HUN REN Centre for Energy Research

SPACE Research Department

HUN-REN Hungarian Research Network

HUN-REN Centre for Energy Research

Analysis of the Radiation Environment in Lunar Orbit for the RadTel and TriTel Telescopes

P. Pinczés, A. Hirn

HUN-REN Centre for Energy Research, Space Research Department, Budapest, Hungary

WRMISS, Prague, 2026. 09. 02.

Research. Innovation. Impact.

1. Lunar radiation environment

   - Current understanding

   - LRO, Chandrayan-1, Chang'E dosimetric measurements

2. Radiation environment modeling

3. RadTel & TriTel → **SDS**

   - Instrument details

   - MoonRad mission

1. Lunar radiation environment

- Our basic understanding of Lunar radiation environment:

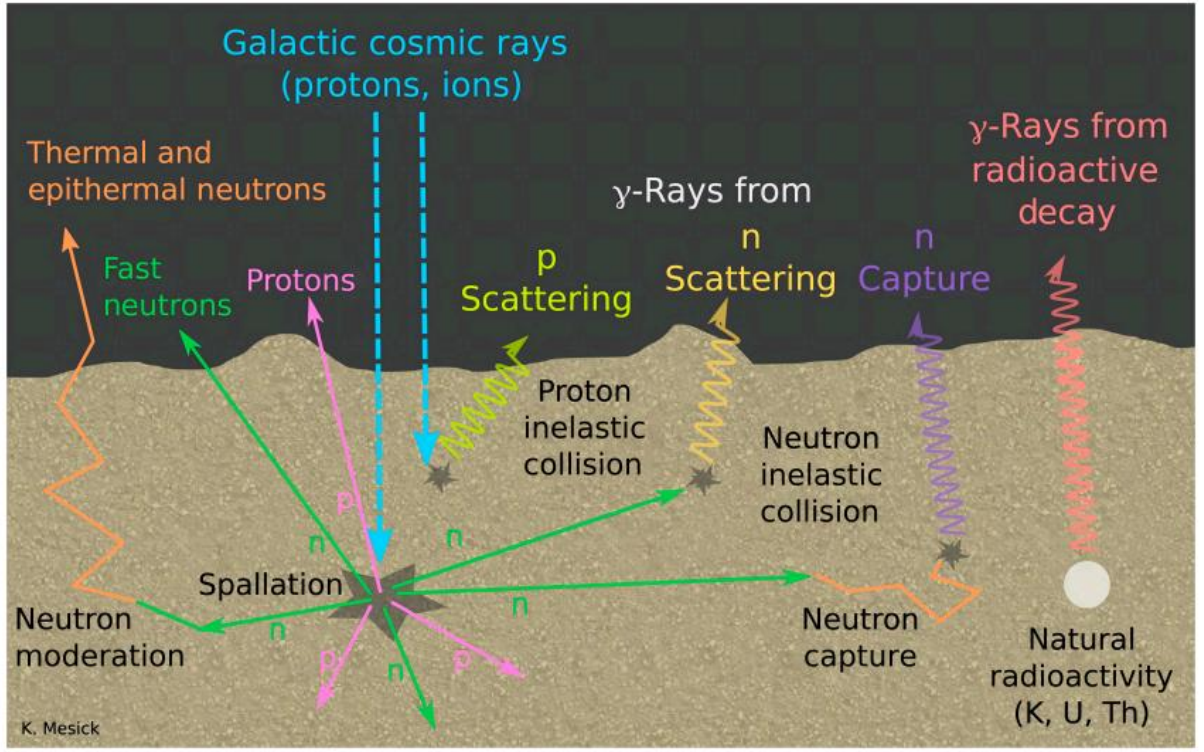
  - no atmosphere

  - no global magnetic field

  → GCR & SPE reach surface unblocked

  → trapped not present

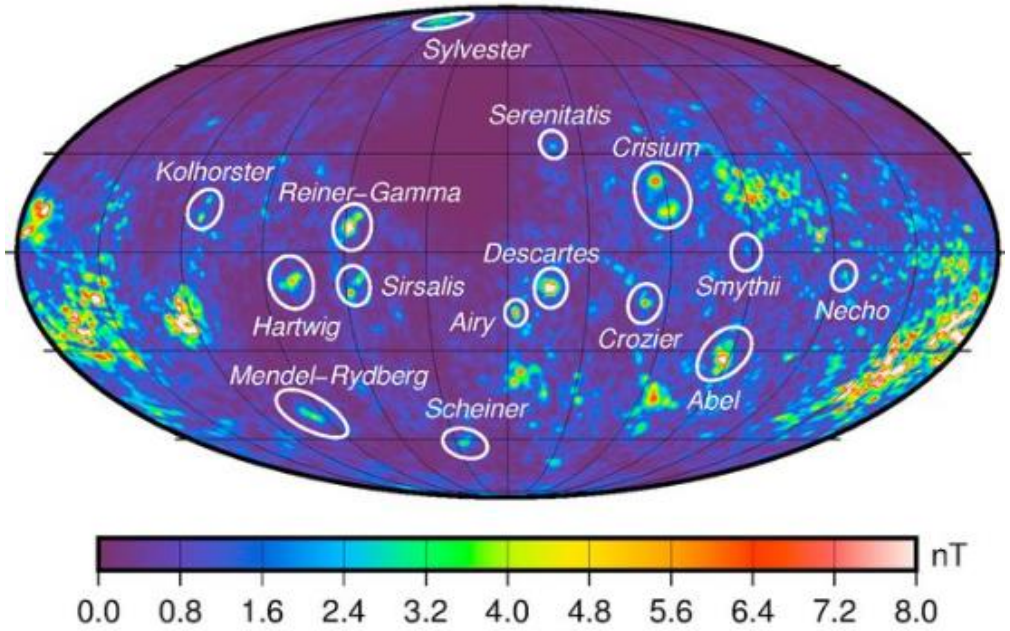
  → albedo neutrons
  (+charged & gamma)



Mesick et al., 2018,

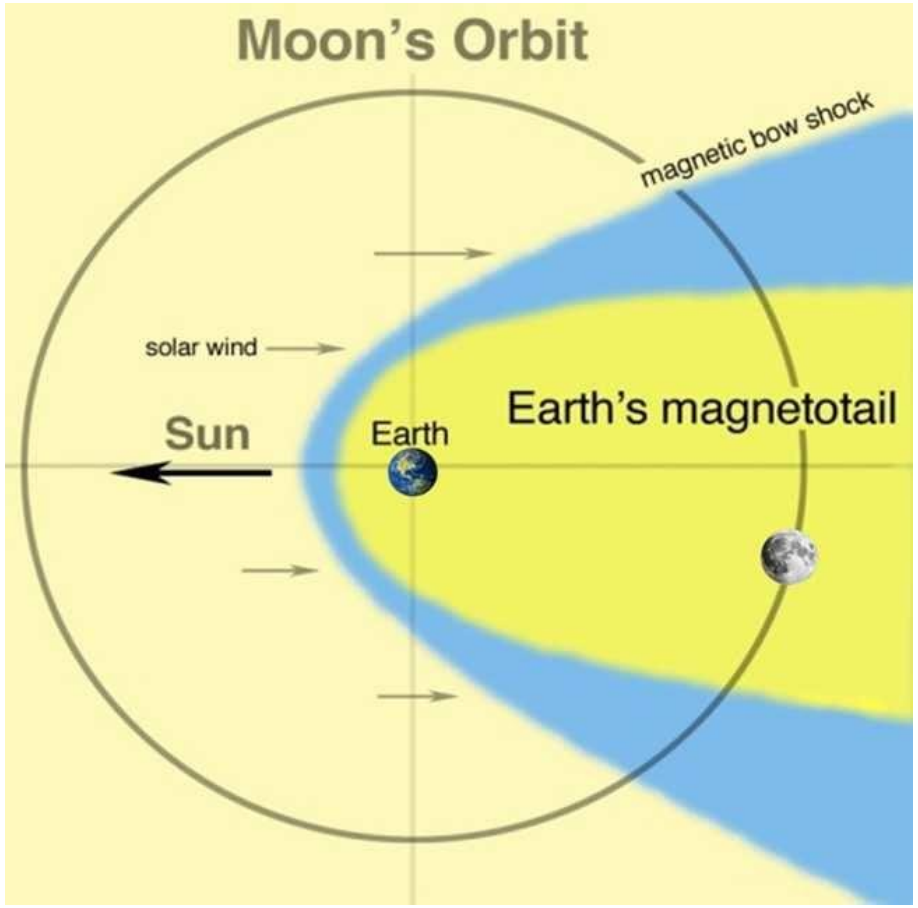
2 effects altering particle path:

1) local magnetic anomalies (at 30 km)



Oliveira & Wieczorek, 2017

2) Earth's magnetotail

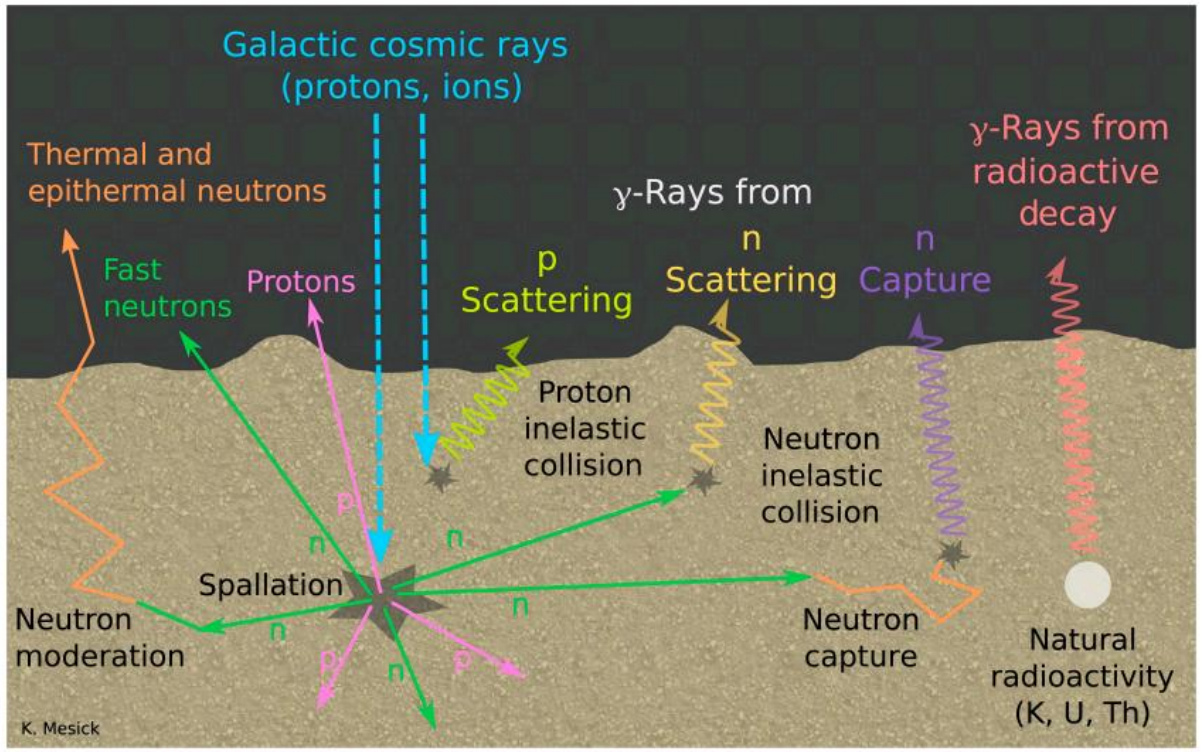


Dandouras et al, 2020

- How do we know this:
  - Apollo: astronauts with dosimeters, not time-resolved
    → cumulative only

  - First time-resolved on surface:
    Chang'E 4 LND
    dose rate: *13.2 ± 0.7 µGy/h* total avg.
    3.1 ± 0.5 µGy/h neutron avg.

  - LRO flew above Chang'E
    → LND: *10.2 ± 1.1* µGy/h
    → Crater: 10 µGy/h in Si

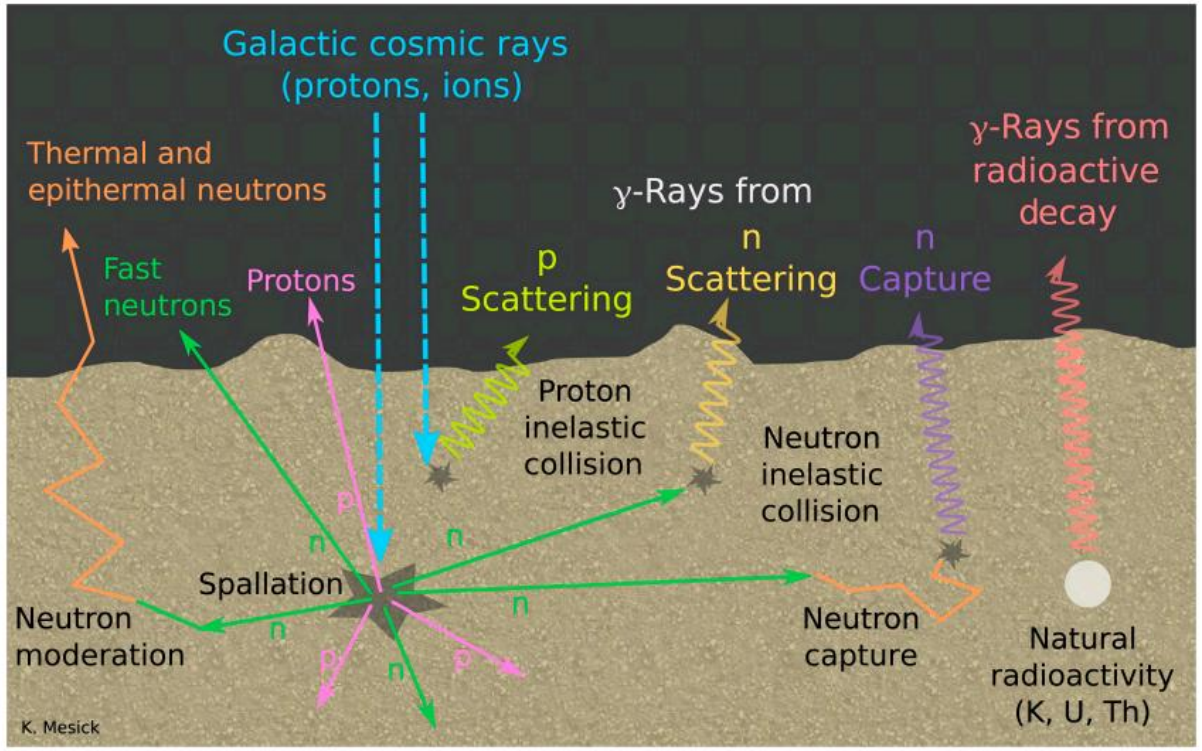


Mesick et al., 2018

- ISS comparison:
  523 µSv/day GCR, by DOSTEL
  1369 µSv/day, by LND
  → GCR 2.6 times higher at solar min.

- Shielding on the Moon:
  - 1 subsurface measurement
    Apollo 17
    Lunar Neutron Probe Experiment

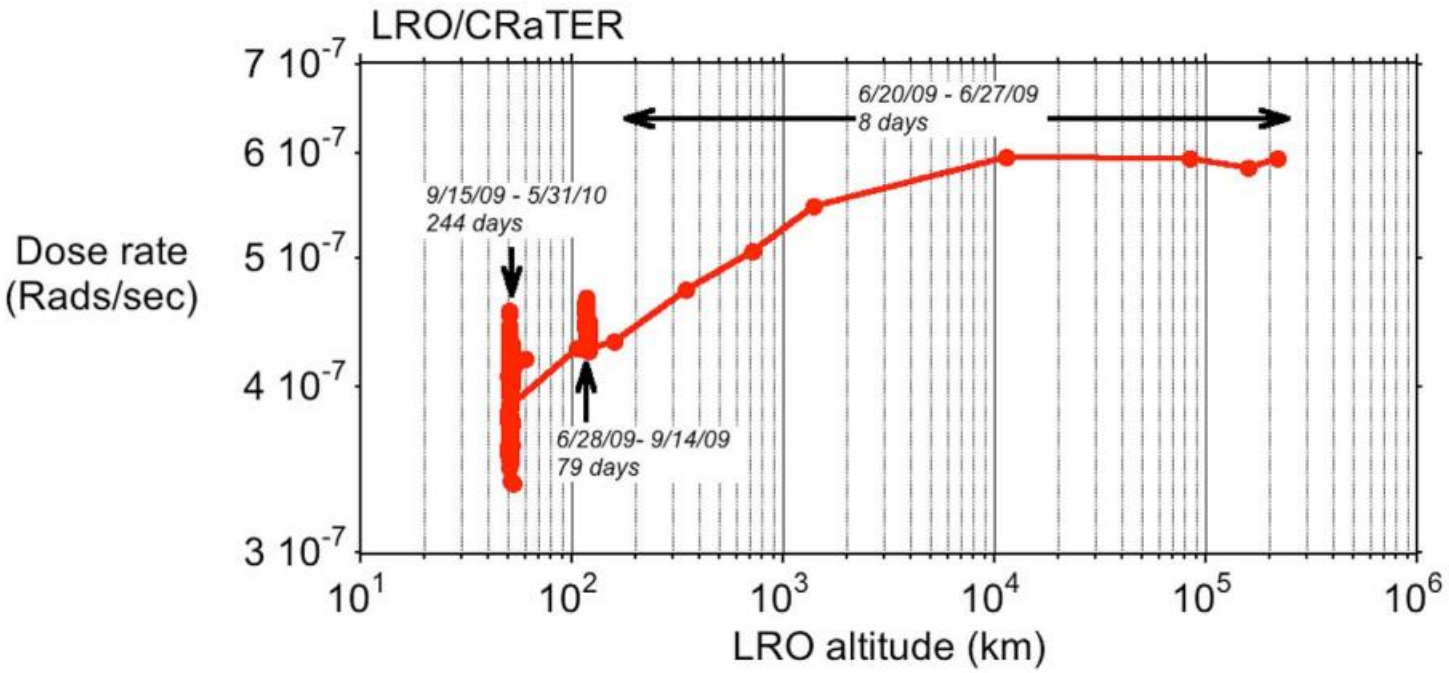
  Geant4 simulations
  - RedMoon (Dobynde & Guo, 2022)
  - Matthiä & Berger, 2025



Mesick et al., 2018

- LRO Crater data from microdosimeter:

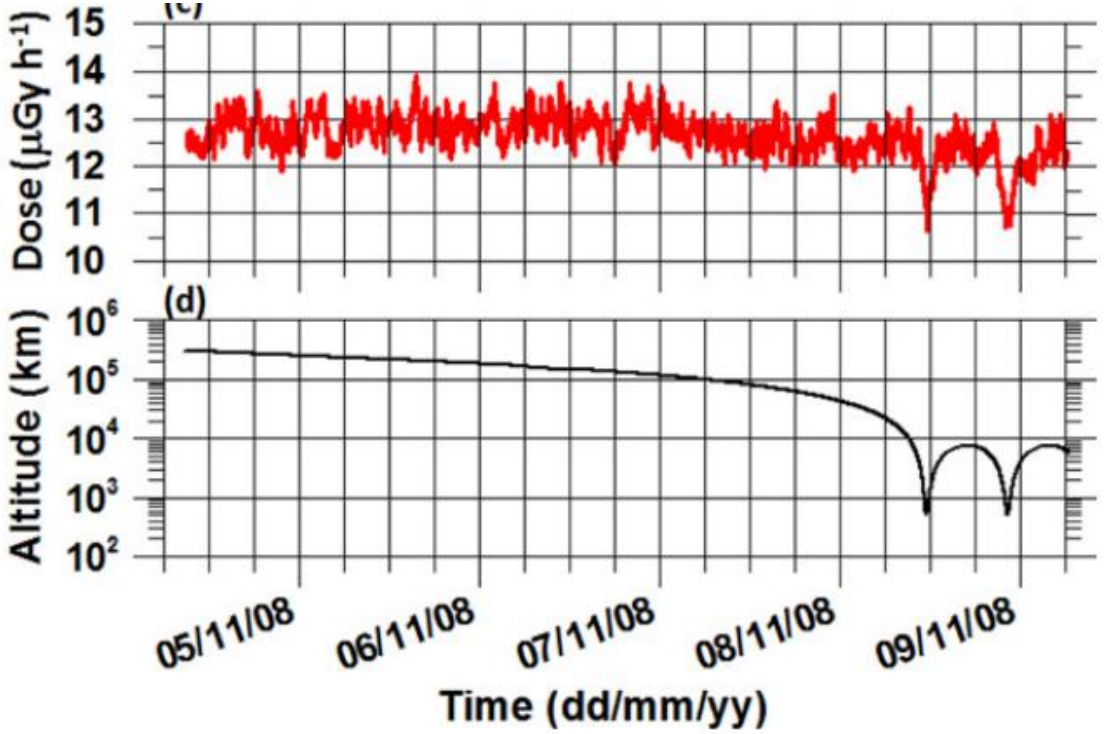
50 – 200 000 km dose rate profile (0.8 mm Al shielding)



Altitude [km]	Dose (in Si) [µGy/h]
0	10
50	12.5
200	14
10 000	21

100 rad = 1 Gray
Mazur et al, 2011

- Chandrayaan-1 RADOM data:
  50 – 200 000 km dose profile → shows lower doses than LRO
  due to: lower GCR flux & 1.7 mm Al shielding



Dachev et al, 2011

LRO Crater data, 2009.06.

Altitude [km]	Dose (in Si) [μGy/h]
0	10
50	12.5
200	14
10 000	21

2. Radiation environment modeling

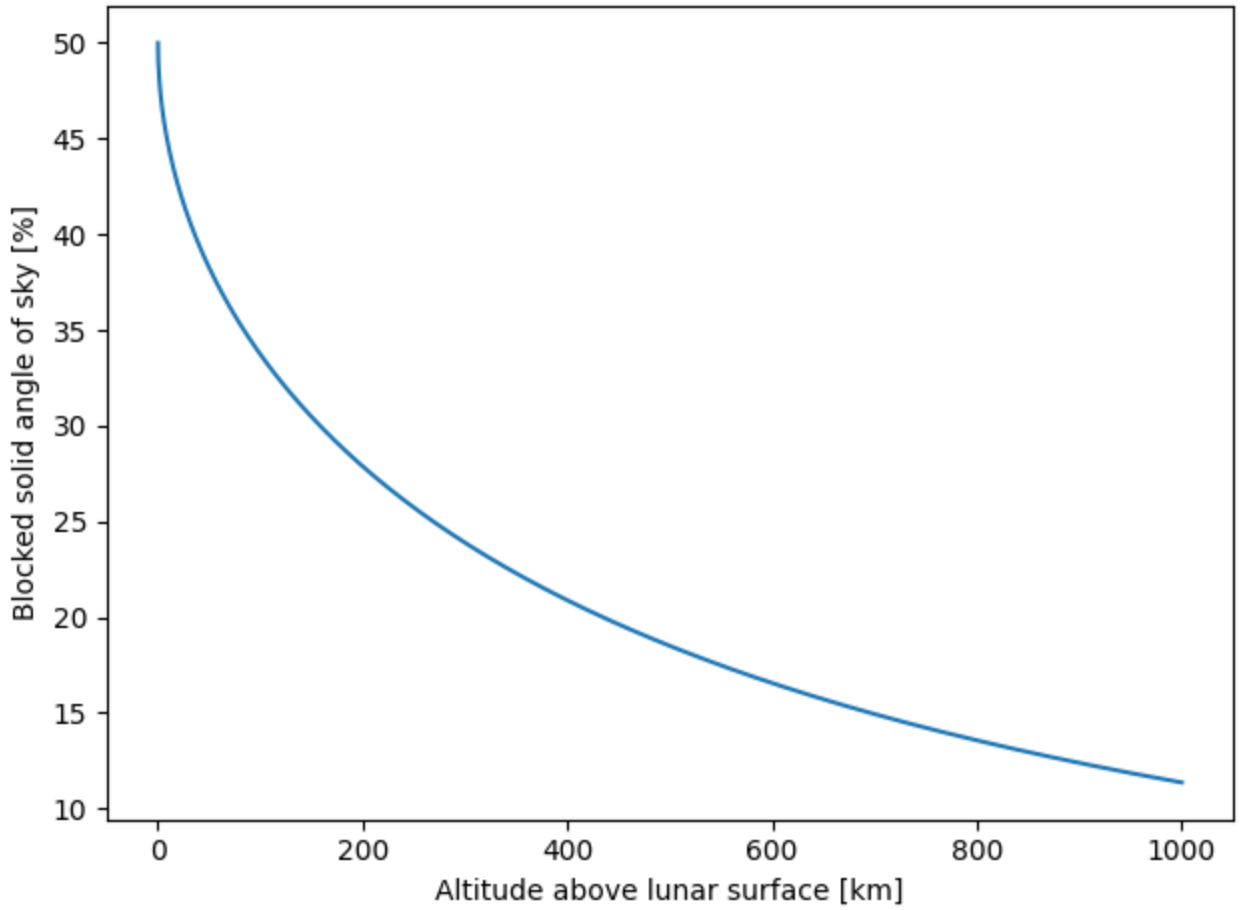
- European Cooperation for Space Standardization, Space environment
  → required models & environments

ECSS-E-ST-10-04C, section 1.8:

> Science missions also take place at the Lagrangian points of the Sun-Earth system or Earth-Moon system, locations which are usually considered interplanetary from the point of view of the radiation environment.

- In reality not interplanetary because:
  I) albedo particles
  II) Earth's magnetotail
  III) magnetic anomalies
  IV) Moon surface shadowing

- Blocked solid angle for flat surface:



- In reality not interplanetary because:
  I) albedo particles
  II) Earth's magnetotail
  III) magnetic anomalies
  IV) Moon surface shadowing

in ECSS

Model required	Particle type	Newer models
AE-8, AP-8	trapped electrons, protons	IRENE AE-9, AP-9
ESP	solar proton fluence	ESP-Psychic / SAPPHIRE 1 in N
CREME96	solar peak flux	SAPPHIRE 1 in N
ISO 15390	galactic cosmic rays	-
-	**Lunar albedo neutrons**	**GLACE**

Geant4 Lunar Albedo Computed Environment

Looper et al, 2023

- In reality not interplanetary because:
  I) albedo particles
  II) Earth's magnetotail
  III) magnetic anomalies
  IV) Moon surface shadowing

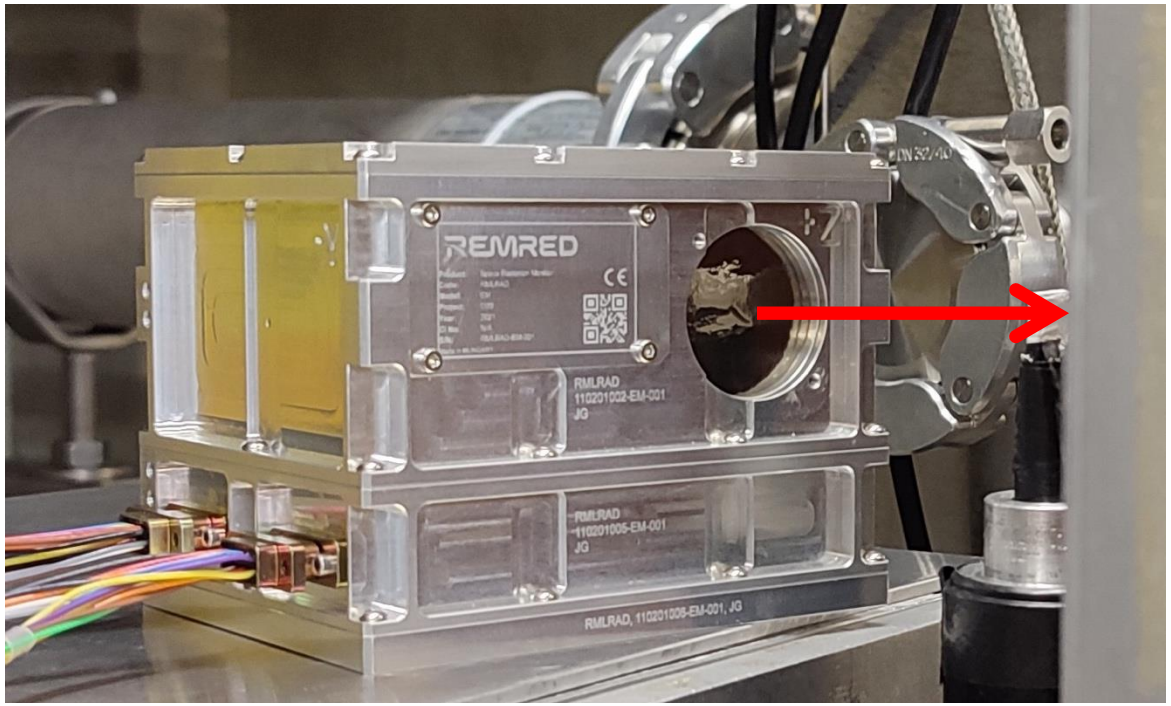
3. RadTel & TriTel

- Space Dosimetry System (SDS)
- Combines RadTel & TriTel
- will support reference modeling with measurement data
  → radiation models for the Lunar environment.

- In reality not interplanetary because:
  I) albedo particles
  II) Earth's magnetotail
  III) magnetic anomalies
  IV) Moon surface shadowing

- RadTel:
  - RADCUBE old design, 4 + 3 detectors → flight proven
  - updated, 6 planar Si detector → 100 - 3000 µm thick
  - particle type & energy identification
  - coincidence, anticoincidence

  - energy range:
    - p+ → 3.5-400 MeV
    - e- → 0.3-3.9 MeV
    - ion → 10-400 MeV/nuc
  - channels:
    - p + → 10 differential, 1 integral
    - e- → 5 differential, 2 integral

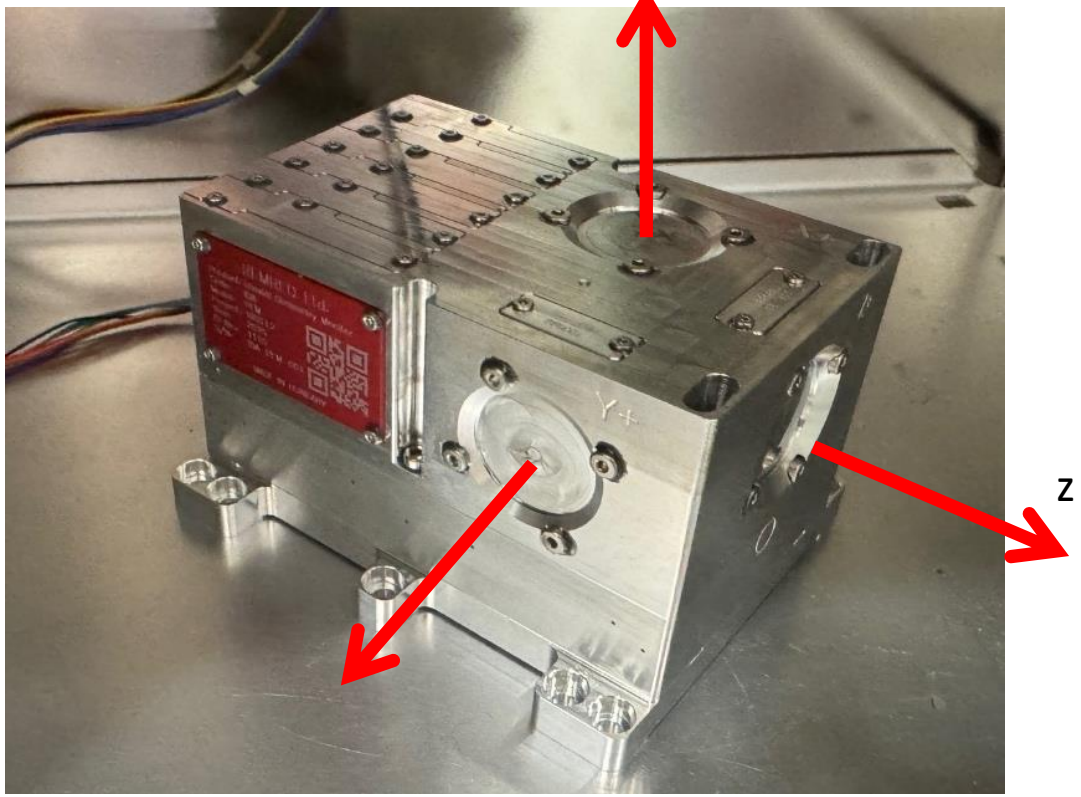


- TriTel:
  - ISS Columbus + Zvezda → flight proven
  - 3-axis telescope → directional measurement

  - LET in water:
    0.2-120 keV/µm

  - energy range:
    p+ & He+ → > 6 MeV/n
    e- → > 400 keV

  - channels:
    3 x 128 → LET measurements



- Combining TriTel and RadTel → Space Dosimetry System (SDS)

SDS instrument	**TriTel**	**RadTel**
Channels	3x128 (LET)	p: 10(+1), e: 5(+2)
Energy range	p & He ions: > 6 MeV/n e: > 400 keV	p+: 3.5-400 MeV e-: 0.3-3.9 MeV
Flight opportunity for SDS	**MoonRad**	
Other flight opportunities	Gateway-IDA (cancelled)	Aurora-D (D3S)
Past missions	ISS-Columbus ISS-Zvezda	RADCUBE (LEO CubeSat)
Proposed for CLPS	SDS-LUNARIS IDA-DASH	SDS-LUNARIS
LET H_2O (keV/µm)	0.2-120	-

- MoonRad mission concept:

  - Hungarian platform manufactured by Remred
  - science prime: HUN-REN Centre for Energy Research

  - currently in Phase A study phase →SDS + LunPAN (University of Geneva, comprising Pix.PAN and NeuPix)
    backup concept: RadPlasmag (SDS+EPT/HET+plasma measurements +fluxgate magnetometer)

  - 300 kg SmallSat
  - high inclination, high excentricity (100-1000 km)
  - SDS originally designed for MSR-ERO

- MoonRad mission science goals:

  1) Monitoring radiation environment characteristics and dynamic processes

  2) Support reference modelling of Moon rad. env.

  3) Radiation protection for crew health, by accurately quantifying, monitoring, and mitigating human exposure to ionizing radiation.

  expected launch before 2030

- Surface situation covered to some extent - simulations

- In reality not interplanetary because:
  I) albedo particles – flux & energy height profile → NeuPix
  II) Earth's magnetotail
  III) magnetic anomalies – deflection, redirection?
  IV) ~~Moon surface shadowing~~

→ MoonRad with possible answers

HUN REN | Centre for Energy Research

HUN-REN Centre for Energy Research

Thank you for your attention!

- Extra slide:

$$F_a = \frac{1}{1 + \sqrt{1 - (R_m/(R_m + r))^2}}$$

Rm-radius of Moon
r-altitude of LRO

- Rm=1737 km
- LRO altitude at Chang'E ~ 50 km
- Fa ~ 0.8

- Extra slide: GCR changing during 2009-2025, LRO Crater data

