapy

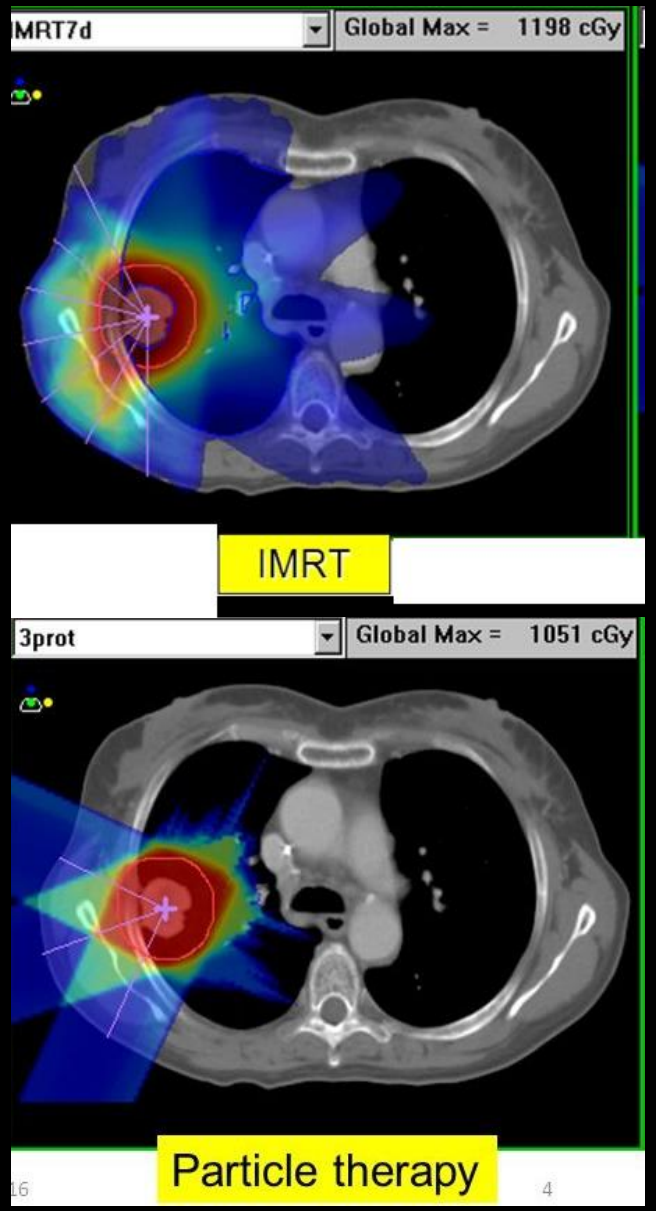
- energetic protons/ions are produced in an accelerator
- energetic protons/ions are directed at the tumor
- Varying the energy of the protons/ions results in good deep control
- Beam can be focused to the size of a pin
- less damage to healthy tissue than electron or gamma therapy

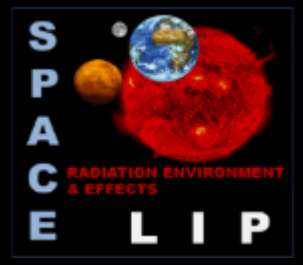
Therapy with hadrons

therapeutic application of accelerators:

particle-based radiotherapy,
including protons and heavy ions







and there is more…

Questions today
Theses tomorrow