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Planetary plasma instrument background counts Database & Service

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1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
2. **Dissemination level:**

PU	PP	RE	CO
Public	Restricted to other programme participants (including the Commission Service)	Restricted to a group specified by the consortium (including the Commission Services)	Confidential, only for members of the consortium (excluding the Commission Services)

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1. Introduction

The H2020 Europlanet-2020 programme, which ended on Aug 31st, 2019, included an activity called PSWS (Planetary Space Weather Services), which provided 12 services distributed over four different domains (A. Prediction, B. Detection, C. Modelling, D. Alerts) and accessed through the PSWS portal (http://planetaryspaceweather-europlanet.irap.omp.eu/):
A1. 1D MHD Solar Wind Prediction Tool – HELIOPROPA,
A2. Propagation Tool,
A3. Meteor showers,
A4. Cometary tail crossings – TAILCATCHER,
B1. Lunar impacts – ALFIE,
B2. Giant planet fireballs – DeTeCt3.1,
B3. Cometary tails – WINDSOCKS,
C1. Earth, Mars, Venus, Jupiter coupling- TRANSPLANET,
C2. Mars radiation environment – RADMAREE,
C3. Giant planet magnetodiscs – MAGNETODISC,
C4. Jupiter's thermosphere,
D. Alerts.
In the framework of the starting Europlanet-2024 programme, the Virtual Activity (VA) SPIDER (Sun-Planet Interactions Digital Environment on Request) will extend PSWS domains (A. Prediction, C. Modelling, E. Databases) services and give the European planetary scientists, space agencies and industries access to 6 unique, publicly available and sophisticated services in order to model planetary environments and solar wind interactions through the deployment of a dedicated run on request infrastructure and associated databases.
C5. A service for runs on request of models of Jupiter's moon exospheres as well as the exosphere of Mercury,
C6. A service to connect the open-source Spacecraft-Plasma Interaction Software (SPIS) software with models of space environments in order to compute the effect of spacecraft potential on scientific instruments onboard space missions. Pre-configured simulations will be made for Bepi-Colombo and JUICE (JUpiter ICy moon Explorer) missions,
C7. A service for runs on request of particle tracing models in planetary magnetospheres,
E1. A database of the high-energy particle flux proxy at Mars, Venus and comet 67P using background counts observed in the data obtained by the plasma instruments onboard Mars Express (operational from 2003), Venus Express (2006–2014), and Rosetta (2014–2015);
E2. A simulation database for Mercury and Jupiter's moons magnetospheres and link them with prediction of the solar wind parameters from Europlanet-RI H2020 PSWS services.
A1. An extension of the Europlanet-RI H2020 PSWS Heliopropa service in order to ingest new observations from Solar missions like the ESA Solar Orbiter or NASA Solar Parker Probe missions and use them as input parameters for solar wind prediction;

This report the status of the service E1 led by IRF Kiruna, Sweden, made operational at the end of the first year of the project.

2. SEPs flux proxy data at Mars and Venus. Motivation

High energy particles produced by space weather events (e.g., Coronal Mass Ejections, Corotating Interaction Regions) impact the space system. Monitoring and predicting the flux are thus main areas of interest. The interaction of high energy particles and planets is also a vital investigation. Though, not all the planetary missions include dedicated high energy particle detectors. Mars Express and Venus Express, the ESA's missions to Mars and Venus, did not equip with the high energy particle instrument. Instead, in this data package, we provide a database of proxy data of high energy particles in SPIDER.

3. Solar Energetic Particles flux proxy data at Mars and Venus. Derivation

The Solar Energetic Particle (SEP) can penetrate through the instrument wall, interacting with the detector (MicroChannel Plate, MCP), producing the background counts. Since the high energy particles get through the non-ideal way, these particles do not experience any filtering. Therefore, the produced "signal" is constantly distributed. For the Ion Mass Analyzer (IMA) onboard Mars Express and Venus Express, the nominal particles (ions with energies <15 keV) enter through the instrument aperture, filtered according to their energy, direction, and mass. Thus, the nominal dataset is a time series of a 4-dimensional matrix of count rates (like a 4-D histogram). The non-filtered high energy particles are, on the other hand, distributed almost evenly. Since there are some areas in the 4-D histogram where the nominal particle can reach, the areas can be used as a background monitor, providing a high-energy particle flux proxy.

Figure 1 shows an example of raw data collapsed into 2-dimensional representation. The signal (count rate) of the ions as a function of energy step and mass channels is represented. A comparison between panels obtained during the nominal time and the high fluence of energetic particles are shown. In addition to the "blobs," which are signals produced by the real incident ions, relatively constant background counts can be seen during space weather events (Futaana et al., 2008).

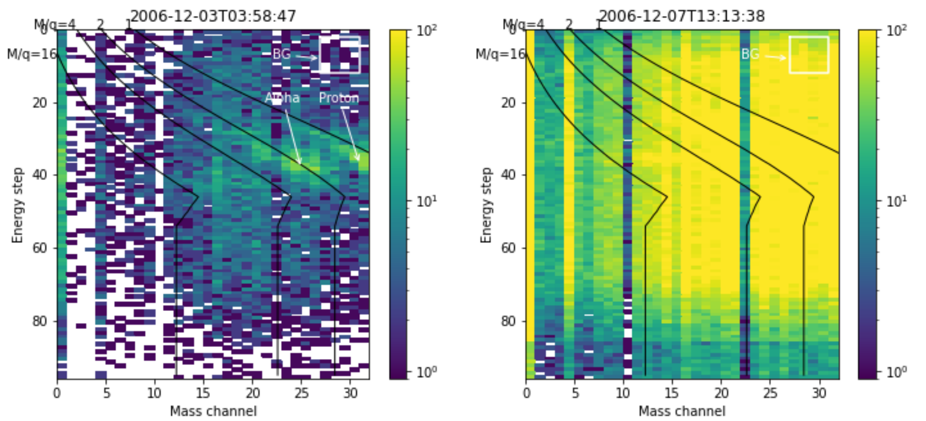

Figure 1: The Ion Mass Analyzer raw data at the Mars position during (left) nominal condition and (right) SEP period in December 2006 (Futaana et al. 2008). The color scale represents the ion counts registered to each energy-mass bin, and the black curves show ideal locations where real ions with specific mass-per-charge (M/Q=16, 4, 2, 1 [amu/e]) is registered. The real proton and alpha are seen around the energy step 40, at the different mass channel for the nominal case (left). The background (BG) caused by SEP overwhelms the real signal during the harsh event (right). The top right white box labelled with BG shows the area used to derive the proxy data.

In the energy-mass representation, the IMA sensor has areas where no real ions can reach. For example, in Figure 1, an upper right corner is such a region. Therefore, the area can be used for background monitoring.

For Mars Express IMA, we integrate the energy step 2 to 12 and mass step 27 to 30. For Venus Express IMA, we integrate the energy step 2 to 18 and mass step 25 to 30. The integration is done every 192s, during which one measurement cycle of IMA is completed.

4. Dataset

The dataset in the first delivery contains

- High energy particle proxy at Mars: Nominal mission start (2004) to the end of 2019. The data is sampled with a cadence of 192s.

- High energy particle proxy at Venus: Nominal mission start (2006) to the mission end (2014). The data is sampled with a cadence of 192.

Figure 2 shows the example of the time series of the dataset.

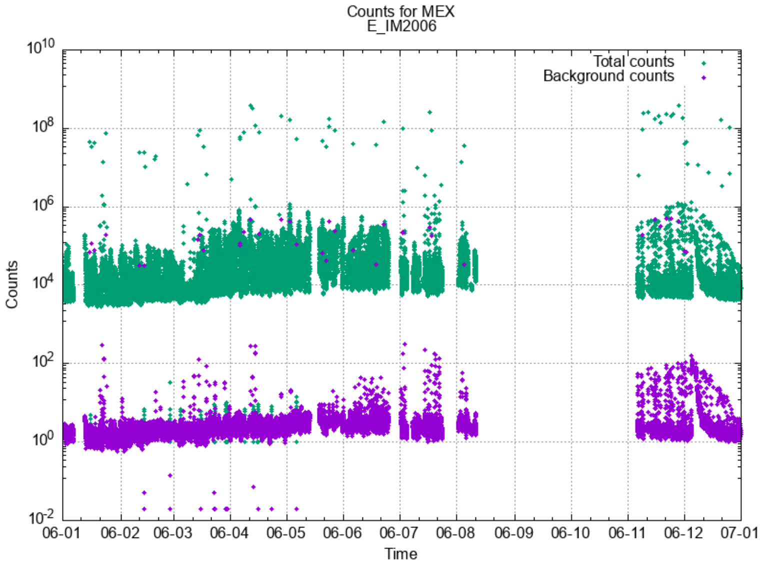

Figure 2: The background proxy data in the year 2006. There was a severe space weather event in December, where a significant increase in background counts are seen.

5. E1 Service made operational

The database is publicly available in the CDPP (Space Plasma Data Center) /AMDA (Automated Multi Dataset Analysis) tool (http://amda.cdpp.eu)

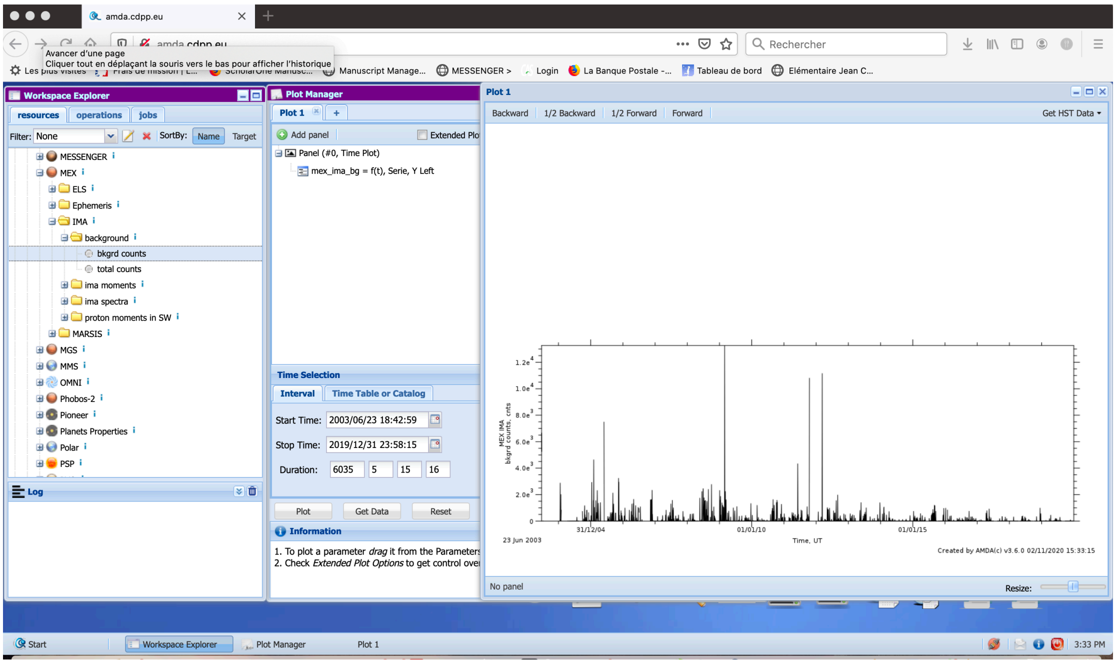

Figure 3: Overview of AMDA functionalities applied to the dataset; left: data tree; middle: data plot selection; right: visualization of the complete time-series of background counts from Mars Express/IMA.

6. Limitations

- The background data can exhibit an only relative difference of high energy particle fluence within a single sensor. No comparison between Mars Express and Venus Express and Rosetta can be conducted.

- It is not straightforward to "deconvolve" the proxy counts to the real flux (or differential flux) of the energetic particles. There are non-linear effects in the response of the background against the incoming particle energy.

- In a single sensor, short-term variation is not straightforward to interpret. The instrument is not designed to monitor the background counts. The response of the sensor against the high energy fluence has not been characterized. Although the data is sampled every 192s, short-term variations with a period shorter than an hour are highly unlikely reliable. Short-term spikes (only for several samples) are not reliable as well.

- In a single sensor, there are several operation modes, which impact the background proxy. The most significant effect comes from the "background subtraction" mode. If this mode was used, the sensor subtracts the low count in the measurement bin in the data onboard. On the positive side, this mode helps high compression, supporting the long-time operation. As a drawback, the background proxy data cannot be coherent.

7. Perspectives

1. Addition of metadata, cleaning spikes: Operation mode (see Limitation) information is needed for interpreting the proxy data. We will add this information with proper notes.

2. Delivery of high-energy particle fluence at Comet 67P: The same method from Mars Express and Venus Express can be applied to Rosetta Ion Composition Analyzer (ICA) data onboard Rosetta. The data is available between 2014 and 2016 when the Rosetta spacecraft was in operation.

3. Delivery of high-energy particle fluence at Mars to the latest data: Mars Express is in operation, and we foresee the further extension of the mission. IMA instrument is healthy so that the same parameters will be derived at Mars.

4. Identification of SEP event onset time at Mars, Venus, and Comet 67P: Using the time series of the high energy proxy data, we can derive the SEP event arrival for respective spacecraft. It can be seen as a sudden increase in the proxy data. We will produce lists of the onset time of such events at a respective planet location.