OVER 2800 DAYS IN SPACE- THE RAMIS RADIATION DETECTOR ON THE DLR EU:CROPIS MISSION

Max Radenhäuser for the Eu:CROPIS RAMIS team:

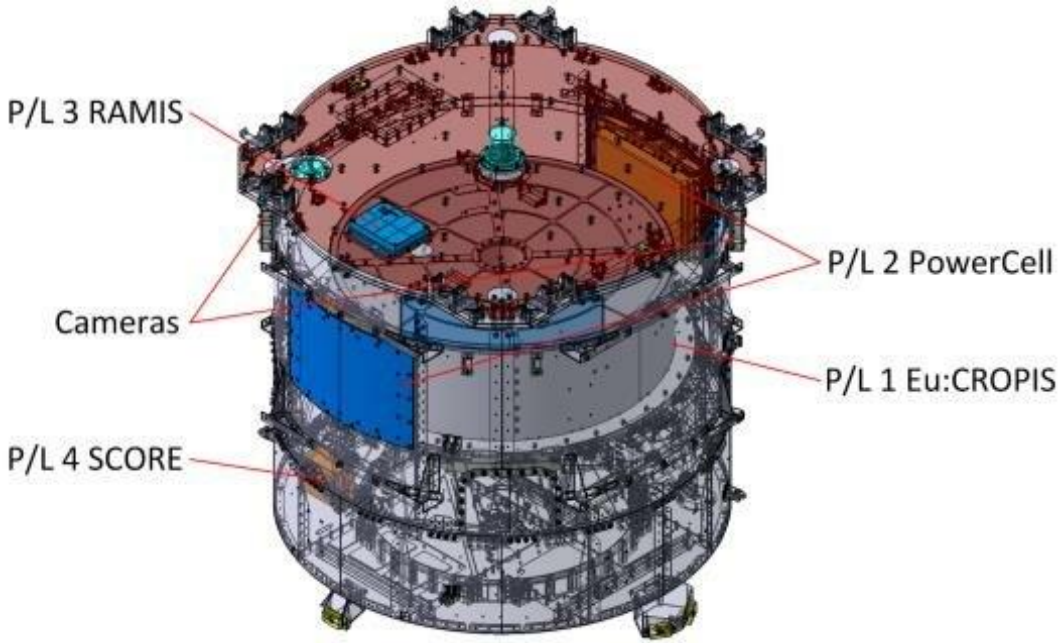
DLR-ME & DLR-MUSC & GSOC-EUC-FLD & DLR-RY

What we will discuss

- **Short reminder: What is RAMIS?**
- **Update: Machine Learning classified data**
- **Long term changes in the radiation environment**
- **Comparison to SREM, LEO-DOS and CRaTER**

Reminder Eu:CROPIS: Compact satellite



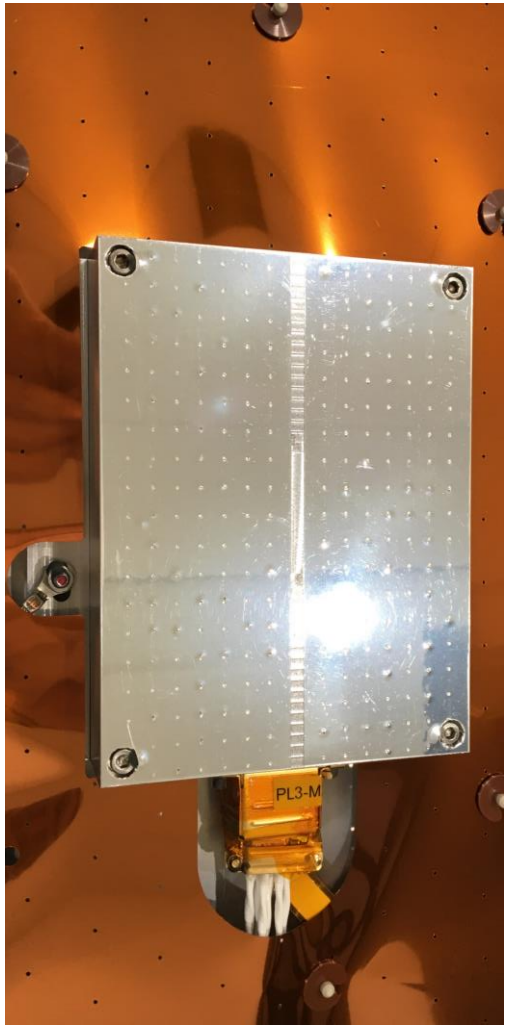


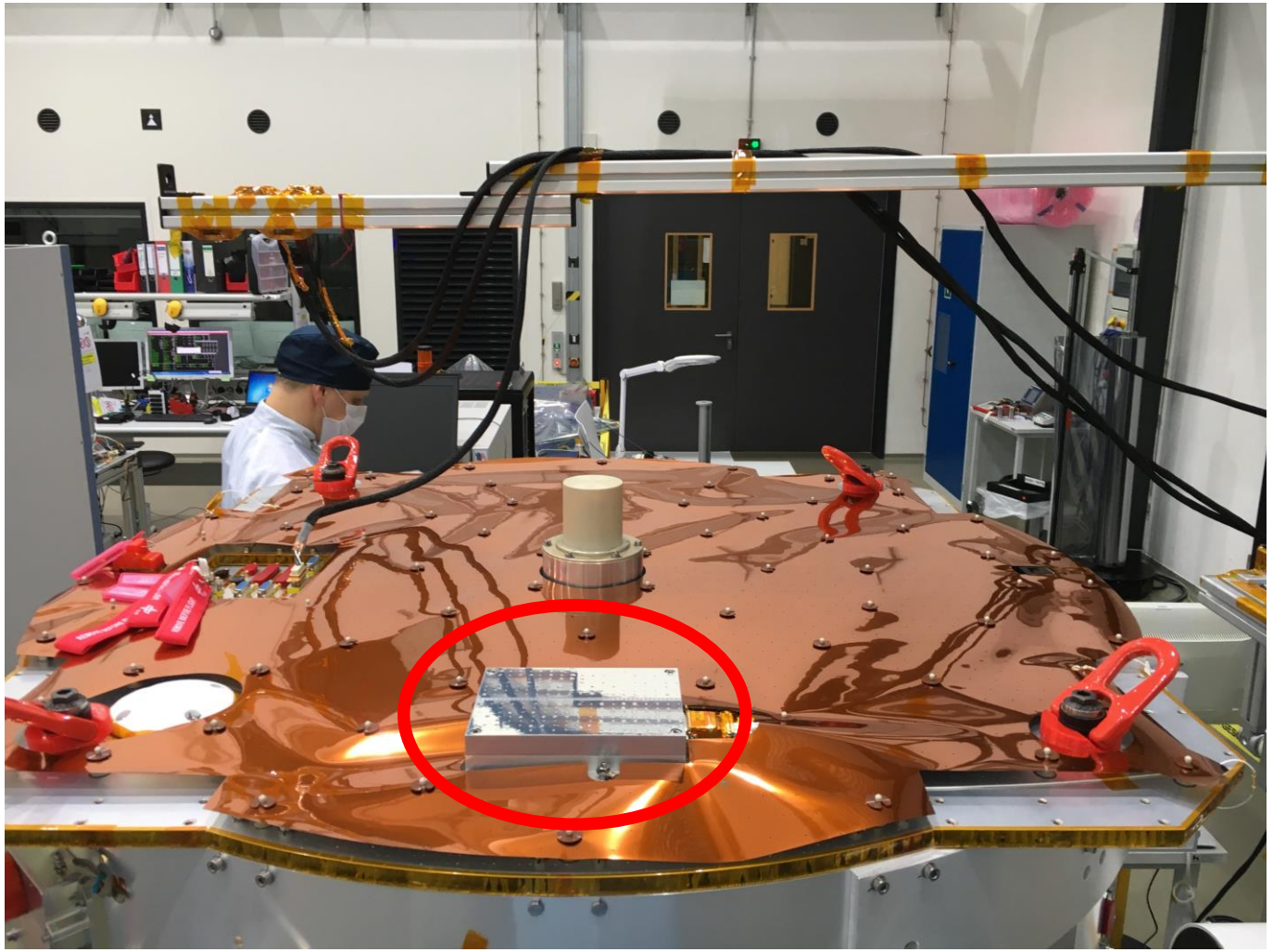
Hauslage, J. et al. (2018) https://doi.org/10.1007/s12217-018-9654-1
https://www.dlr.de/en/research-and-transfer/projects-and-missions/the-eu-cropis-mission

Reminder Eu:CROPIS: RAMIS FM Models (December 2017)









Reminder RAMIS: Fact Sheet



RAMIS	FM	
Dimensions	140 x 140 x 35	mm^3
Mass	608	g
Supply voltage	28	V
Power consumption	1.82	W

Single Detector Data		
Radius	0,51	cm
Thickness	300	µm
Area	0,817	cm^2
Mass	57,11	mg
GF	5,133	$sr*cm^2$

Telescope Data		
Distance between the diodes	0,73	cm
Opening angle	109	°
GF	1,423	$sr*cm^2$
Mean path length	335,85	µm

Ranges		
Energy range (in Si)	0.09 – 145	MeV
LET Range (in H2O)	0.15 – 228	keV/µm

	D1	D2
Electron Energy [MeV]	1.38	1.48
Proton Energy [MeV]	24.3	25.6

Reminder RAMIS: Publication

Radiation exposure in low Earth orbit measured with the RAMIS instrument on the DLR Eu:CROPIS satellite

Daniel Matthiä[1,*], Thomas Berger[1], Karel Marsalek[1], Birgit Ritter[1,§], Bartos Przybyla[1], Joachim Aeckerlein[1], Michael Wirtz[1], Moritz Kasemann[1], Aleksandra Rutzynska[1], Markus Rohde[1], Maximillian Radenhäuser[1], Jens Hauslage[1], Hans-Herbert Fischer[2], Stephan Sous[2], Sven Jansen[2], Miguel Lino[3], Daniel Schulze[3], Gary Morfill[3], Toni Delovski[4], Falk Nohka[4]

[1]German Aerospace Center (DLR), Institute of Aerospace Medicine (ME), Cologne, Germany
[2]German Aerospace Center (DLR), Microgravity User Support Center (MUSC), Cologne, Germany
[3]German Aerospace Center (DLR), German Space Operations Center (GSOC), Oberpfaffenhofen, Germany
[4]German Aerospace Center (DLR), Institute of Space Systems (RY), Bremen, Germany
[§]Now at: Royal Observatory of Belgium, Brussels, Belgium

*Corresponding author: daniel.matthiae@dlr.de

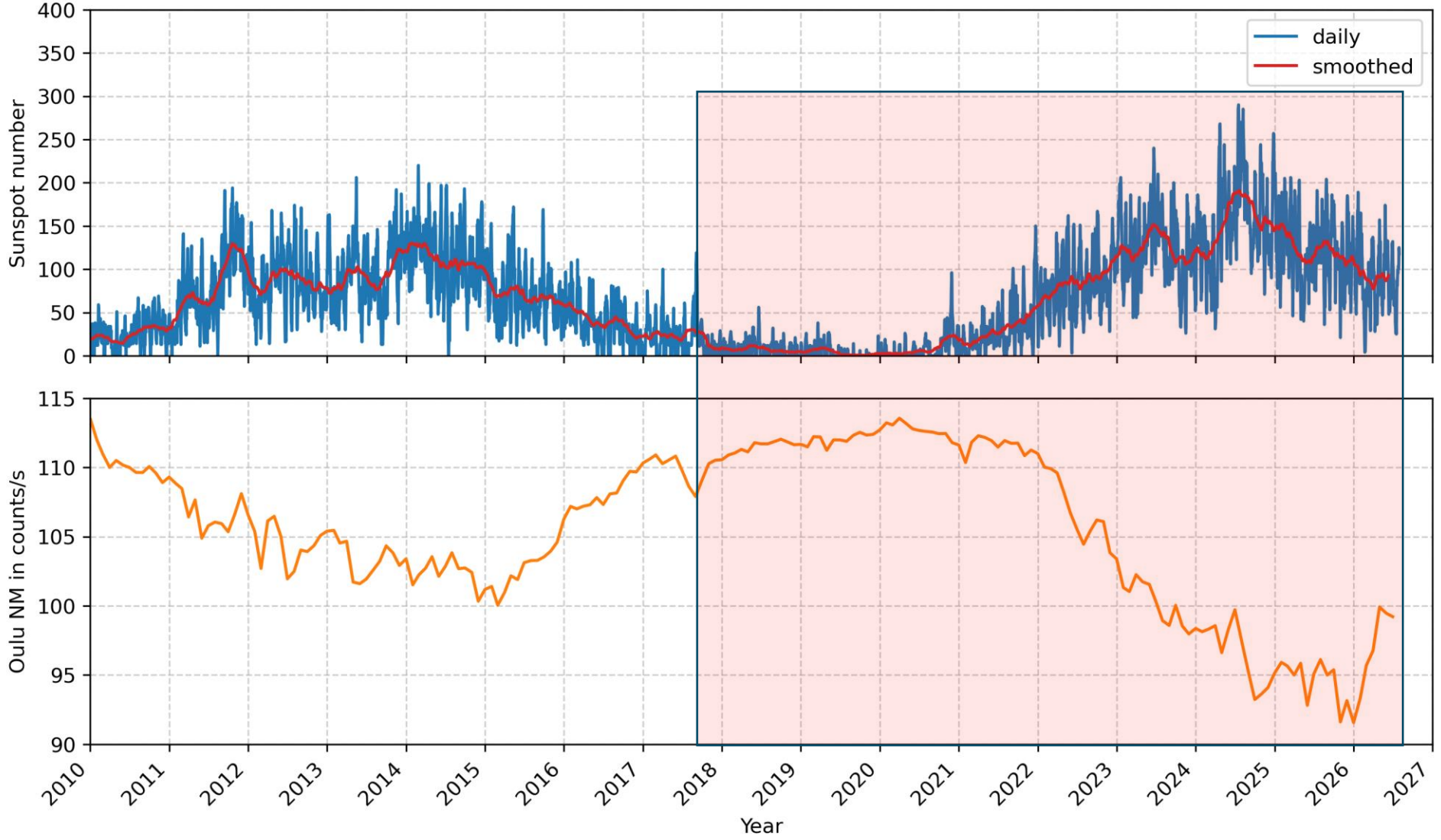
Key points:

- The RAMIS instrument is a silicon telescope measuring energy deposition spectra, absorbed dose and dose equivalent of cosmic radiation.
- RAMIS has been flying on the DLR Eu:CROPIS satellite since 2018 in a low Earth orbit and has been providing data on galactic cosmic radiation, radiation belt particles and solar energetic particles ever since.
- Energy deposition spectra measured by RAMIS can be used to estimate the linear energy spectra of cosmic radiation and their biological relevance through the quality factor of the field.

Keywords: radiation exposure; galactic cosmic radiation; solar energetic particles; radiation belts; low Earth orbit.

Matthiä, D., Berger, T., Marsalek, K., Ritter, B., Przybyla, B., Aeckerlein, J., Wirtz, M., Kasemann, M., Rutczynska, A., Rohde, M., Radenhäuser, M., Hauslage, J., Fischer, H.-H., Sous, S., Jansen, S., Lino, M., Schulze, D., Morfill, G., Delovski, T., & Nohka, F. (2026). Radiation exposure in low Earth orbit measured with the RAMIS instrument on the DLR Eu:CROPIS satellite. Submitted to Journal of Space Weather and Space Climate. https://doi.org/10.5281/zenodo.19366711

Reminder RAMIS: Solar Cycle



Reminder Machine Learning:

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A machine learning algorithm for the classification of radiation data

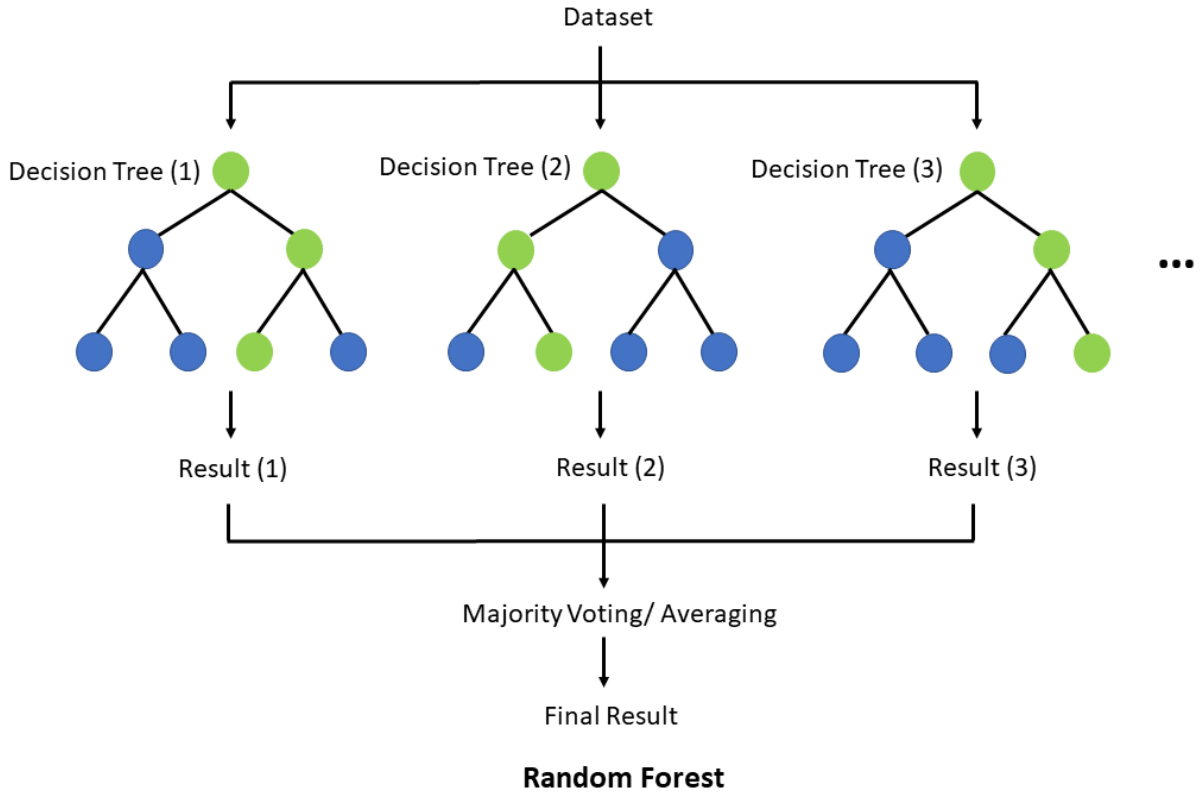
K. M. Radenhäuser[1,2], D. Matthiä[1], J. Aeckerlein[1], M.E. Innocenti[2], M. Kasemann[1], K. Marsalek[1], B. Przybyla[1], A. Rutczynska[1], and T. Berger[1]

[1] Radiation Biology Department, Institute of Aerospace Medicine, German Aerospace Center, Germany
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[2] Institute of Theoretical Physics 1, Ruhr-University Bochum, Germany

ABSTRACT

Due to the increasing activity in space, both by public and private actors, detailed knowledge about the radiation exposure in low Earth orbit is indispensable. The RAMIS experiment onboard the Eu:CROPIS satellite has measured the radiation exposure at an orbit of about 600 km since December 2018. The dataset obtained by that mission gives invaluable insights into the complex nature of the radiation fields and their variation due to the solar cycle and related solar particle events. One major challenge in the analysis of these fields is the separation of different radiation components. In this paper, a solution based on the Random Forest machine learning algorithm is presented, which, once established, enables a fully automated classification of radiation data. The implementation of this algorithm and its training is described in detail, so that space radiation scientists with limited experience with machine learning algorithms, can easily adapt it to their own data. The benefits of using this method are shown in four exemplary use cases.

Key words. RAMIS, space weather, space radiation, machine learning algorithm, radiation belts, galactic cosmic radiation, solar storms



Reminder Machine Learning:

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A machine learning algorithm for the classification of radiation data

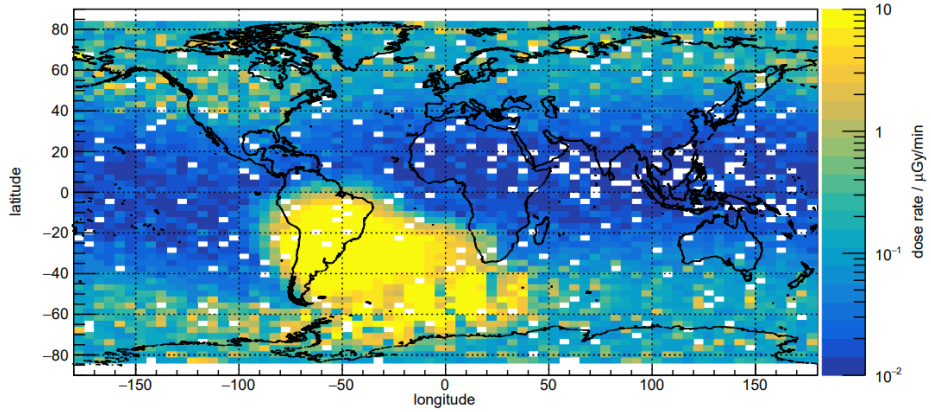
K. M. Radenhäuser[1,2], D. Matthiä[1], J. Aeckerlein[1], M.E. Innocenti[2], M. Kasemann[1], K. Marsalek[1], B. Przybyla[1], A. Rutczynska[1], and T. Berger[1]

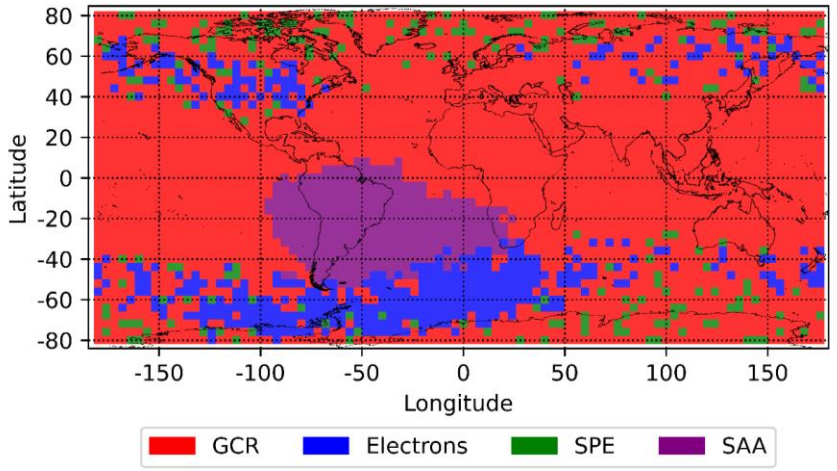
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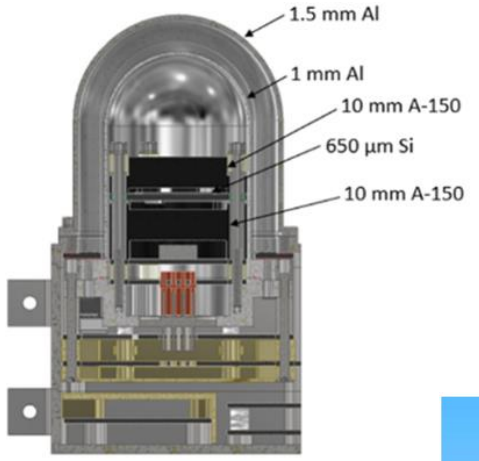




Comparison to other missions

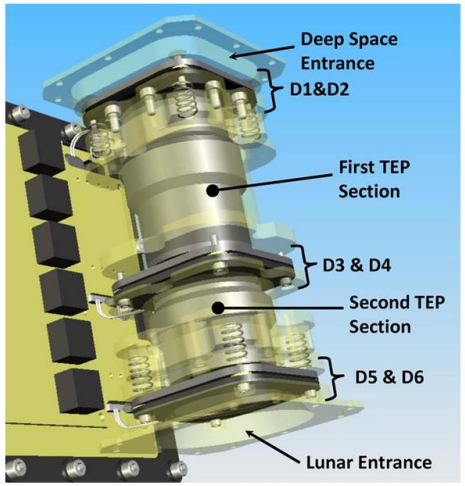
- **Standard Radiation Environment Monitor: SREM**





- **Low Earth Orbit Space Radiation Dosimeter: LEO-DOS**

- **Cosmic Ray Telescope for the Effects of Radiation: CRaTER**



Comparison to SREM

SREM on Proba-1

sun-synchronous orbit ~560 km
Data: https://srem.psi.ch/static/srem_home.shtml
https://srem.psi.ch/cgibin/srem_data_sec.pl V0
Detector used: TC1, TC2, TC3
Data: count rates every 30 seconds



TABLE I
LIST OF THE SREM CHANNELS AND THE CORRESPONDING ENERGY RANGES OF DETECTED PROTONS AND ELECTRONS [3]

SREM	Proton Energy	[MeV]	Electron Energy	[MeV]
Bin	E_{min}	E_{max}	E_{min}	E_{max}
TC1	27	∞	2.00	∞
S12	26	∞	2.08	∞
S13	27	∞	2.23	∞
S14	24	542	3.20	∞
S15	23	434	8.18	∞
TC2	49	∞	2.80	∞
S25	48	270	–	–
C1	43	86	–	–
C2	52	278	–	–
C3	76	450	–	–
C4	164	∞	8.10	∞
TC3	12	∞	0.80	∞
S32	12	∞	0.75	∞
S33	12	∞	1.05	∞
S34	12	∞	2.08	∞

I. Sandberg, I. A. Daglis, A. Anastasiadis, P. Bühler, P. Nieminen and H. Evans, "Unfolding and validation of SREM fluxes," *2011 12th European Conference on Radiation and Its Effects on Components and Systems*, Seville, Spain, 2011, pp. 599-606, doi: 10.1109/RADECS.2011.6131429

Comparison to SREM

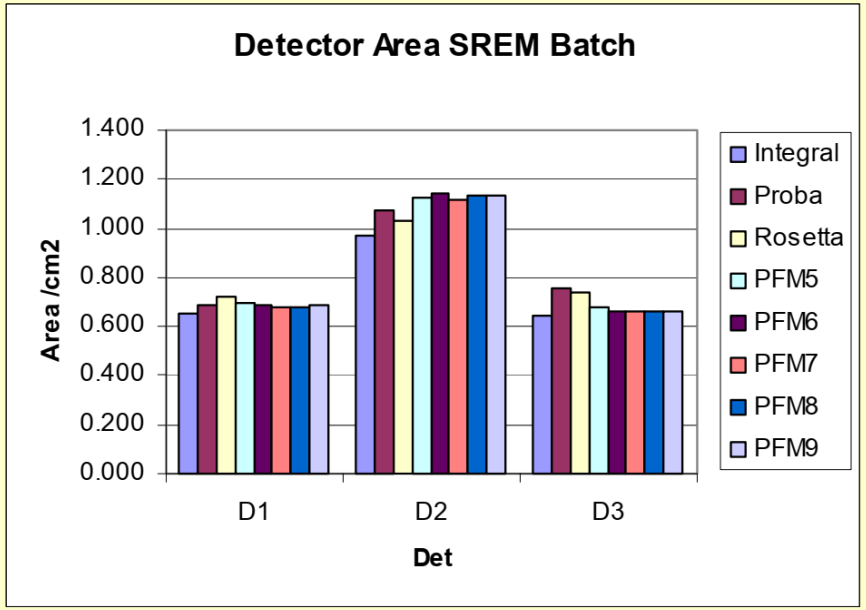
PAUL SCHERRER INSTITUT

Sensitive Area

Measured during calibration

Exposures at 0∞and 300 MeV
Low intensity, flat beam
Consistency within < 10%

Differs from nominal values
(connected with det. technology)



TC1 → D1 <A>= 0.69 cm²
TC2 → D2 <A>= 1.09 cm²
TC3 → D3 <A>= 0.68 cm²

(Error for single detector < 0.01cm²)

6

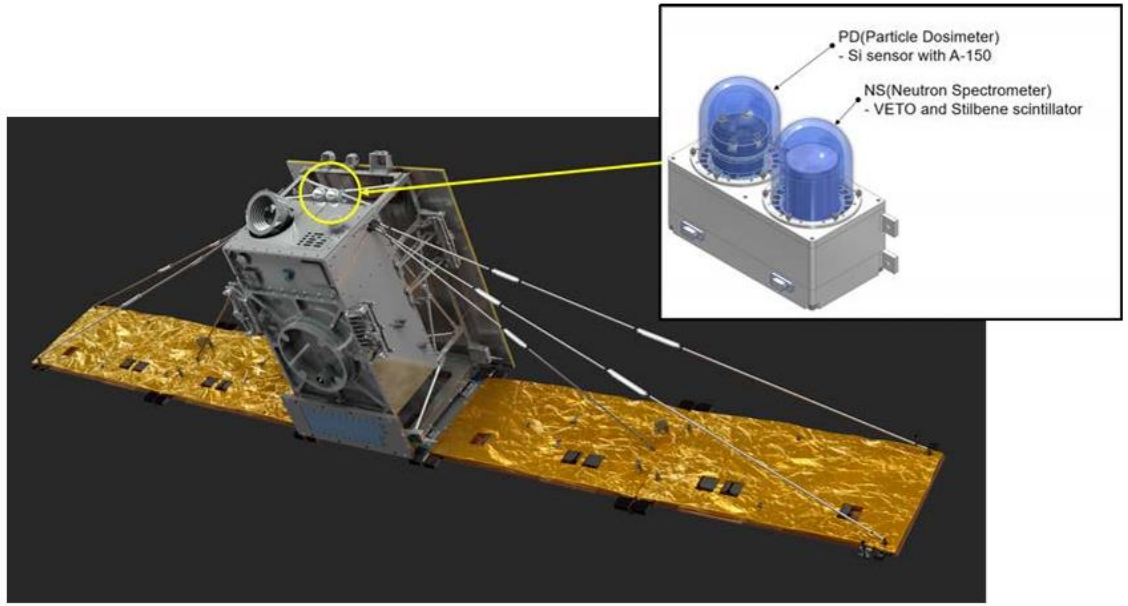
LABORATORY FOR ASTROPHYSICS

Comparison to LEO-DOS

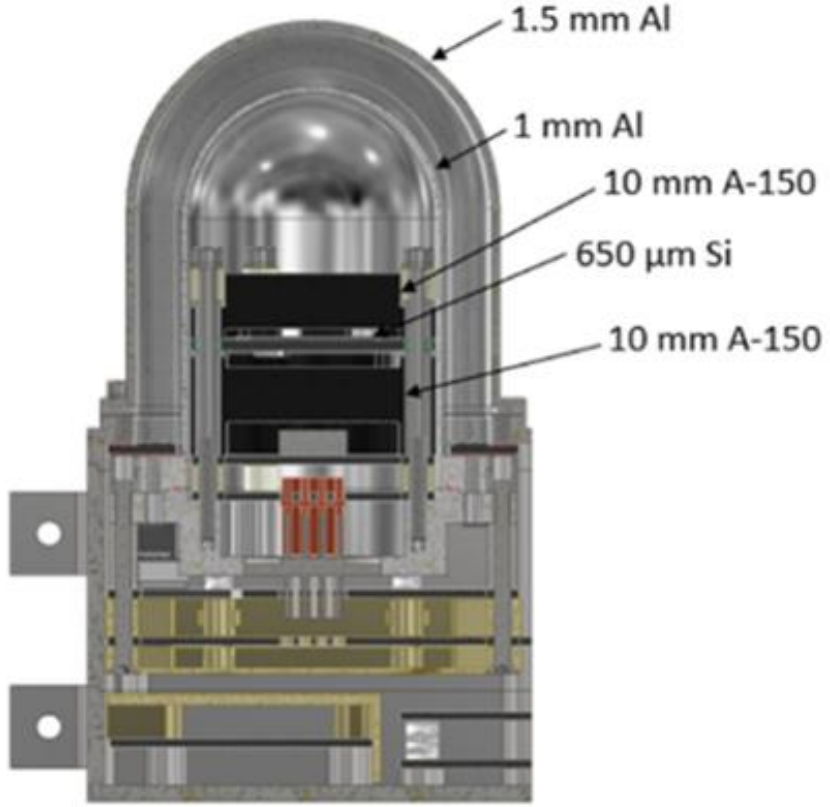
LEO_DOS on NEXTSat-2

Polar orbit~550 km

Data: Jung, J., Kwak, Y.-S., Nam, U.-W., Oh, S., Park, W.-K., Youn, S., et al. (2026). LEO-dos absorbed dose observations during the May 2024 geomagnetic superstorm. *Geophysical Research Letters*, 53, e2025GL121591. https://doi.org/10.1029/2025GL121591



Nam, U.-W., "Initial Results of Low Earth Orbit Space Radiation Dosimeter on Board the Next Generation Small Satellite-2", Journal of Astronomy and Space Sciences, vol. 41, no. 3, pp. 195–208, 2024. doi:10.5140/JASS.2024.41.3.195

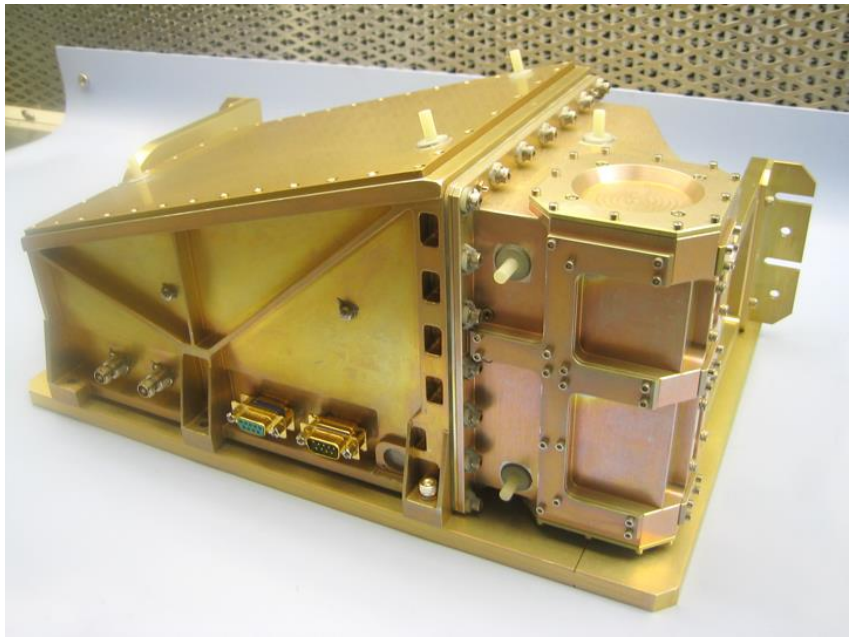


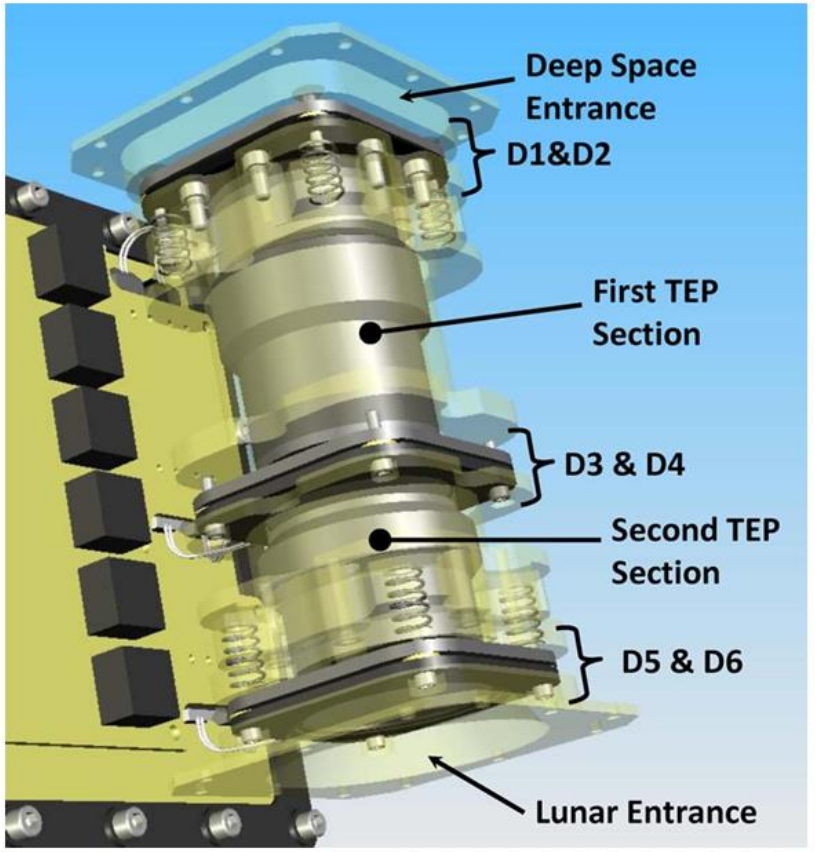
S. Youn, U. Nam, S. Kim, W.-K. Park, J. Kwak, J. Sohn, B. Moon, J. Lee, Y.-J. Choi, J. Kim, H. Kim, H. Park, H. Park, T. Jang, I. Jun, S.-J. Ye
Monitoring the radiation environment in high-latitude low-Earth orbit during an ascending phase of the solar cycle
Acta Astronaut., 240 (2026), pp. 398-407, 10.1016/j.actaastro.2025.11.053

Comparison to CRaTER

CRaTER on NASA‘s Lunar Reconnaissance Orbiter (LRO)

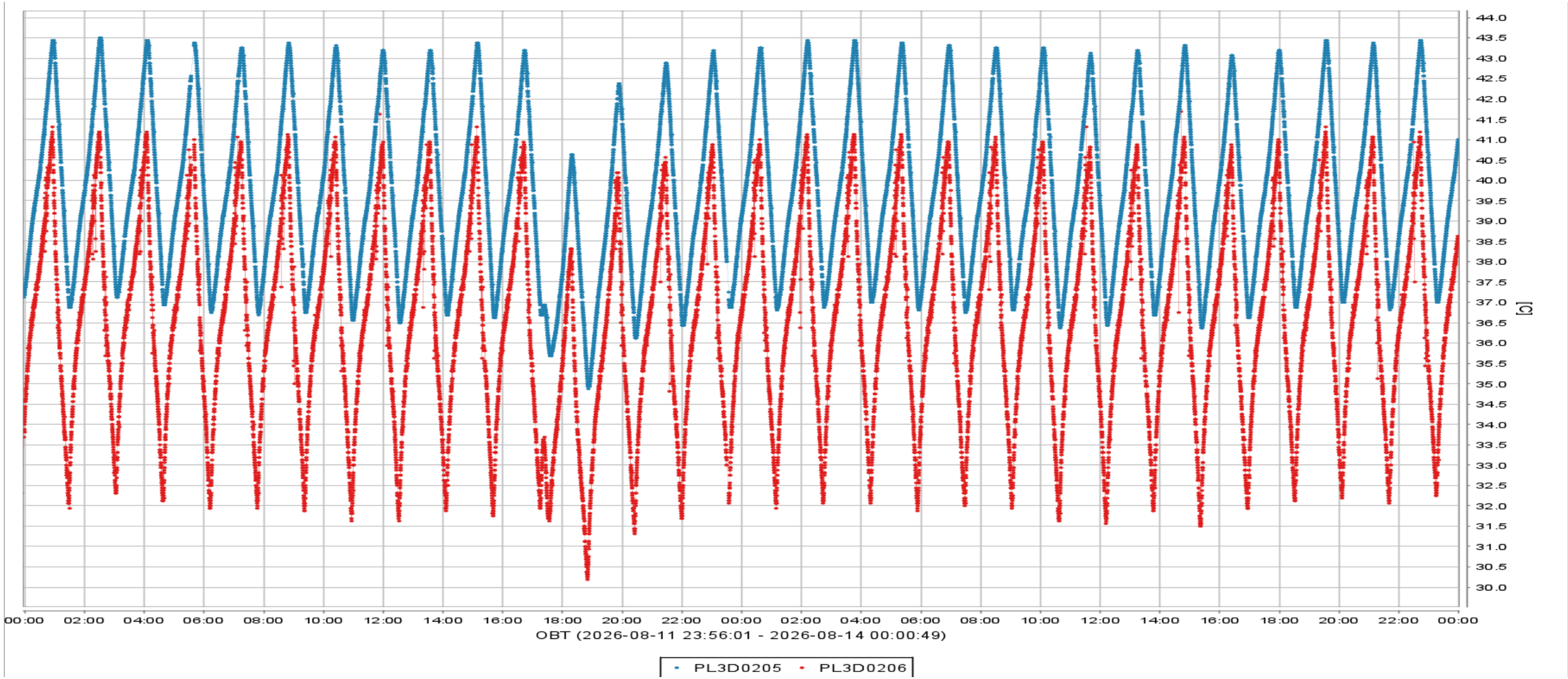
Lunar polar orbit~30-50 km
Data: https://crater-web.sr.unh.edu/
https://crater.unh.edu/instrument.shtml
Detector used: D1&2, D3&4, D5&6





Spence, H.E., Case, A.W., Golightly, M.J. *et al.* CRaTER: The Cosmic Ray Telescope for the Effects of Radiation Experiment on the Lunar Reconnaissance Orbiter Mission. *Space Sci Rev* **150**, 243–284 (2010). https://doi.org/10.1007/s11214-009-9584-8

Solar eclipse: 2026



Solar eclipse: 2026



Credit: Sven Jansen, DLR, Saragossa

Summary: Over 2800 days RAMIS on Eu:CROPIS

- 2821 days in space
- 2563 days of data
- 40 SPEs identified so far
- Visible influence of the solar cycle
- Good agreement to SREM, LEO-DOS and CRaTER