D14 Space Weather Group

- Space Radiation and Effects -

→ Product/service development & operation
→ Radiation analysis (engineering)
→ Applied research
→ Training/Outreach

protons, neutrons, electrons, heavy ions, … with E>100 keV

ESA S2P SWE Service Network

→ R-ESC

s/c design & operation
launch operation
human space flight
aviation

→ SSCC

1st line support
user support campaigns

SPENVIS → Space environment and Effects

LUNAR GATEWAY → radiation analysis around/at the Moon (GCR+SEP)

VSWMC → coupling of models from sun to Earth (SEP + TRAP)

HMT → solar energetic particle propagation (SEP)

DENSER → machine learning for predicting solar energetic particle (SEP)

RB-FAN → trapped radiation nowcast & forecast (TRAP)

GLORAB → modelling trapped radiation at low altitude (TRAP)

PECASUS → SWX service for aviation (GCR + SEP)

ALARM → (space) weather hazards for aviation (GCR+SEP)

ESERO → education (GCR+SEP+TRAP)

Preparing a space mission: will spacecraft+payload survive in the space environment (*radiation*, plasma, microparticles, …)?

Radiation & Effects Analysis

- When, where, how long?

→Computer models

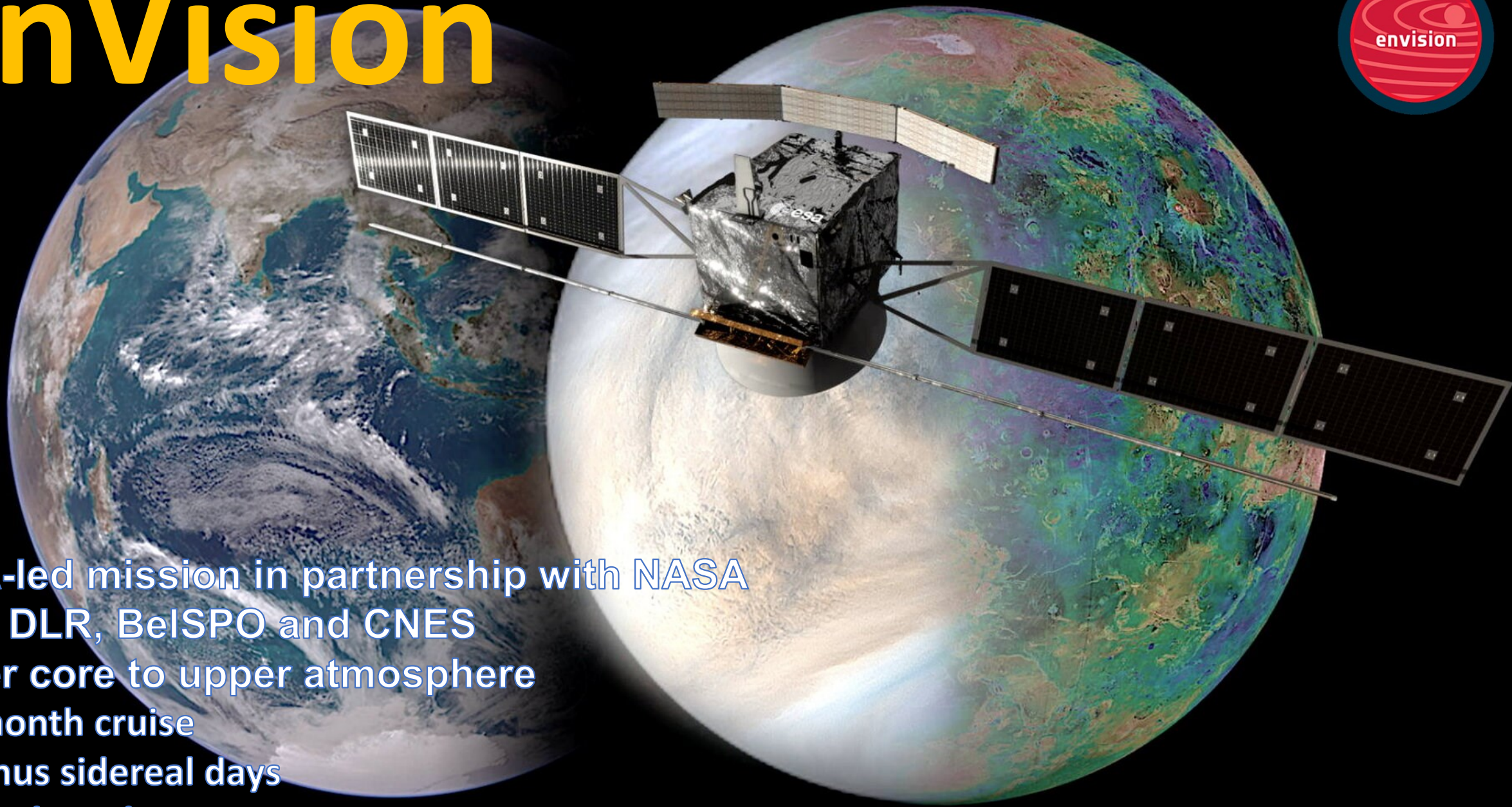
→SPENVIS: quick estimate

(www.spenvis.oma.be)

Radiation testing

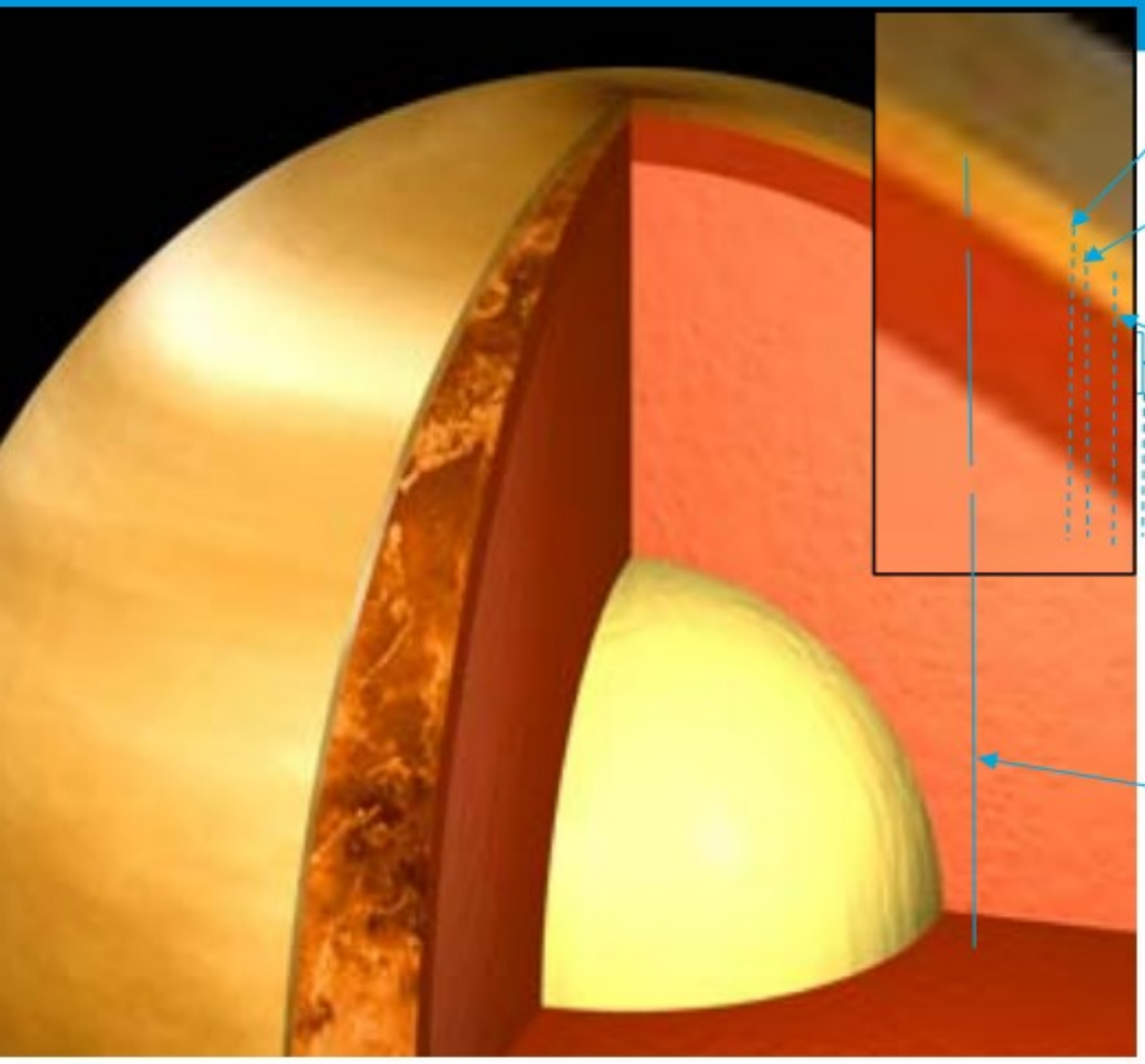
- System level + parts level
- Which tests?
  - Radiation dose
  - Single event effects
- Where?
  - CYCLONE (UCL, Belgium)
  - CHARM (CERN, Switzerland)
  - …

EnVision



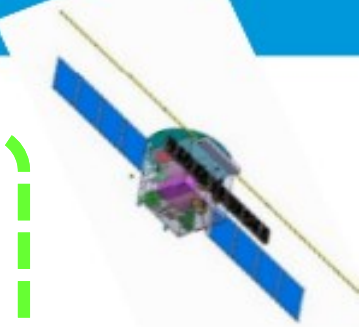
- ESA-led mission in partnership with NASA
- ASI, DLR, BeISPO and CNES
- inner core to upper atmosphere
- 15-month cruise
- 6 Venus sidereal days
- Target launch 2032

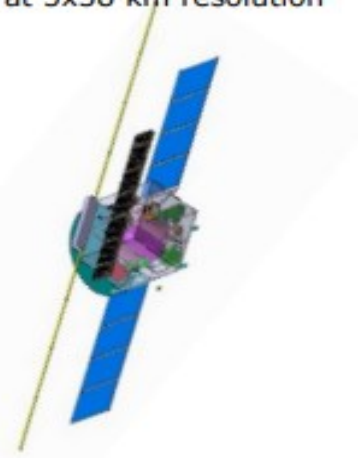
Detecting active geologic processes on Venus
-past and today-



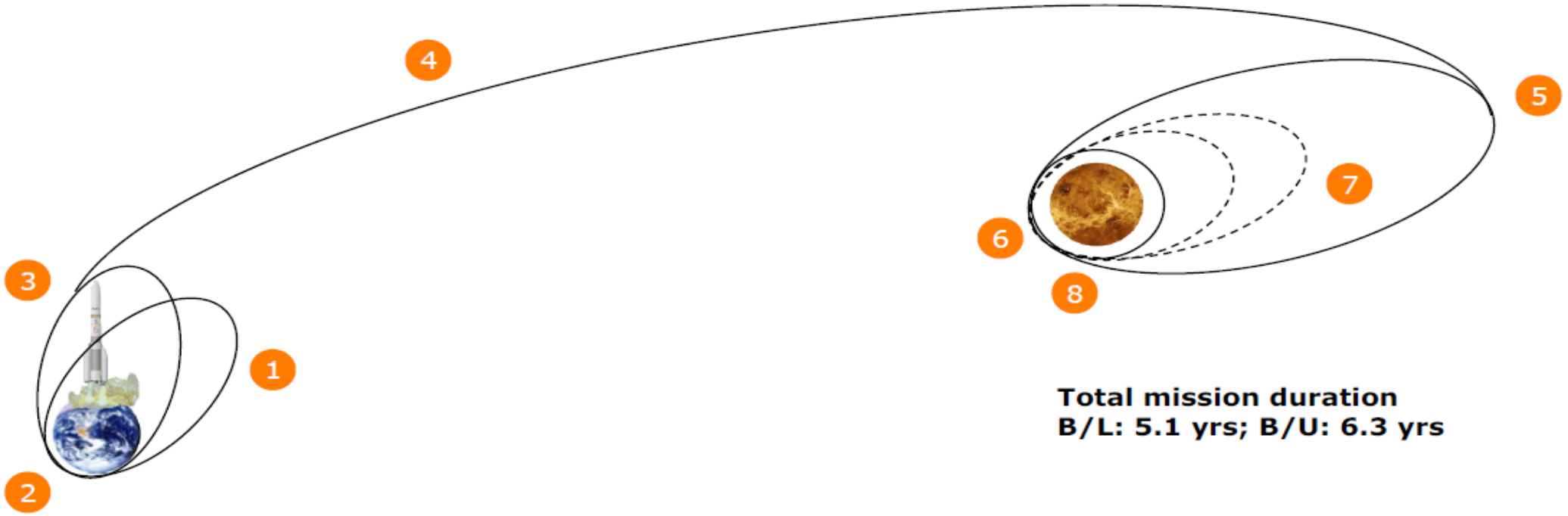
Measurement		
Higher atmosphere	**VenSpec-U**	Mapping SO, SO_2 and UV absorber at cloud top. @210-240nm (0.2nm), @190-380 (2nm), ~100 km spatial resolution
Lower atmosphere	**VenSpec-H**	Mapping of near surface atmosphere H2O, HDO at 0-15 km @1.08-1.2 µm, H2O, HDO, OCS, SO2 at 30-40 km @ 2.44-2.47 µm, ~100 km spatial resolution
Surface	**VenSpec-M**	mapping mineralogy by surface emission at 6 channels 0.82-1.2 µm at <50 km resolution
Crust profile	**SRS**	Subsurface radar down to 1000 m depth and ~10m resolution @ 9 MHz
atmosphere, crust, planet mantle and core	**RadioScience**	2-way mapping, radio occultations, gravity field, love number k2

VenSAR
Surface morphology, 1-30 m, cm changes by inter-ferometric measurements, @ 3.2 GHz, radiometry with relative precision of 1K at 5x38 km resolution





Mission Timeline - Chemical Propulsion



Total mission duration
B/L: 5.1 yrs; B/U: 6.3 yrs

1. Launch into HEO with Ariane 62
   B/L: 24/11/2032; B/U: 12/05/2033
2. Escape Sequence Manoeuvre 1
3. Escape Sequence Manoeuvre 2
   B/L: 24/12/2032
4. Interplanetary transfer
   B/L: 134 days;
5. VOI
   B/L: 7/5/2033
6. Apocytherion lowering
7. Aerobraking
   B/L: ~25 months
   Note: 4 months margin applied
8. Science Operations
   2.66 yrs / 4 Venus cycles

SPACE RADIATION ENVIRONMENTS

- Inside Earth's magnetosphere:

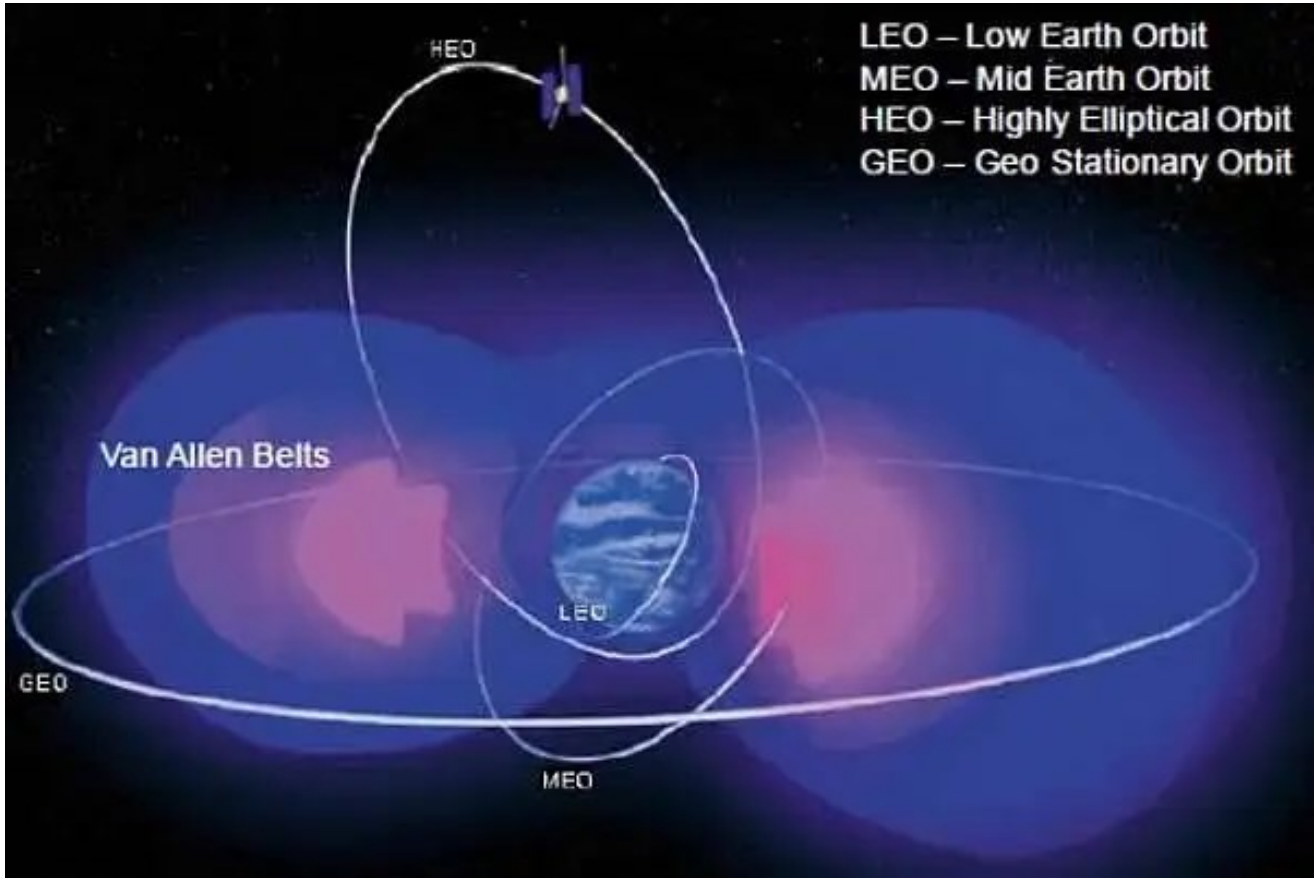
→Mainly trapped radiation belts

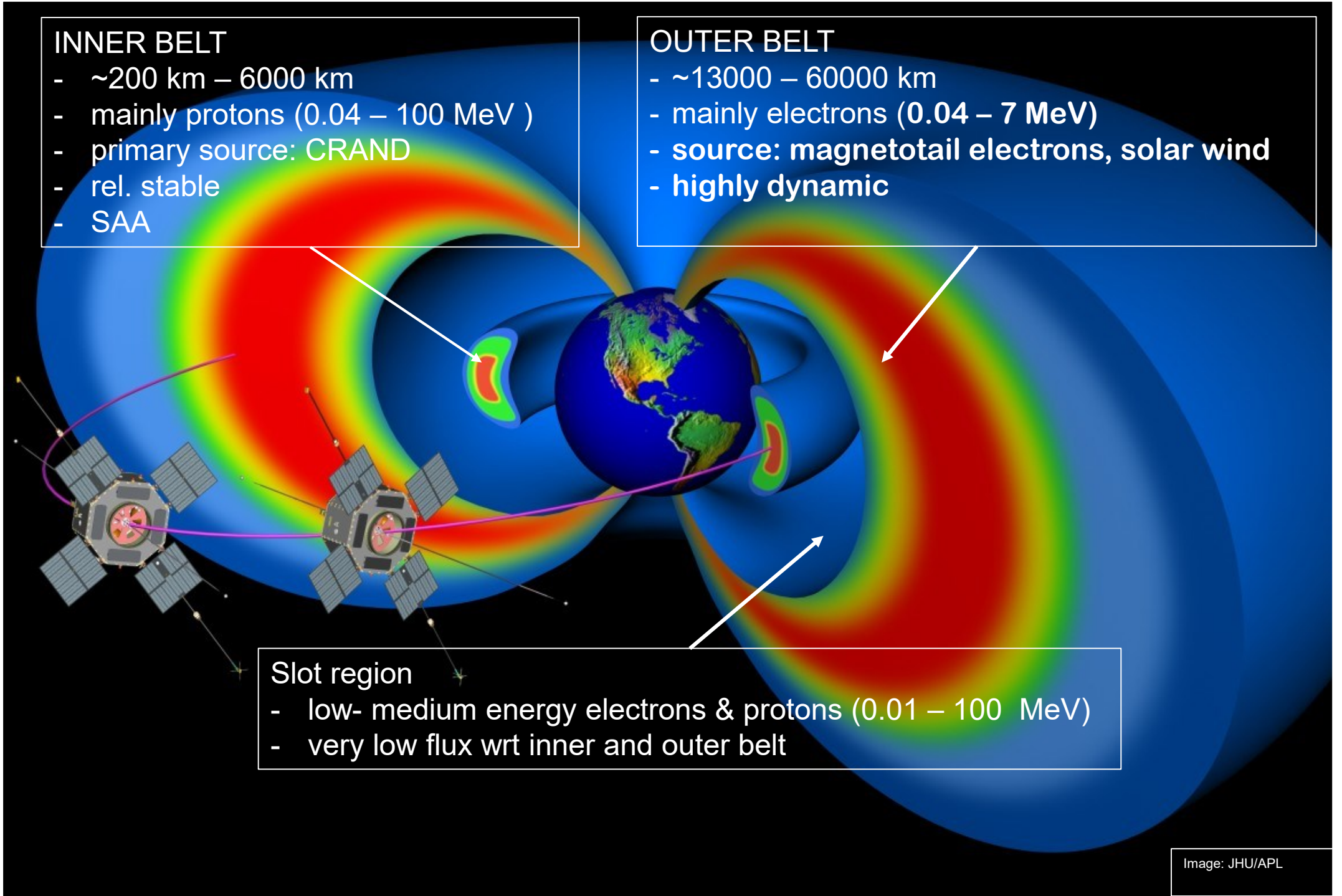
→Short-term

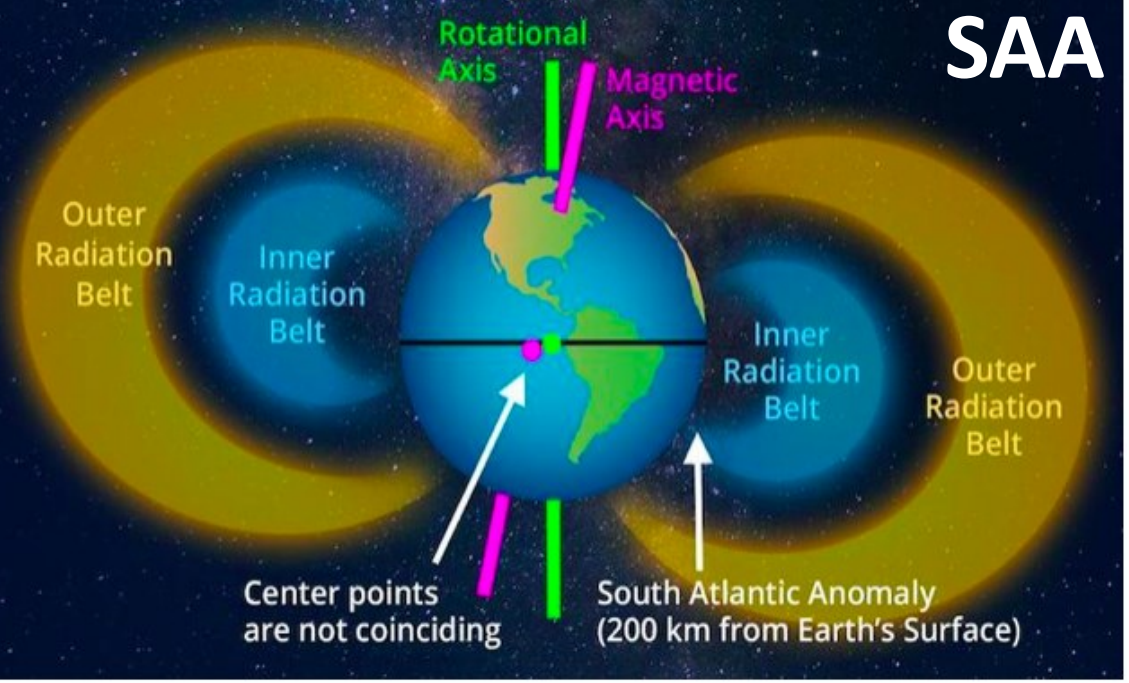
- Outside Earth's magnetosphere:

→GCR + SEP

→Long-term

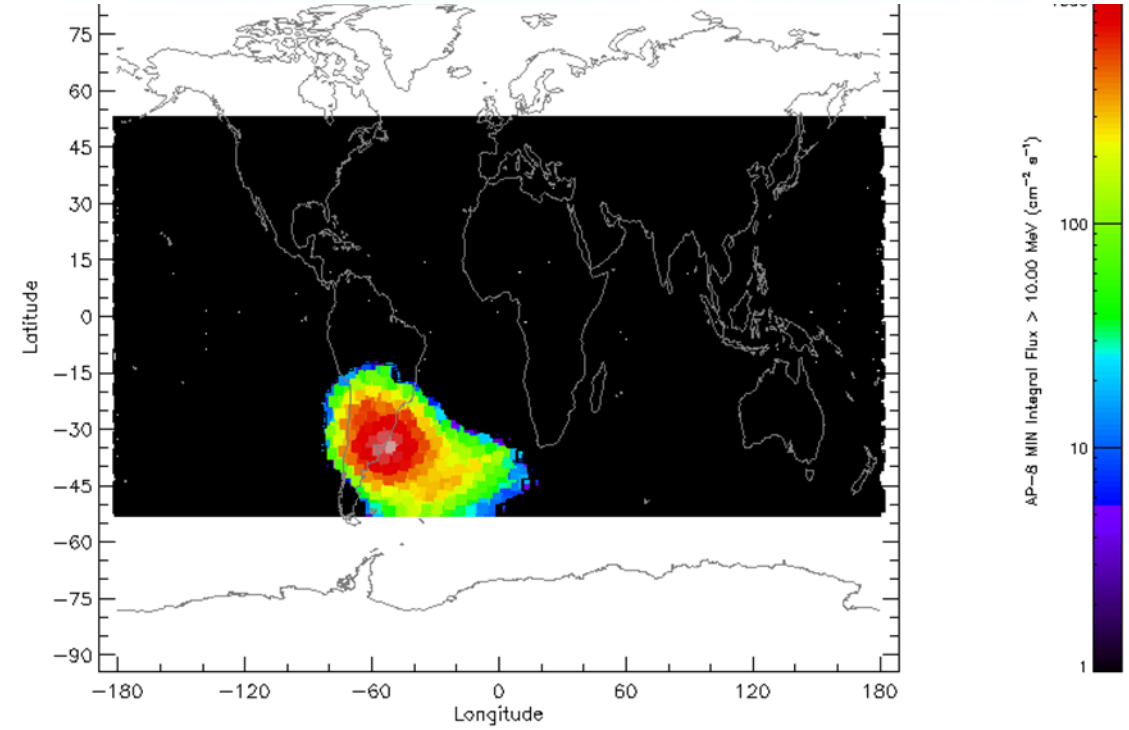


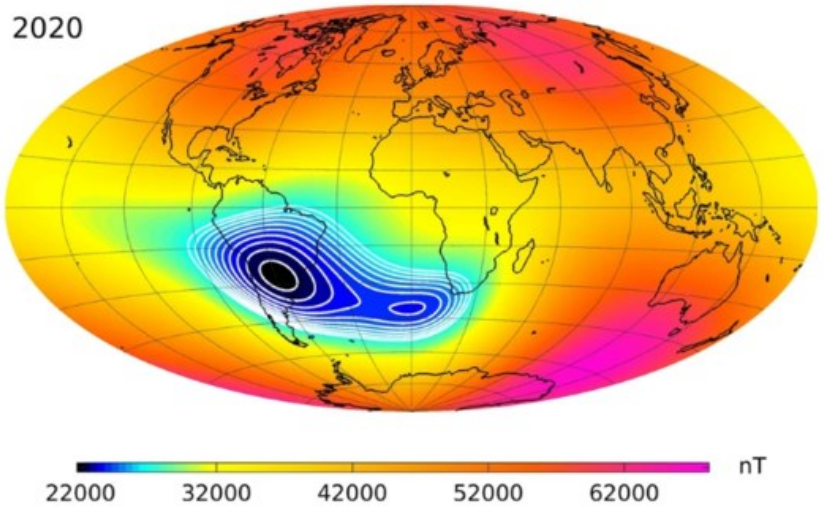

INNER BELT
- ~200 km – 6000 km
- mainly protons (0.04 – 100 MeV)
- primary source: CRAND
- rel. stable
- SAA
OUTER BELT
- ~13000 – 60000 km
- mainly electrons (**0.04 – 7 MeV**)
- **source: magnetotail electrons, solar wind**
- **highly dynamic**
Slot region
- low- medium energy electrons & protons (0.01 – 100 MeV)
- very low flux wrt inner and outer belt
Image: JHU/APL



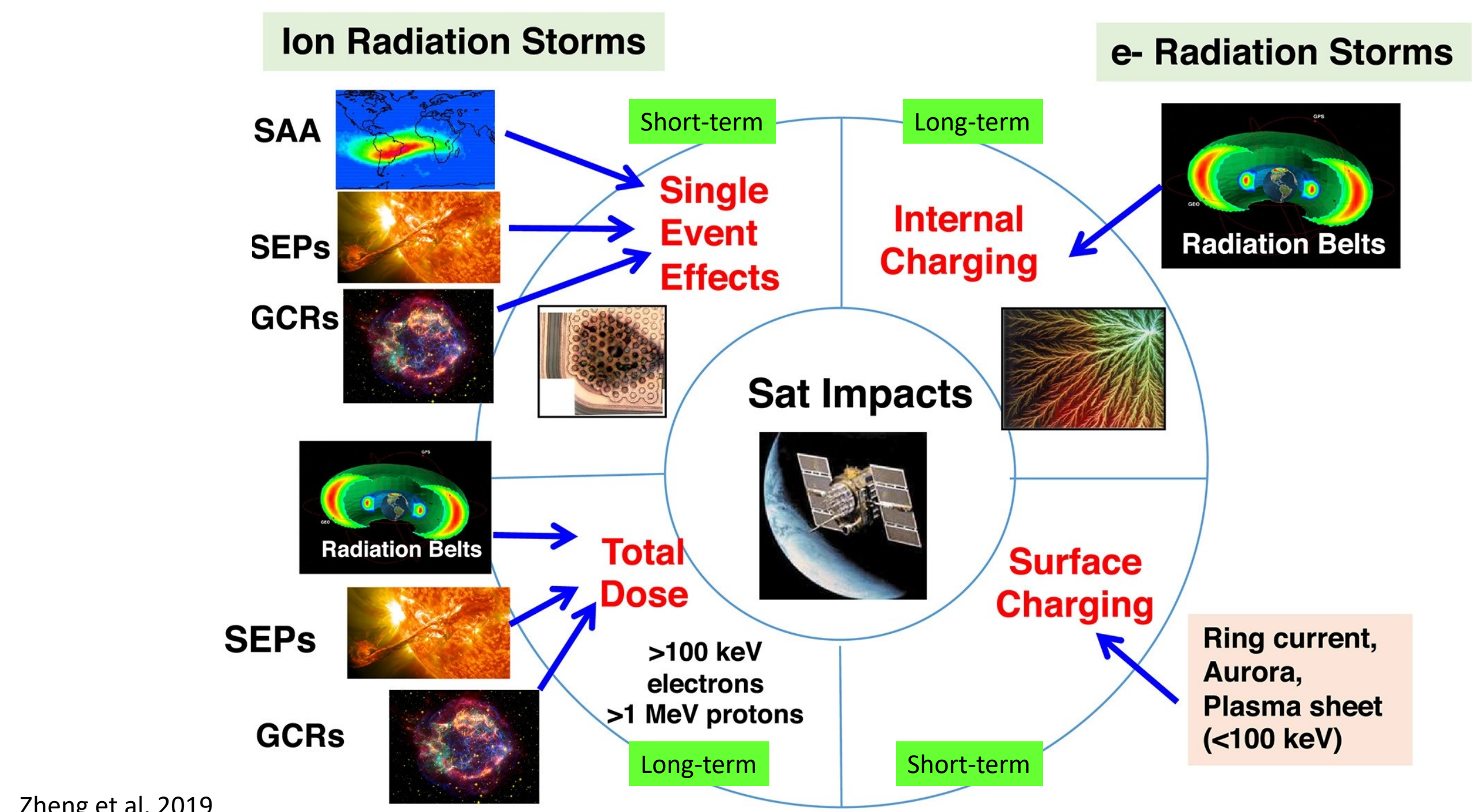
West drift: 0.3°/yr

→ extra shielding on ISS
→ false alarms on Skylab Apollo Telescope Mount's solar flare sensor
→ HST no observations
→ astronauts "shooting stars" (phosphenes)
→ failures of the Globalstar network's satellites in 2007
→ PAMELA experiment: antiproton levels
→ Crashing laptops on Space Shuttle flights
→ transient problems on SpaceX CRS-1 Dragon spacecraft
→ destruction of the Hitomi, Japan's most powerful X-ray observatory
→ …

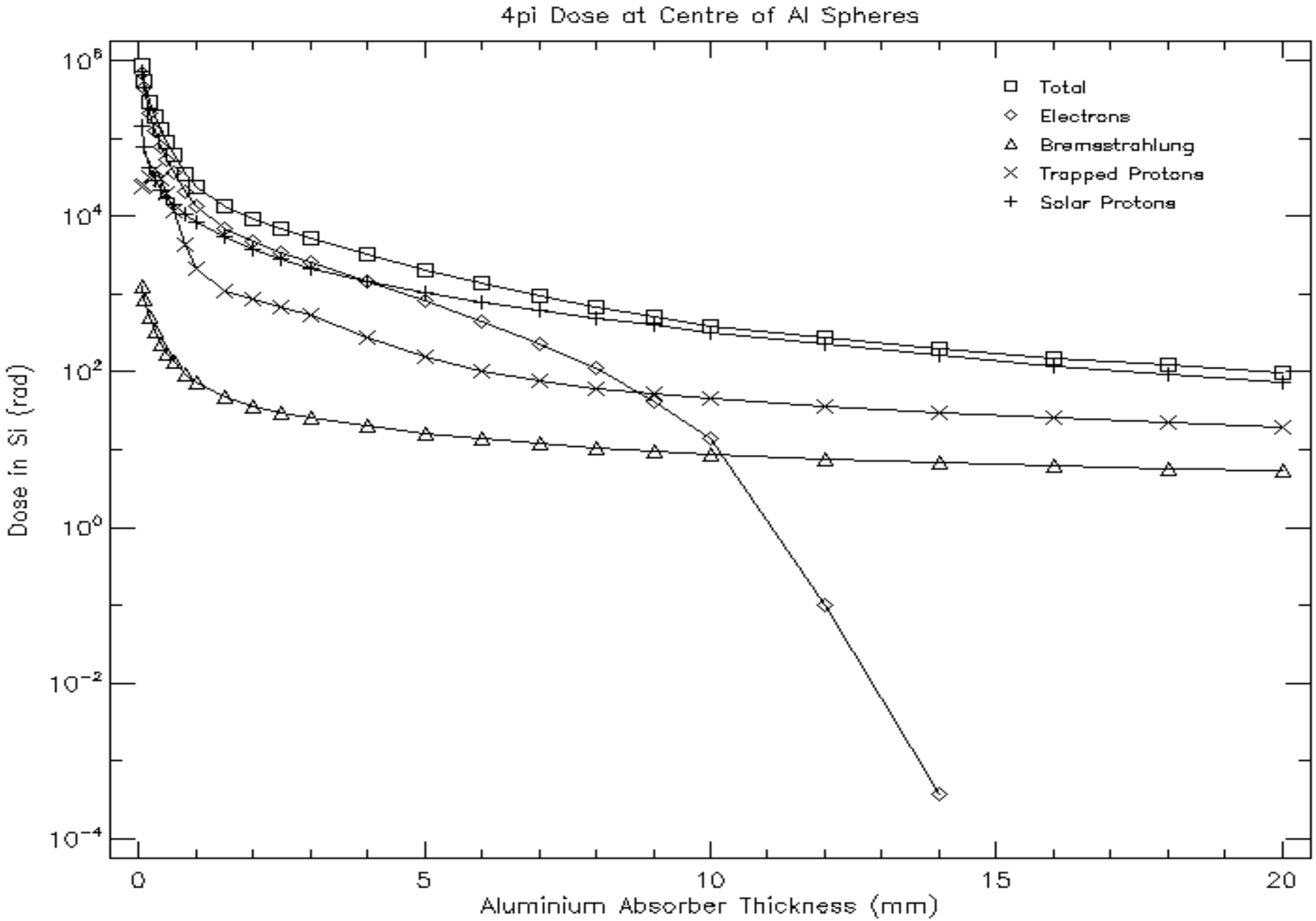


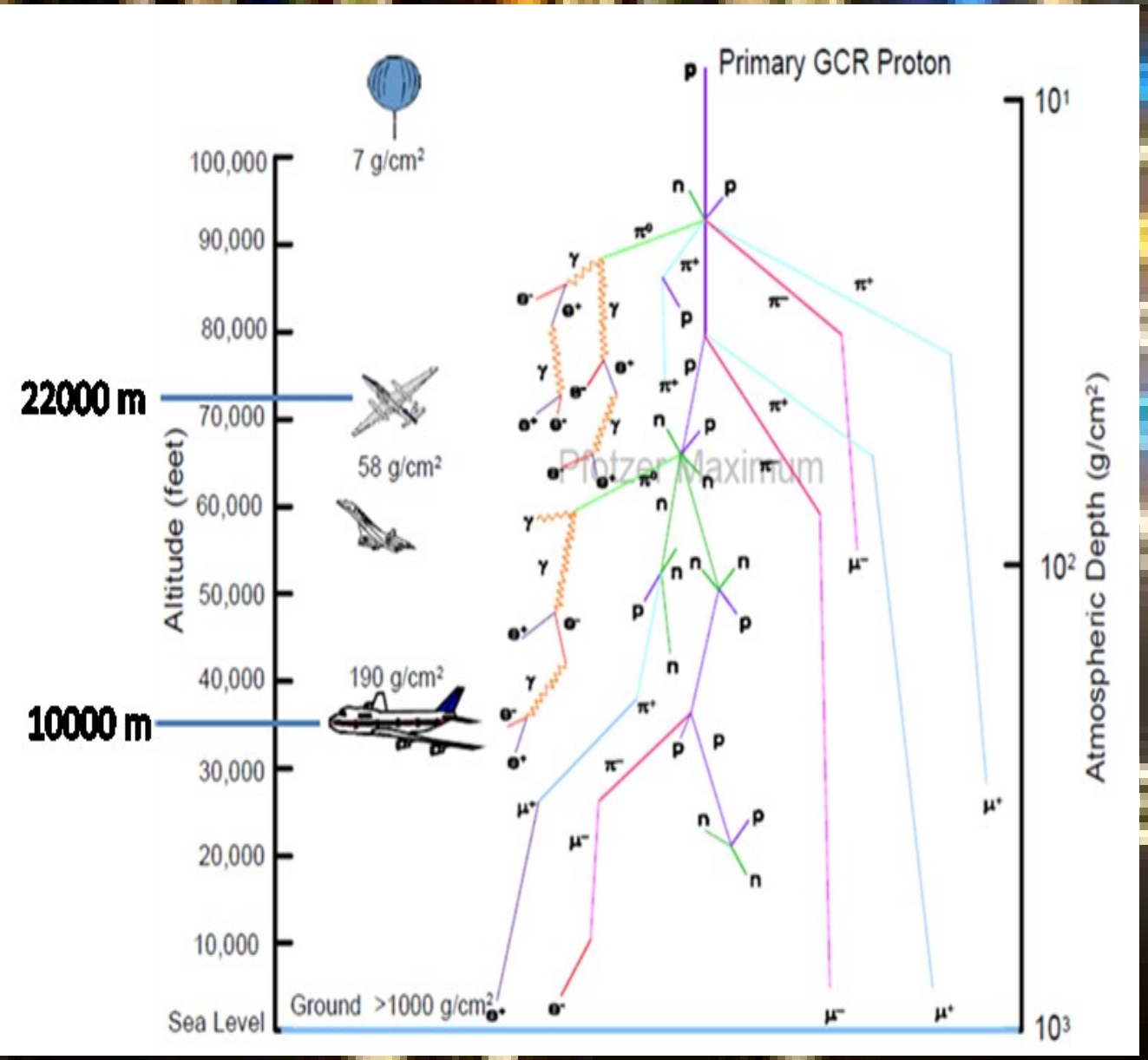



TRAP+SEP+GCR at HEO (9000-150000 km, 56°)
AP8-mi (IN+OUT)
AE8-max (IN+OUT)
SAPPHIRE (SEP)
ISO-SolMin (GCR)
SRREM-p+ (SLOT)
SRREM-e (SLOT)
10 MeV p+ → 0.8 mm Al
Flux (#/cm2/s/MeV)
1,0E+09
1,0E+08
1,0E+07
1,0E+06
1,0E+05
1,0E+04
1,0E+03
1,0E+02
1,0E+01
1,0E+00
1,0E-01
1,0E-02
1,0E-03
1,0E-04
1,0E-05
1,0E-06
1,0E-07
1,0E-08
0,01
0,1
1
10
100
1000
10000
100000
E(MeV)



Zheng et al. 2019


4pi Dose at Centre of Al Spheres
Total
Electrons
Bremsstrahlung
Trapped Protons
Solar Protons
Dose in Si (rad)
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
0
5
10
15
20
Aluminium Absorber Thickness (mm)



Devices are becoming smaller and more sensitive

01110111	01101001	01101110	01100100	01101111	01110111	01110011
w	i	n	d	o	w	s

Bit flipped changing windows.com to whndows.com

01110111	01101000	01101110	01100100	01101111	01110111	01110011
w	h	n	d	o	w	s

BLEEPINGCOMPUTER