An Integrated Framework for the Radiation Environment in Space, on Mars and on the Moon and its Implications for Human Space Flight

Bruna Lima October 2024 IDPASC

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
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The Radiation Challenge in Space Exploration

- Space radiation is a significant threat to astronauts and electronic equipment.
- Mars has minimal magnetic protection compared to Earth and no protection at all in the case of the Moon.
- Cosmic rays and solar events pose health risks.

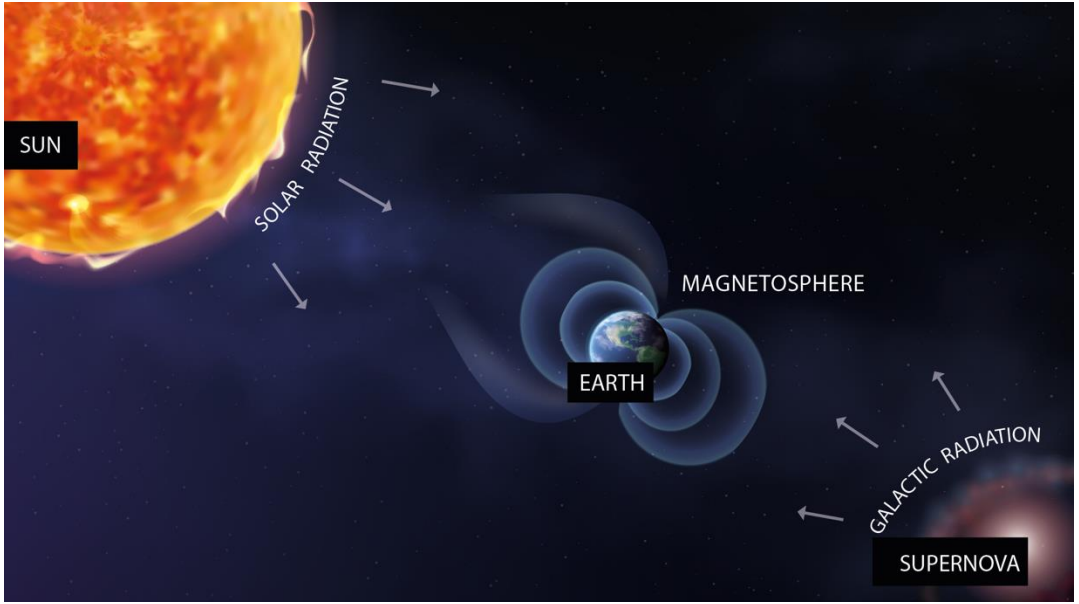


Figure 1: Cosmic radiation can be galactic and solar. The Earth's magnetosphere deflects cosmic rays and protects us from solar flares. (Image: L. Han/IAEA)

Why Is This Important Now?

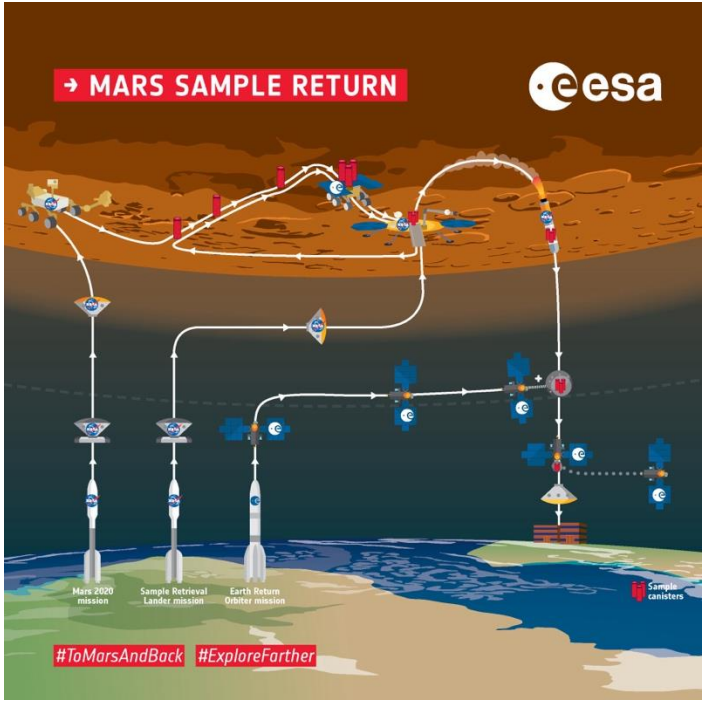


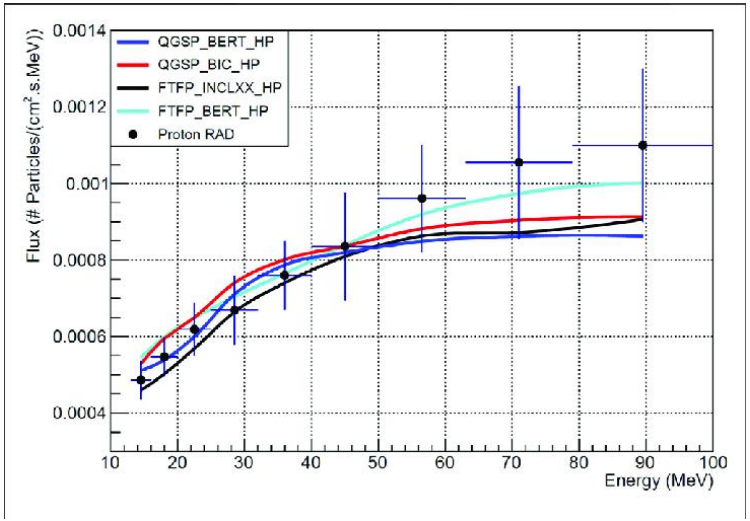
Figure 2: Mars Sample Return overview infographic Credit ESA–K. Oldenburg

- Future human missions to Mars and the Moon are planned.
- Safe exploration requires accurate radiation risk assessment.
- Ensuring astronaut safety is critical for long-term space exploration.

Project Overview – The Solution

Validation and Impact

Building on dMEREM



- Validate models using mission data from JUICE, BepiColombo, and others.
- Assess radiation risks for spacecraft, EVAs, and different astronaut profiles.
- Provide mission planners with reliable data for safer crewed missions.

Figure 3: Proton spectra reaching the Mars surface within the RAD field-of-view due to GCR-protons, helium, carbon and oxygen nuclei described with the GCR ISO-15 390 model, simulated with dMEREM using four different physics lists compared to RAD proton differential flux measurements of September 2017. (Credits:**Validation of dMEREM, the Detailed Mars Energetic Radiation Environment Model, with RAD Data from the Surface of Mars)**

Conclusion

Building a Safer Future for Space Exploration

- Unifying fragmented radiation data for better understanding and accessibility.
- Ensuring astronaut safety for long-duration missions.
- Supporting the next wave of human exploration on the Moon and Mars.

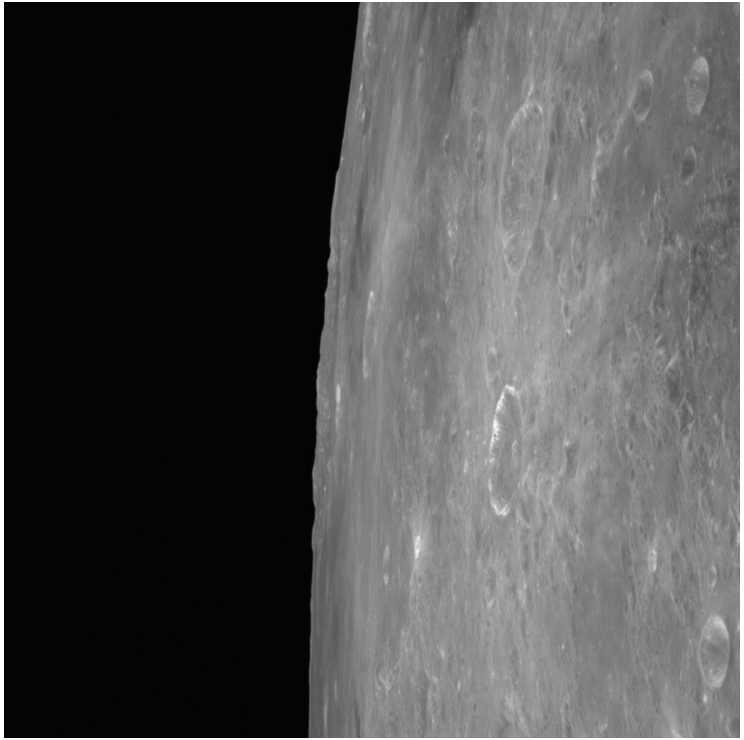


Figure 4: Juice NavCam view of the Moon
Credits: ESA/Juice/NavCam
Acknowledgements: Airbus

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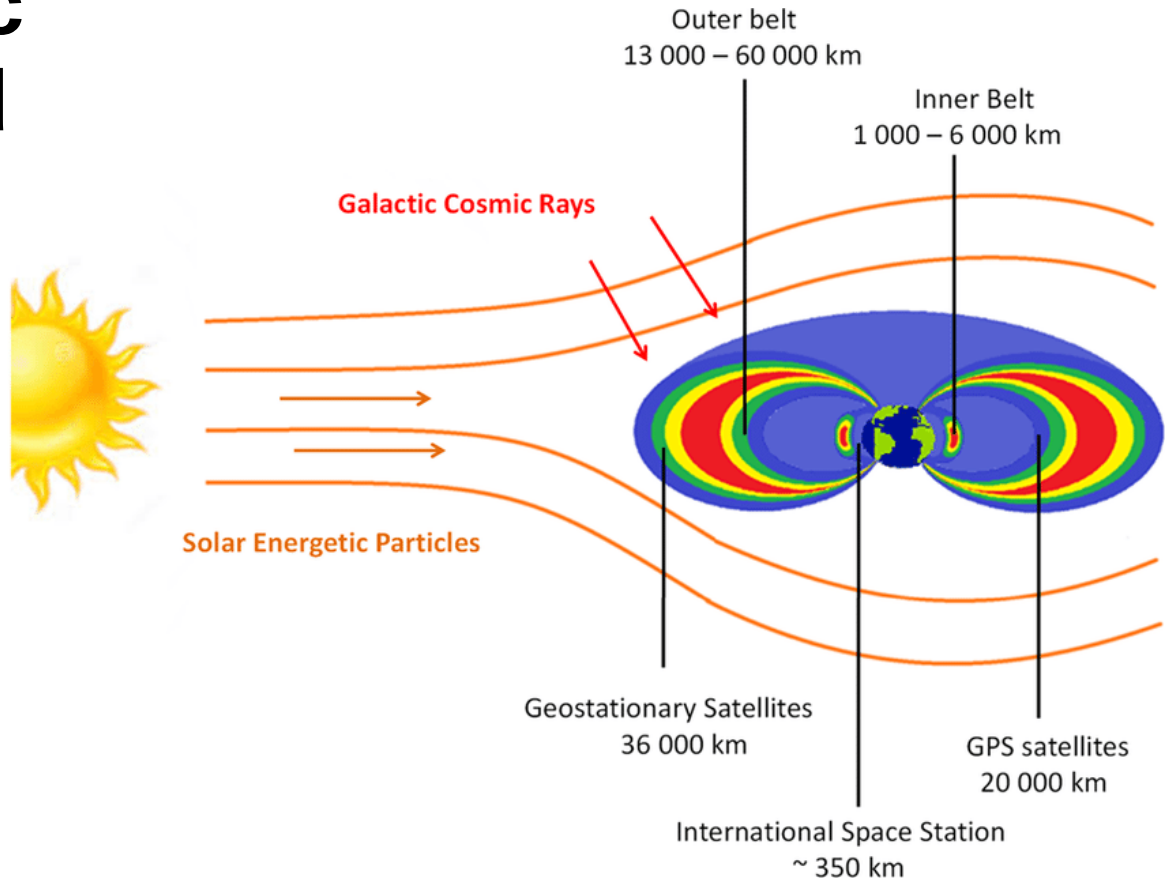
Photo Credit: ESA/Hubble & NASA

Extra Slides

Galactic Cosmic Rays (GCR) and Solar Energetic Particles (SEP)



Credits: Space as a Tool for Astrobiology: Review and Recommendations for Experimentations in Earth Orbit and Beyond - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Earths-particle-environment-dominated-by-galactic-cosmic-rays-and-solar-particles-and_fig3_318029811

Galactic Cosmic Rays (GCR) and Solar Energetic Particles (SEP)

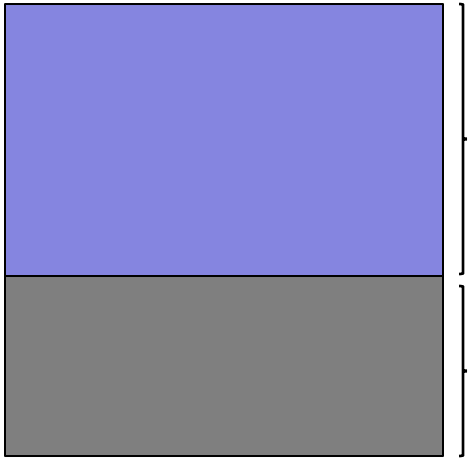
Galactic Cosmic Rays (GCR):

- High-energy particles from outside the solar system
- Originate from supernovae and distant stars
- Composed of protons, heavy ions, and electrons
- Can penetrate deep into planetary atmospheres and affect radiation environments

Solar Energetic Particles (SEP):

- Emitted during solar flares and coronal mass ejections
- Consist mainly of protons, with some heavier ions and electrons
- More intense but localized compared to GCR
- Pose radiation risks to spacecraft, astronauts, and satellites in space

dMEREM



20 atmosphere layers

Regolith (adaptable)

300 km (default)

* If the Magnetic Field is on, the values and configuration are different

- ❑ Geometry Definition and Materials;
- ❑ Primary Particle Generation;
- ❑ Event Generation & Simulation;
- ❑ Physics Processes & Interactions;
- ❑ Sensitive Detectors & Scoring Mechanisms;
- ❑ Tracking & Data Collection;
- ❑ Output & Visualization.