Python Tools for Cosmic-Ray and Solar Particle Analysis with Metis and EPD/HET Data

Preliminary Results on Out-of-the-Ecliptic Observations: The Unique Detection of the SEP Event Dated August 21–24, 2025 with Metis

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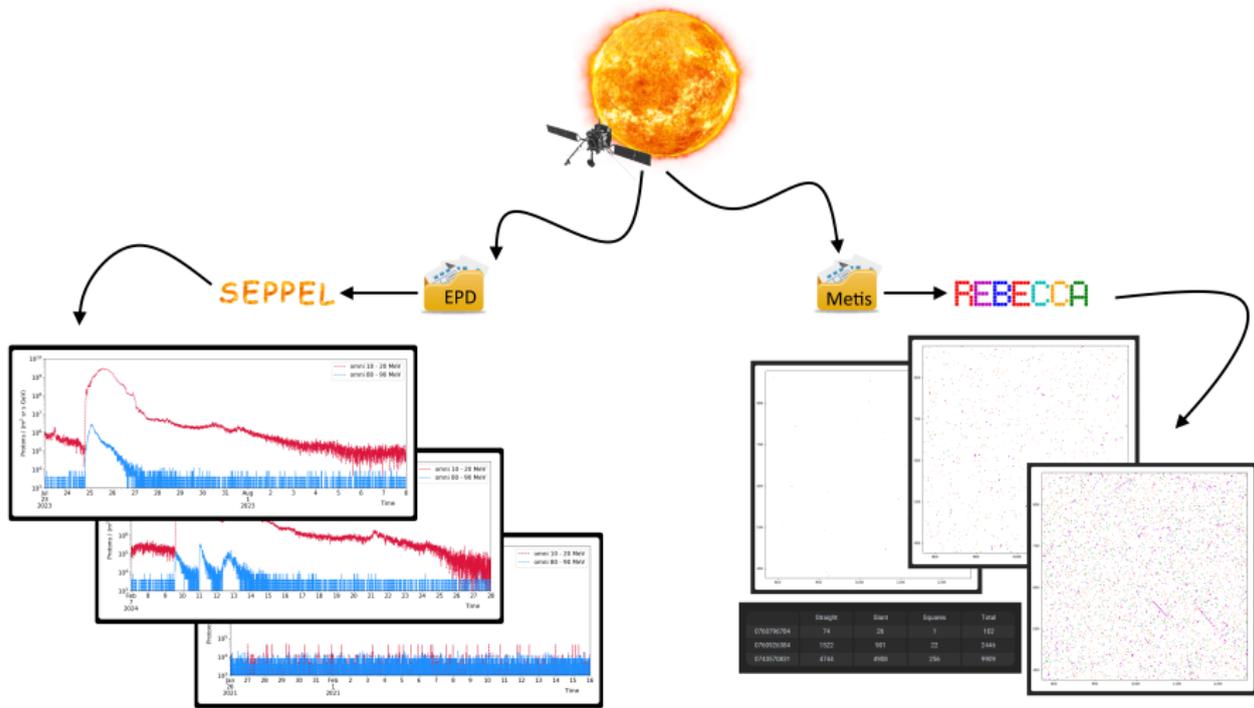**10th Metis Workshop Turin, February 11–13, 2026**

Outline

1. Overview

2. SEPPEL as a Visual Tool for Solar Energetic Particle Events

3. REBECCA to Automate the Cosmic-Ray Matrix Analysis

4. Case Study: The Strongest SEP Event of Solar Cycle 25

5. Conclusions

Motivation

Activity overview

- Monitoring galactic cosmic-ray variations and solar energetic particle events
- Necessity of correlating data from multiple instruments
- ☞ Solar Orbiter multi-instrument observations of X-ray, electron and proton fluxes of solar origin
- Study of the correlation of the overall particle flux outside and inside the spacecraft
- Development of dedicated tools for efficient data analysis and handling

Introduction
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SEPPEL
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REBECCA
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Case Study
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Conclusions
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Solar Energetic Particle Event Analysis

Introduction
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SEPPEL
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Case Study
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Conclusions
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SEPPEL

Public data up to ~ 100 MeV available on SOAR
(https://soar.esac.esa.int/)
Higher-energy data kindly provided by the EPD/HET Collaboration to
study the particle impact both inside and outside the spacecraft

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REBECCA
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SEPPEL

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SEPPEL

different energy ranges

different detectors/fields of view
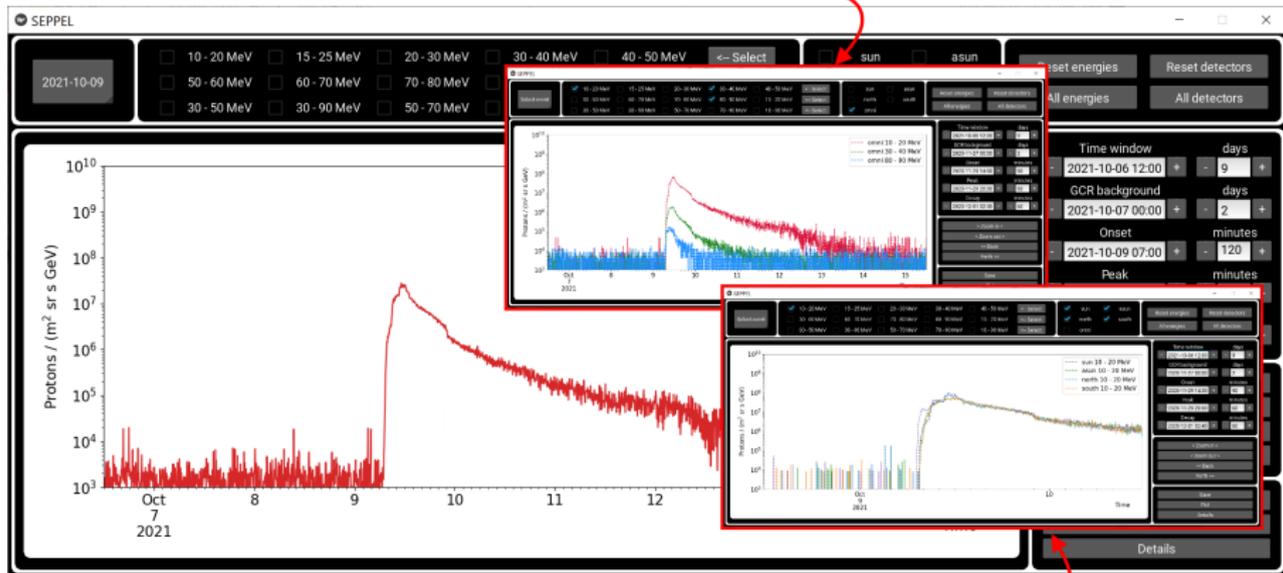
Rodríguez-Pacheco+, A&A 642, A7, 2020
Grimani+, A&A 645, A15, 2021
Grimani+, A&A 677, A45, 2023

Grimani+, A&A 686, A74, 2024
Grimani+, A&A 705, A103, 2026

SEPPEL

Main features

- Flexible and customisable via user-defined files
- Complete workflow
  1. Data download from SOAR
  2. CDF pre-processing
  3. Time series visualisation
  4. Plot customisation
  5. Local saving
- Implemented in Python
  - Standard modules + kivy
- ☞ Available upon request
- ☞ Release on GitHub after proper cross-platform validation

Introduction
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SEPPEL
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REBECCA
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Case Study
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Conclusions
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REBECCA

VL matrices only. Same performance (spurious pixels)

Introduction
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Antonucci+, A&A 642, A10, 2020
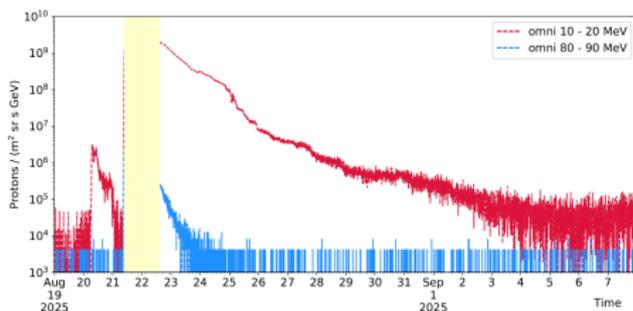Fineschi+, Exp. Astron. 49, 239, 2020

Romoli+, A&A 656, A32, 2021
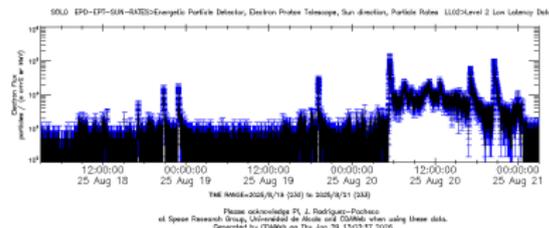Grimani+, A&A 705, A103, 2026

REBECCA

Main features

- Lightweight computation
- ✗ Matrix files to be manually supplied after human quality check
- Automated count based on lessons learned with previous viewers
- Topology identification based on colours
- Complete and fast analysis over multiple matrices (few seconds)
  - Prior visual analysis only possible on small sub-matrices (many hours)
- Implemented in Python
  - Standard modules + CustomTkinter
- ☞ Available upon request
- ☞ Release on GitHub after proper cross-platform validation
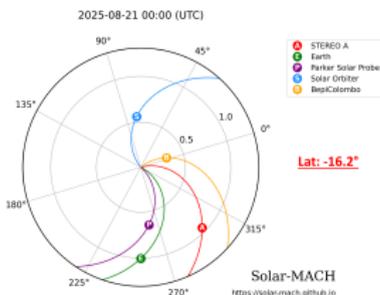
The SEP Event Dated August 21–24, 2025
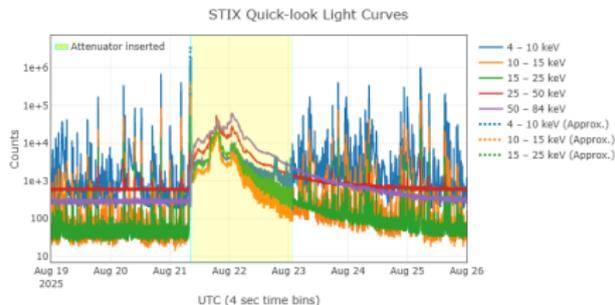

EPD/HET proton data (SEPPEL)

EPD/EPT electron data

https://cdaweb.gsfc.nasa.gov/

https://solar-mach.streamlit.app/

STIX photon data

https://datacenter.stix.i4ds.net/

The SEP Event Dated August 21–24, 2025
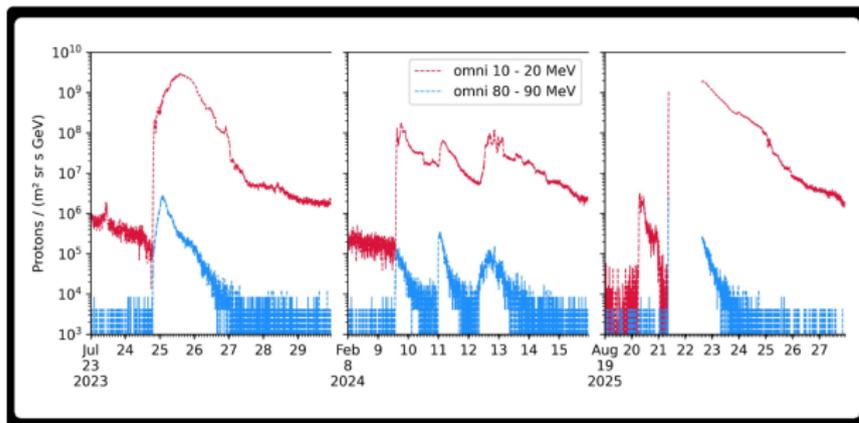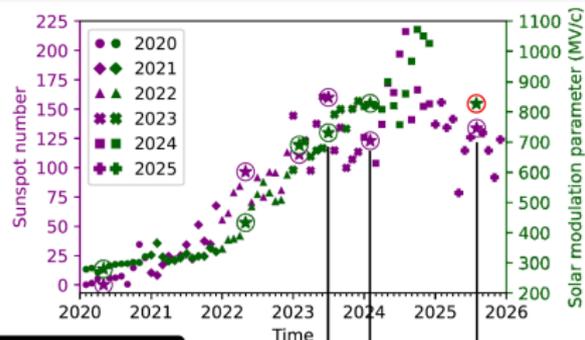
Time	Jul 2023	Feb 2024	Aug 2025
SSN	160.0	123.0	133.7
SMP	731.0	828.0	828.0
Tracks	115±4	102±3	101±4
Lat	-3.8°	5.5°	-16.2°

The SEP Event Dated August 21–24, 2025
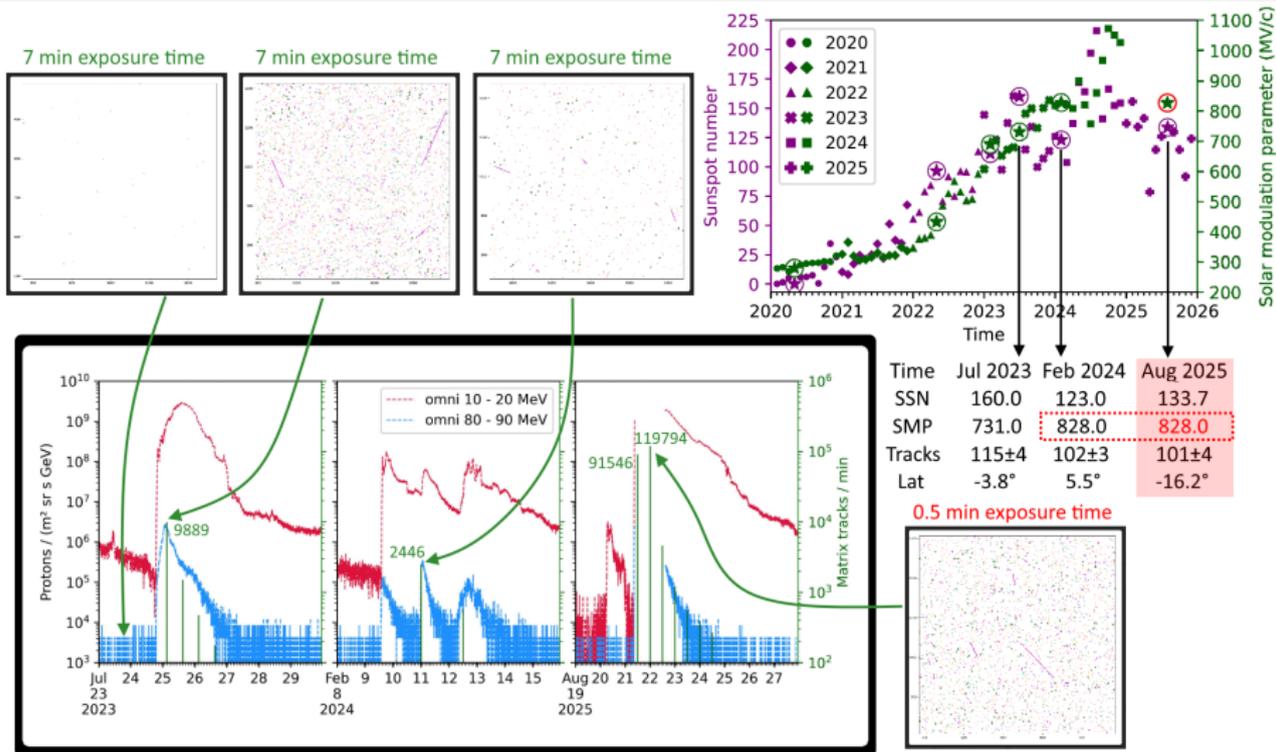
Only Metis followed the whole event dynamics

Conclusions & Next Steps

Current achievements

- Visual tool for galactic and solar particles → SEPPEL
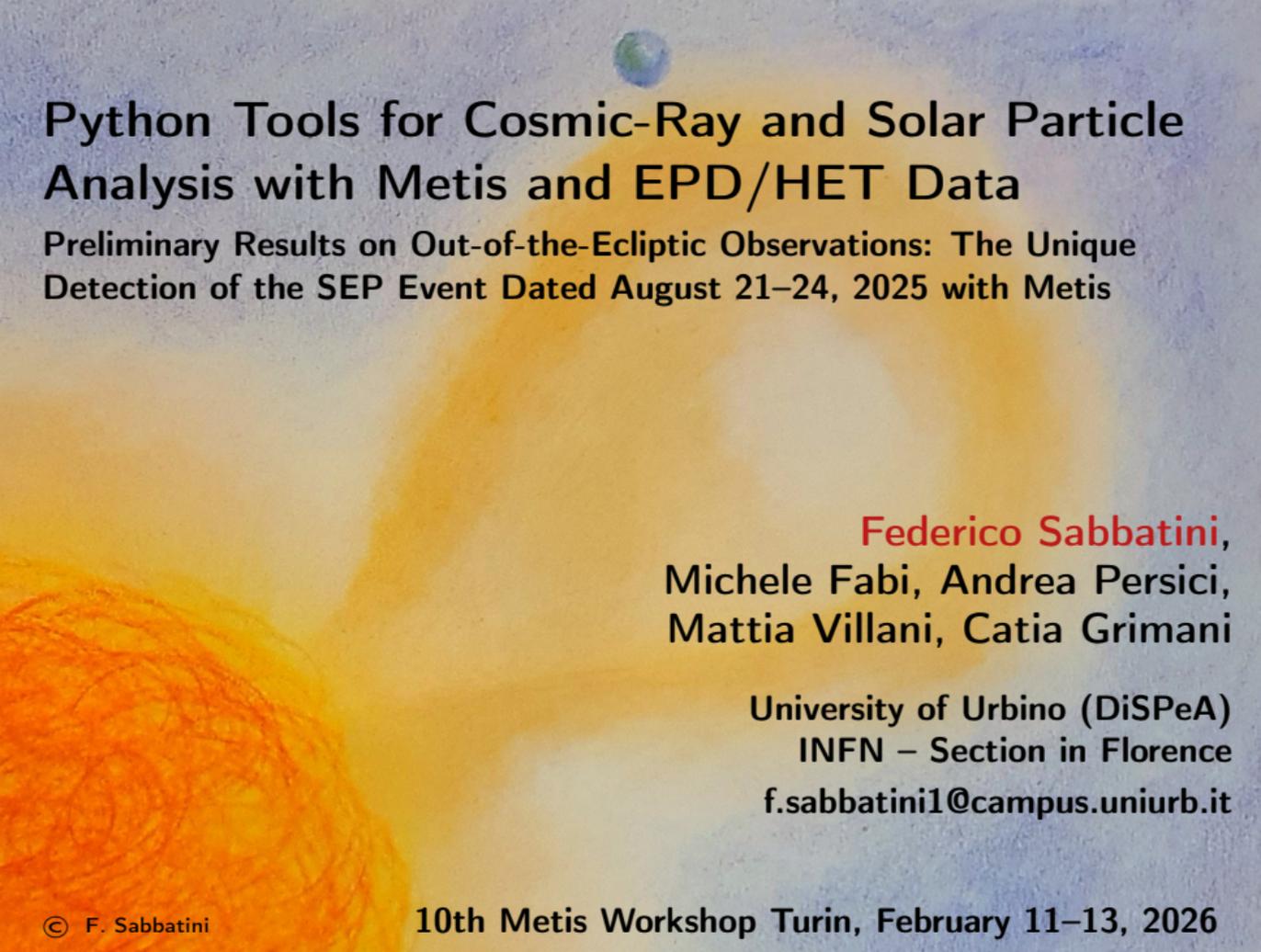- Automated analysis of cosmic-ray matrices → REBECCA
- Current results suggest a solar modulation parameter for August 2025 similar to that of February 2024
- Metis allowed a unique study of the strongest SEP event of Solar Cycle 25

Next steps

- Release SEPPEL + REBECCA
- Reconstruct the August 2025 event by simulating varying proton fluxes to obtain results aligned with the matrix tracks and the observed decay

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