Coupling numerical simulation codes and space environment databases thanks to SPASE

IHDEA meeting– October 2023

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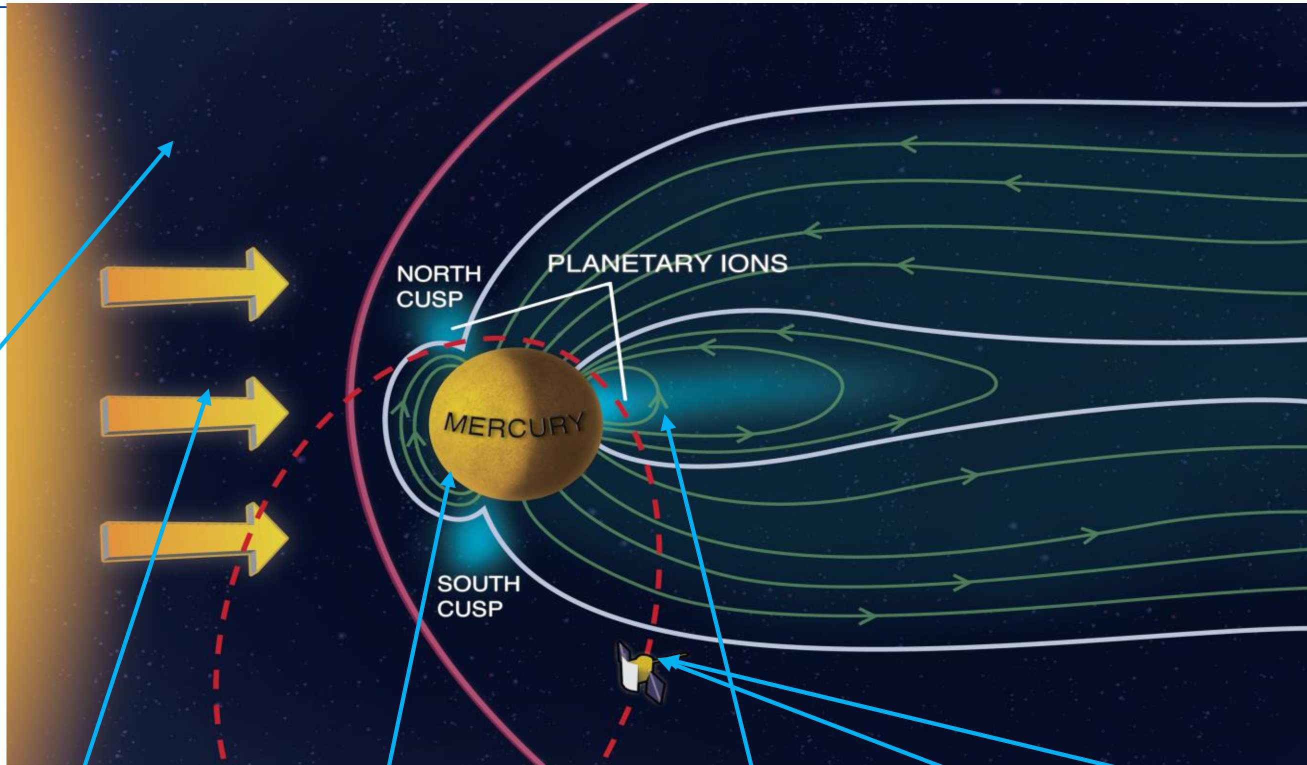
The Europlanet-2024 Research Infrastructure project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 871149.

Context: The Sun Planet Digital Environment work package of the Europlanet 2024 Research Infrastucture



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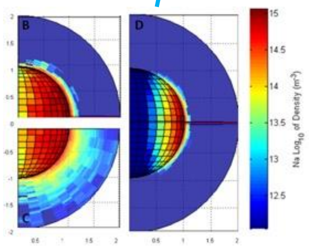
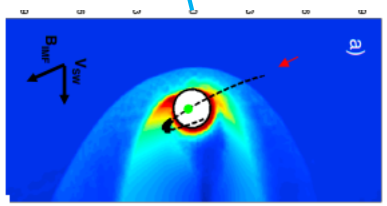
Solar Wind measurement

Propagation Tool

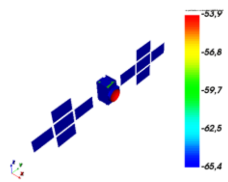
Solar Wind propagation



Exosphere modelling



Magnetosphere modelling



Spacecraft modelling

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Instrument measurement

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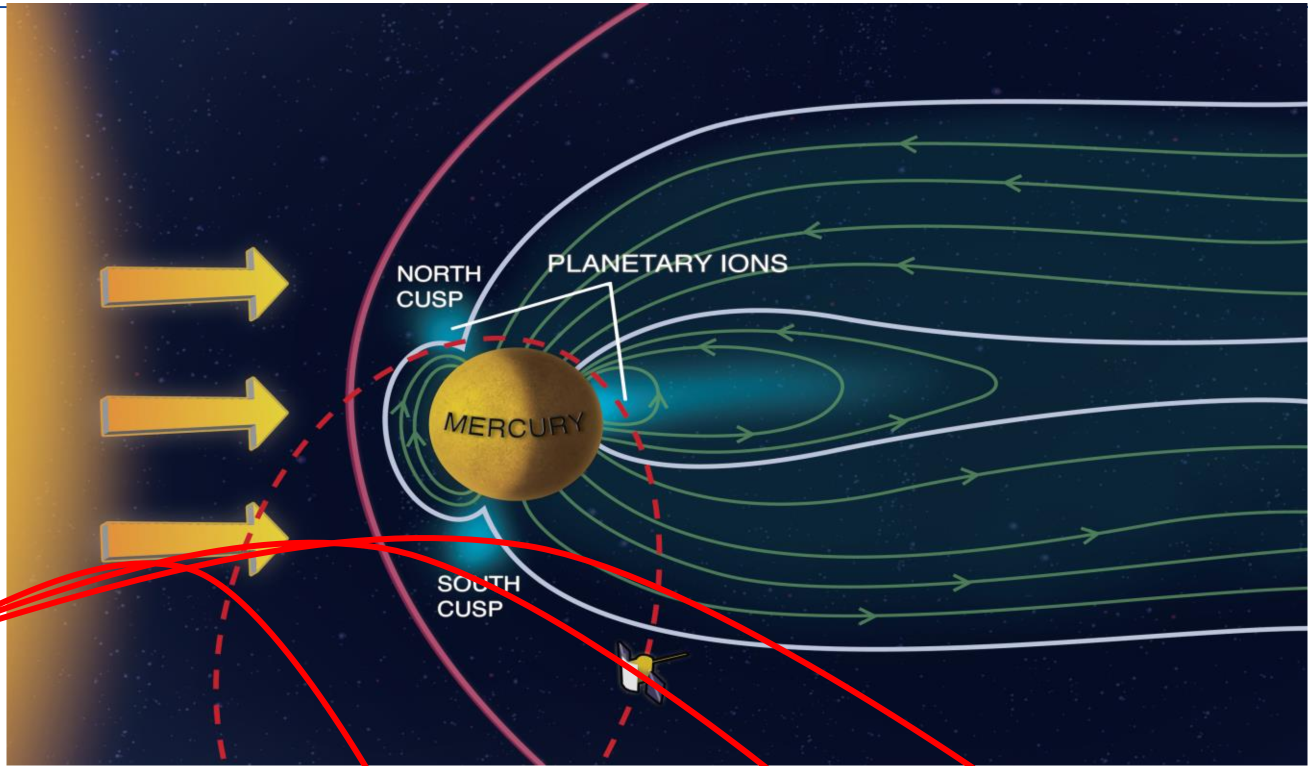

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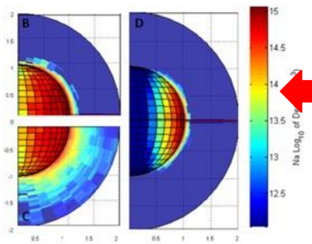

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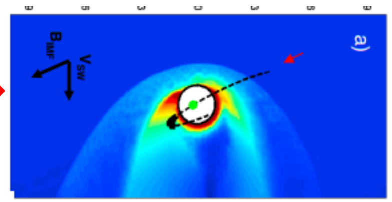

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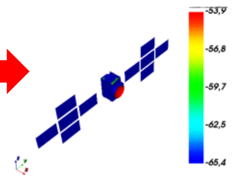

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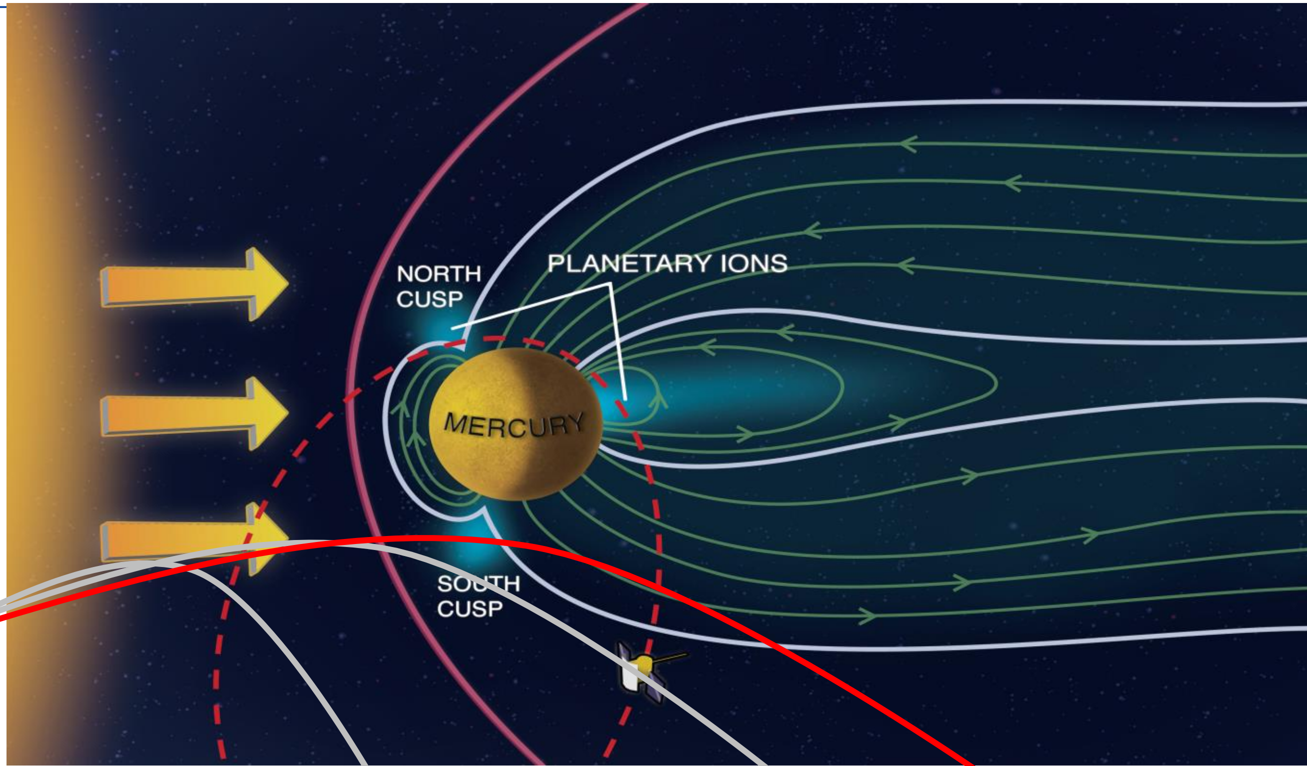

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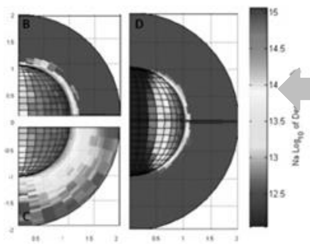

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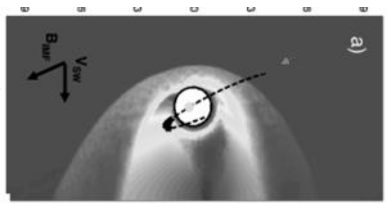

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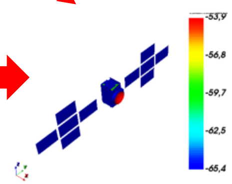

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Context:The Spacecraft-Plasma Interaction Software (SPIS)

- Simulates the charge state and the plasma environment of spacecraft

  geometry + materials + plasma conditions → charge state + local plasma environment

- Multi-physics (plasma, radiations, dusts, contamination, erosion,…), i.e. multiple sub-models
- Open-source, developed by ONERA and Artenum,

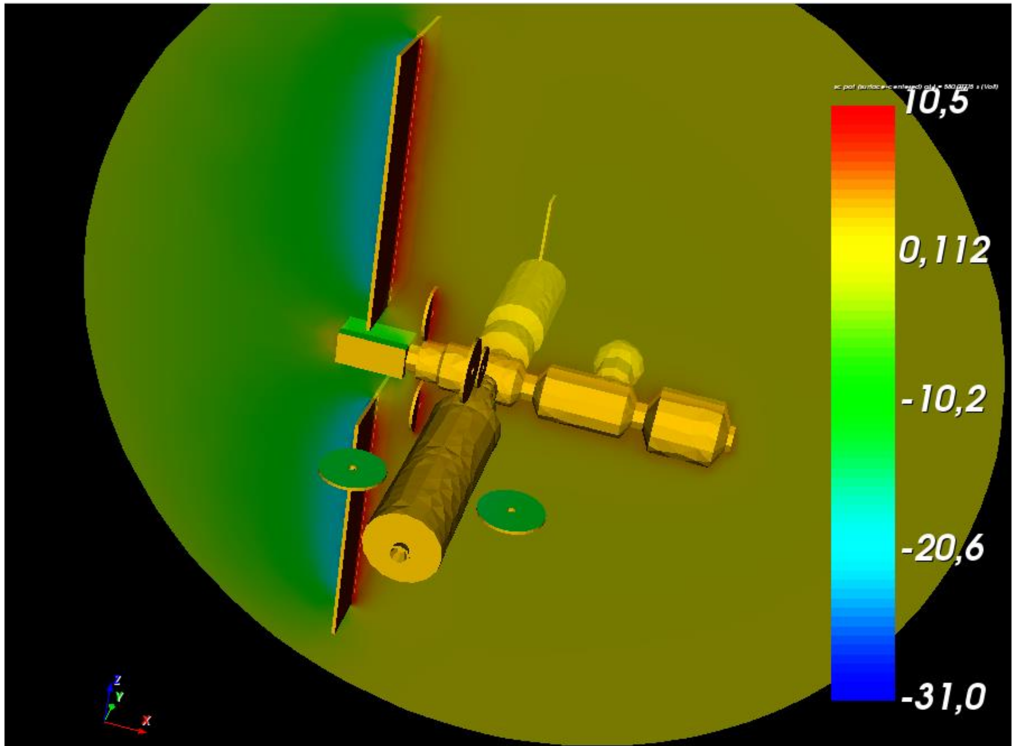
  with support of ESA and CNES

- Originally used by industrials for platform

  electrostatic risk assessment

- More and more used for charging impact on science

  instruments, pre-calibration and data analysis



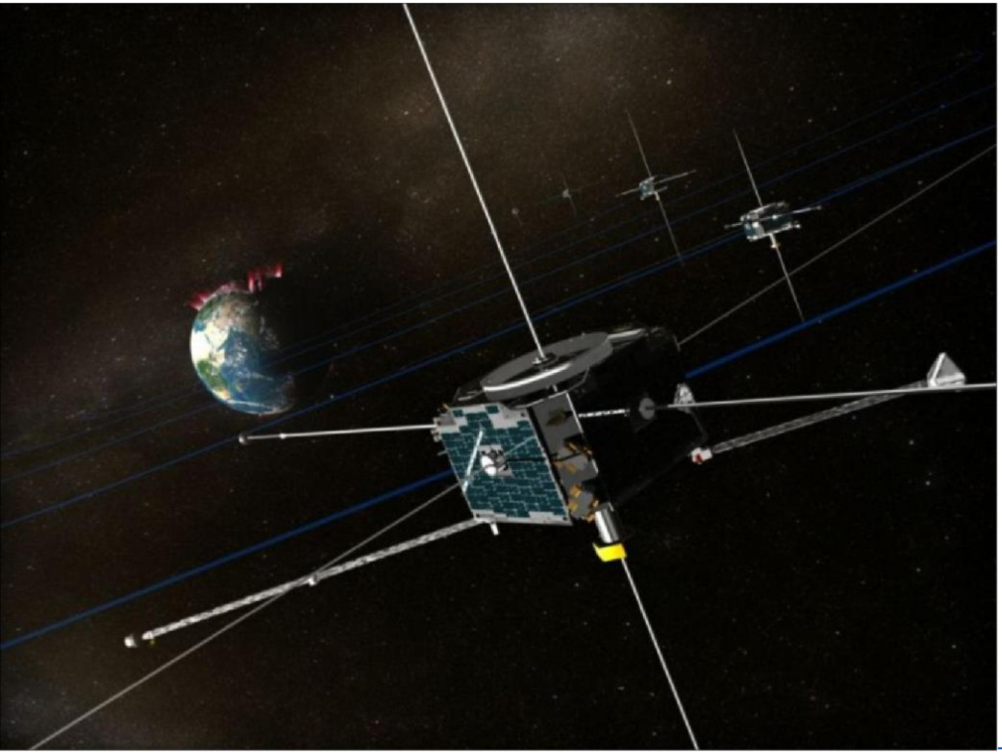
[Dandouras et al., 2023]

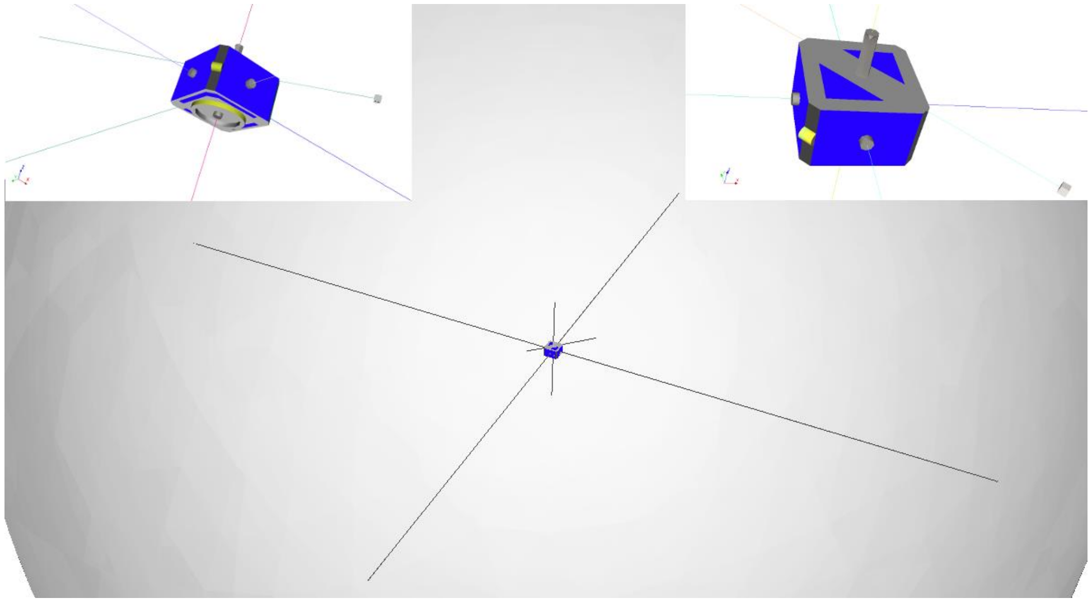
Context: Simulation of THEMIS-B

- To illustrate the new capabilities of SPIS, we perform a simulation of the THEMIS-B spacecraft

- The NASA THEMIS (Time History of Events and Macroscale Interactions during Substorms) mission was to explore the Earth magnetosphere, providing both temporal and spatial resolution though the use of 5 similar spacecraft

- THEMIS spacecraft is meter-sized with 4 ~20 meters antennae + 2 3 meter antennae. The spacecraft has a full instrument suite to measure environment electromagnetic fields and particle distributions.





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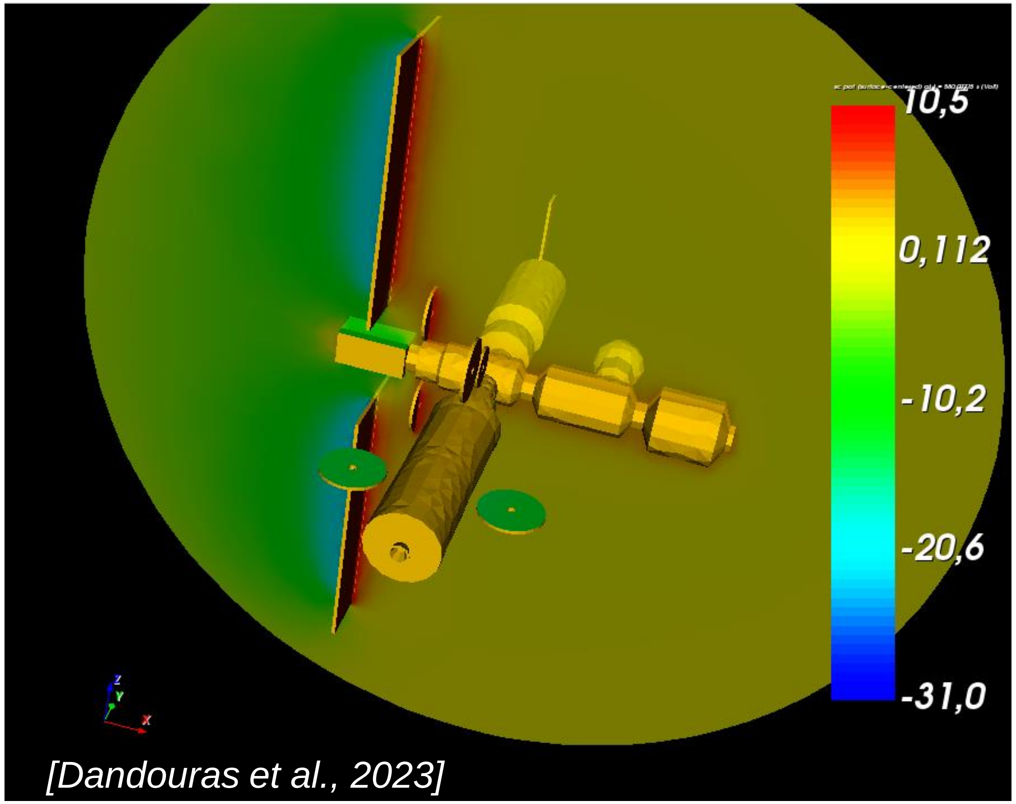
- Open-source, developed by ONERA and Artenum, with support of ESA and CNES
- Originally used by industrials for platform electrostatic risk assessment
- More and more used for charging impact on science instruments, pre-calibration and data analysis
- **Can simulate instrumental observations, but needs accurate environment description as input**



Introduction and Conclusion (in case some fall asleep)

- Multi-physics simulation of science instruments/mission interactions with the environment with SPIS
  - estimate charging levels in actual environments
  - estimates the impact on science instrument (pre-calibration, data inversion…)
- We interface SPIS with SPASE to access instrument measurements databases
  - Use of webservices (AMDA, CDAWeb, Vespa) for registry and data access
  - direct access to HPDE repository for metadata
- We demonstrate:
  - SPASE allows a lot of automated pre-filtering of relevant data with correctly filled metadata
  - Software can easily find and interpret data files from different origin and import the data

    but: - **need an API to list and filter HPDE registry content**

    - **need an (H)API to get the required data in a standardized way**
- **Metadata are not only meant to put your data in large registry, they can facilitate the life of the people working with your data, allowing their handling by tools following the standards**
- **Tools are not intelligent, the more accurate the metadata, the more powerful can be the tools**

The Space Physics Archive Search and Extract (SPASE)

SPASE inside

- Data model (Standardized description) developed for 15+ year by an international alliance
- Targets heliosphere, magnetosphere and plasma environment physics
- Provide a standardized way of describing:
  - which datasets exist, what they are about
  - how they were acquired (mission, instrument, people…)
  - where (not how) to find them, under which format
  - what their content is (meaning, unit, field ID…)
- Human readable AND machine actionable description of the data file content
  - metadata to identify and order/filter the resources
  - metadata keywords to identify the physics meaning of data fields
- **Question:**
  - **Make the tool recognize the fields it can use**
  - **Automated match available / requested data with SPIS I/O ?**

Ingestion of data in SPIS: find the available data (first issue)

- Access all resources registered @ NASA's Heliophysics Data Environment Portal

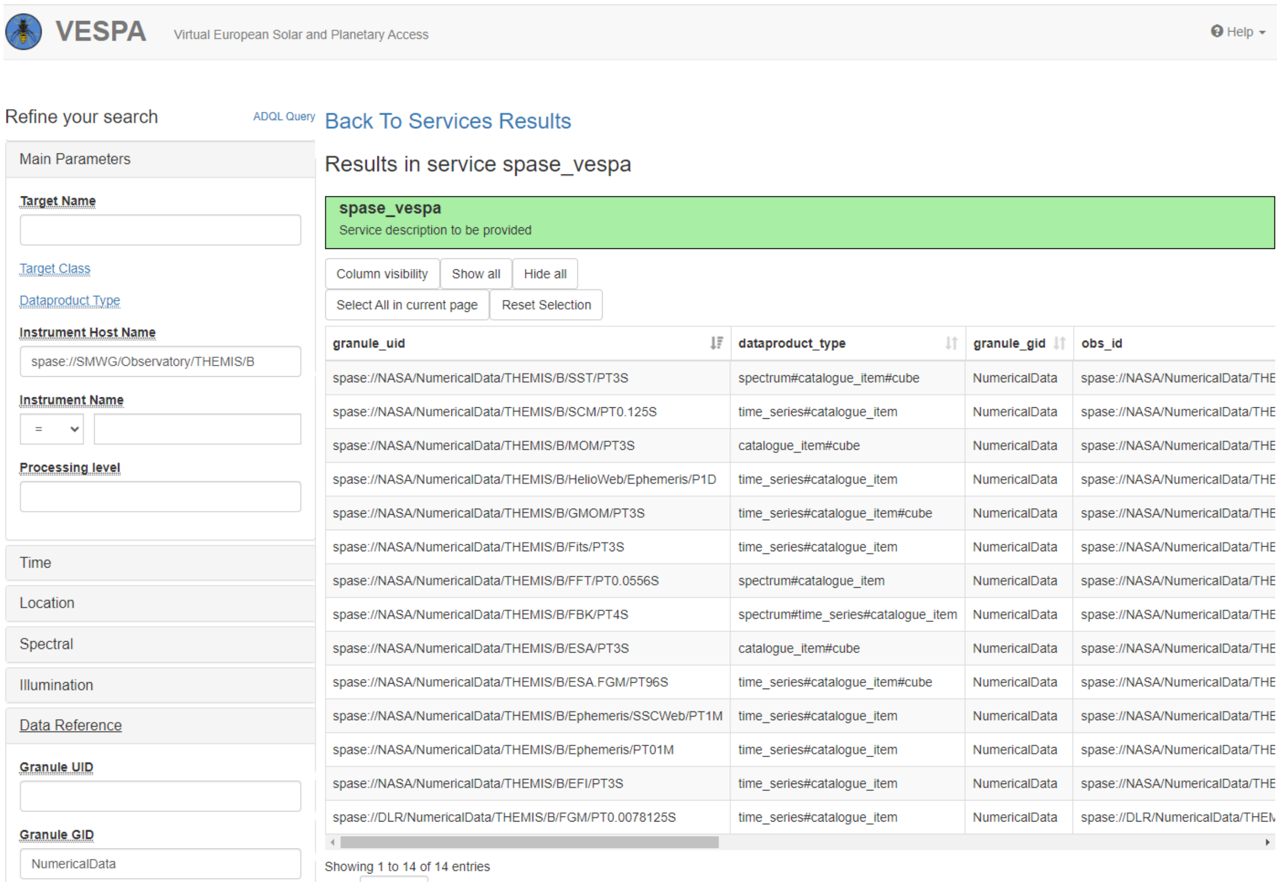
- No registry API:
  - impossible to list the available data:
    downloading and parsing the 16000+ XML files is not a good option!

  - impossible to order the data
    relying on the ID parsing (folder like) is not a good option
    think at how many hours you lost looking for which folder contains the data you want!
    folder ordering unreliability is exactly why data model were invented
    do not try to override the SPASE description by defining ResourceID guidelines!

- To overcome these issues, we built on the VESPA portal from Observatoire de Paris to generate a SPASE registry API based on the EPN-TAP standard

Ingestion of data in SPIS: find the available data (first solution)

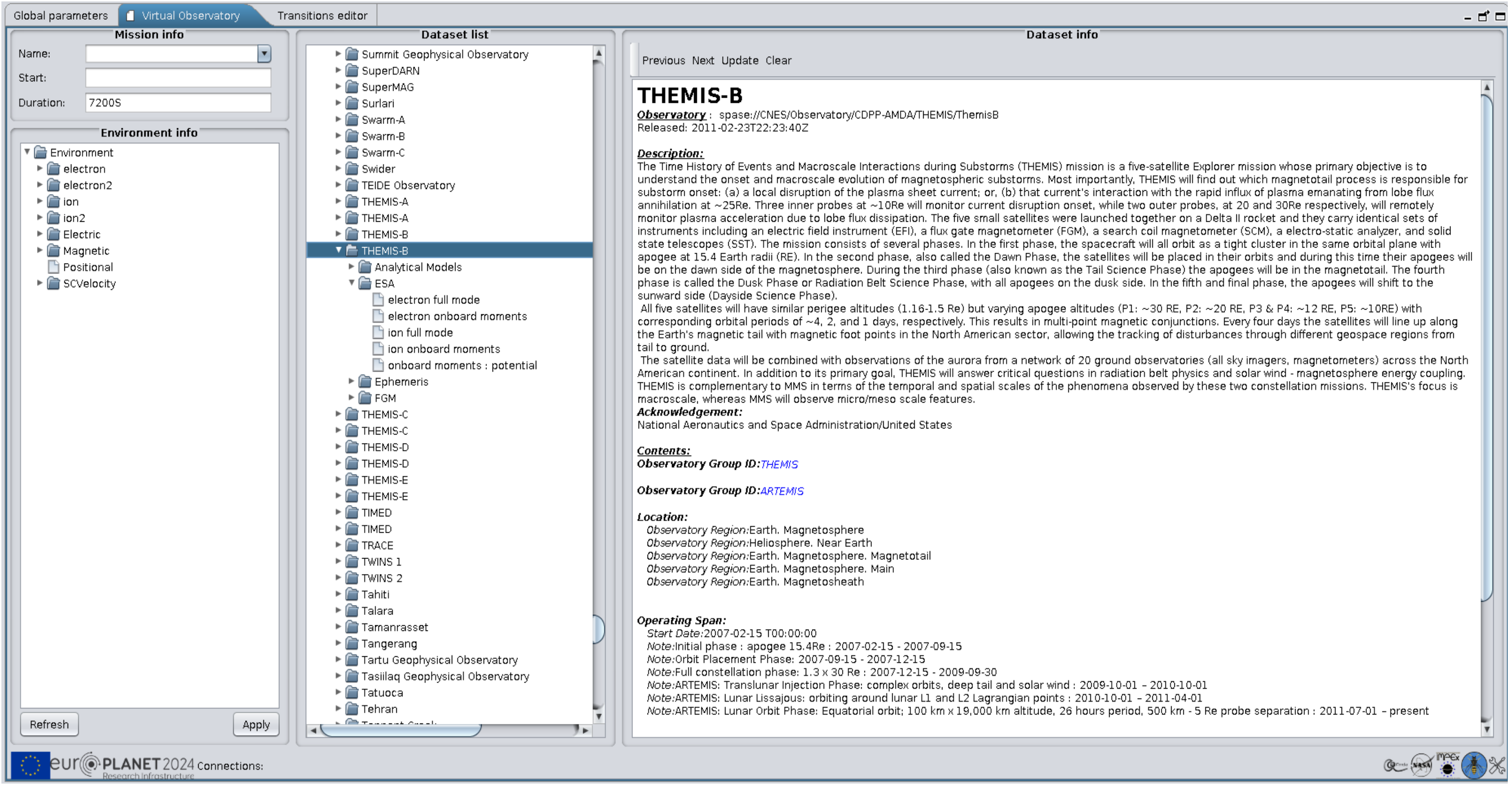
- To overcome these issues, we built on the VESPA portal from Observatoire de Paris to generate a SPASE registry API based on the EPN-TAP standard
- SPIS uses the webservice API



Ingestion of data in SPIS: find the available data

- To overcome these issues, we built on the VESPA portal from Observatoire de Paris to generate a SPASE registry API based on the EPN-TAP standard

- SPIS uses the webservice API to list and order resources, then use hpde.io to get SPASE description



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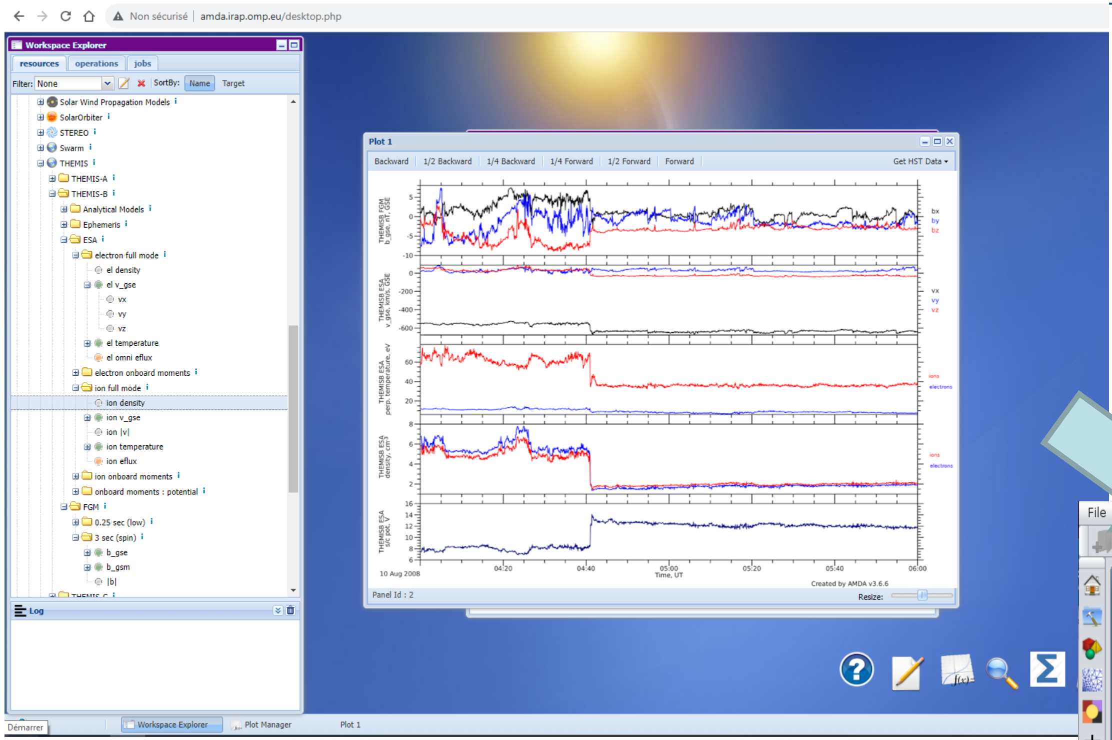
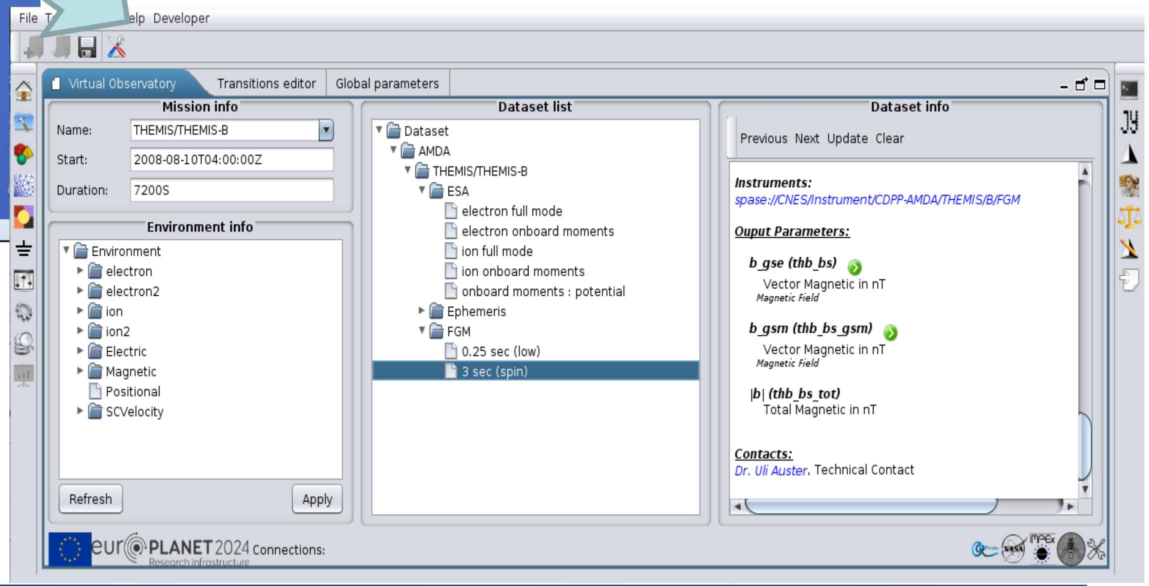
Ingestion of data in SPIS: select the datasets of interest



- Use Virtual Observatory tools to identify period of interest (here THEMIS-B on Aug. 10th, 2008 4AM)
- Report mission, date and duration in SPIS
- Existing datasets are displayed
- **Then, which data field should be used?**



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Ingestion of data in SPIS: find and select data of interest

Data fields/ SPIS inputs description

- SPASE <NumericalData> describe the content of datasets:

    - with a type (Particle, Fields,…)

    - with a physics quantity (density, current…)

    - with supporting qualifiers (vector/scalar, average/peak…)

Renaming in v2.6.0?

- SPIS <SimulationModel> defines environment inputs
    - Particles:
        - Density *(Quantity:NumberDensity)*
        - Velocity *(Quantity:Velocity ; **Qualifiers: Vector**)*
        - Temperature *(Quantity: Temperature)*

    - Field:
        - Electric *(Quantity:Electric ; **Qualifiers: Vector**)*
        - Magnetic *(Quantity:Magnetic; **Qualifiers: Vector**)*

    - Positional (for use with simulated environment)

- Data Content description
    - Name
    - Key
    - Quantity
    - Qualifier
    - Unit
    - **Type**

- Simulation input description
    - Name
    - Label
    - Quantity
    - Qualifier
    - Unit

Ingestion of data in SPIS: find and select data of interest

Data fields/ SPIS inputs comparison

- How to compare output parameters and input properties?
  - List pertinent fields
  - Pair them when possible → no equivalent of type!
  - Weight the comparable pairs
    - Quantity must be identical
    - Unit must be convertible
    - Qualifier must match as much as possible
    - Name matching is not reliable
    - Key matching even less *(unless further specifications)*
- Even though Qualifier comparison may not be perfect match, dimension information may be important and/or required *(Scalar, Vector,Tensor,…)*
- Value Range can be matched if specified *(MinValue,MaxValue)*
- **Exact matching cannot be ensured, user final inspection required anyway.**

- Data Content description
  - Name
  - Key
  - Quantity
  - Qualifier
  - Unit
  - **Type**
- Simulation input description
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Ingestion of data in SPIS: find and select data of interest

Select SPIS model based on available data

- SPIS is multi-physics / multi-models and modular
  - each model described by a <SimulationModel>
  - use AssociationType::PartOf to define submodels
  - use AssociationType::DeriveFrom to define submodels extension

    PopulationModel part of SPIS

    MaxwellianPopulation derive from Population Model

- Models may require different input (detailed in SimulationModel::InputProperties)

- Model selection by user, but SPIS can help by checking which models can be set given the available inputs (in development)

- Data Content description
  - Name
  - Key
  - Quantity
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  - Unit
  - **Type**

- Simulation input description
  - Name
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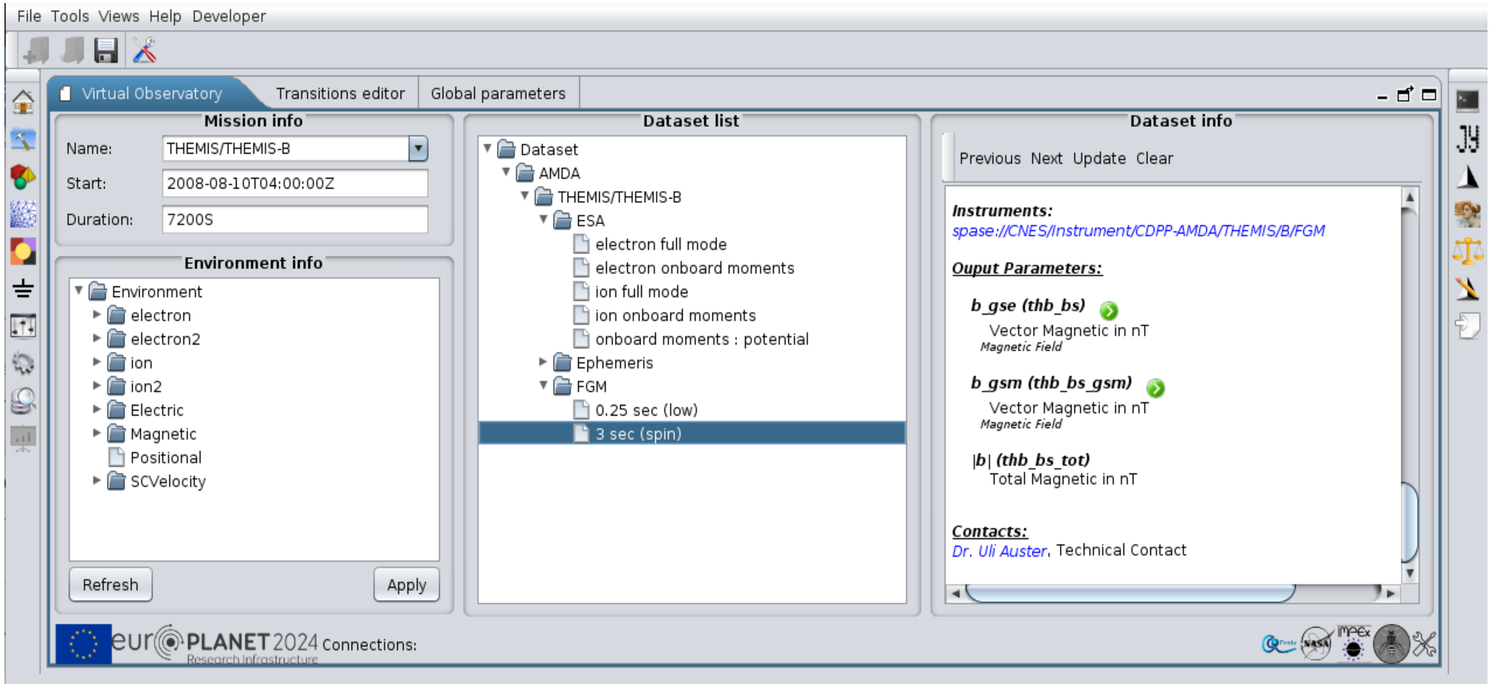
Ingestion of data in SPIS: find and select data of interest
THEMIS examples

- Magnetic Field example:

  - SPIS search for a data description defined as a Field, magnetic qualified as a vector (SPIS is 3D)

  - Two possible matches found for Themis FGM

  - **Magnetic field magnitude discarded (not a vector)**



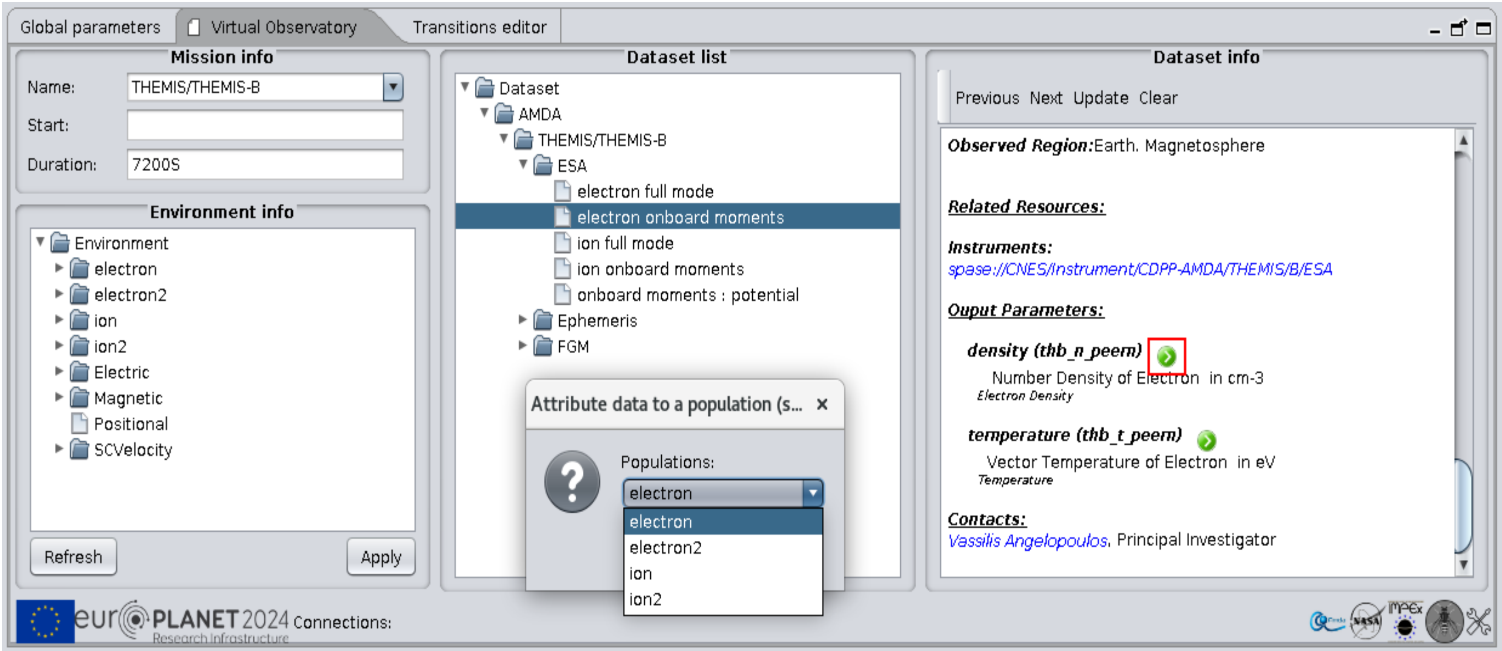
Ingestion of data in SPIS: find and select data of interest
THEMIS examples

- Particle example:

    - density, velocity and temperature found… for which population?

    - SPASE allows some simple description (e-, H+, α, ions, dusts….)

    - SPIS ask the user to attribute the data to a population, with a pre-election based on SPASE



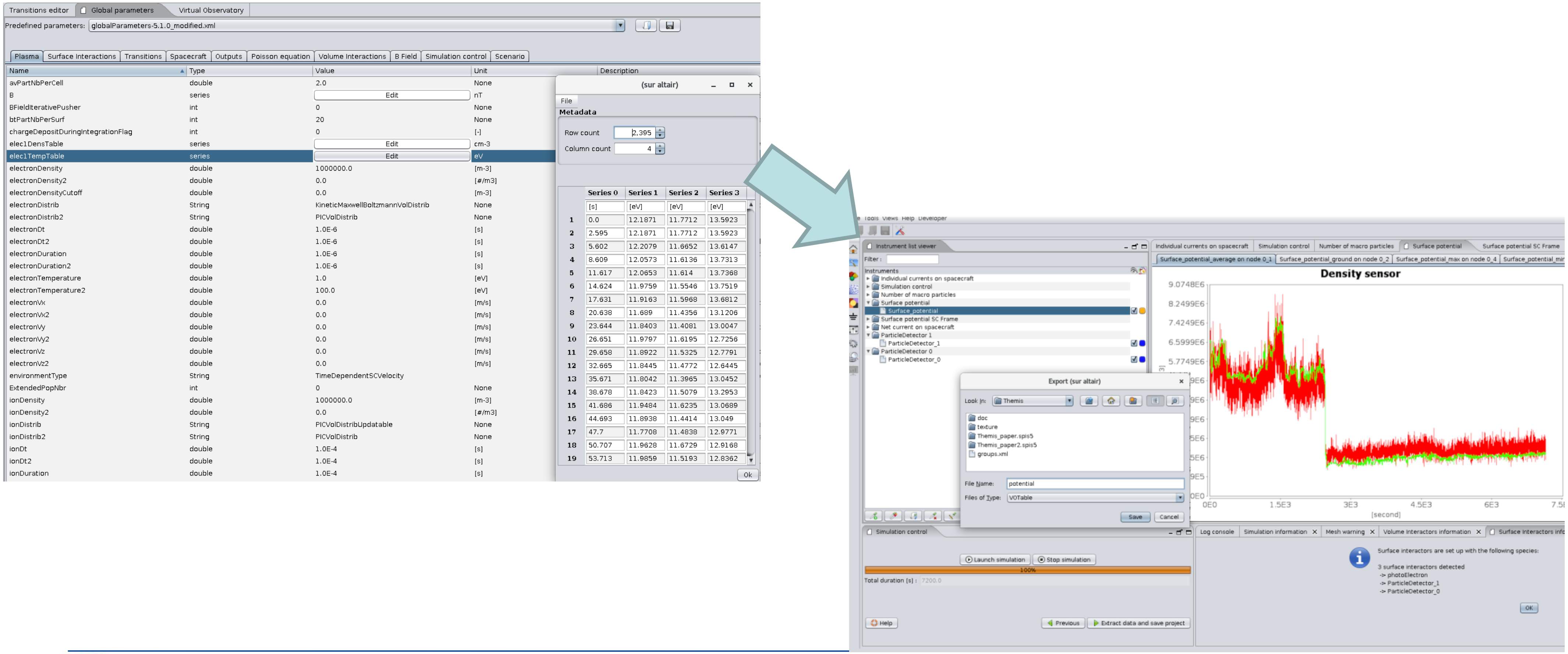
Import the data and run (second issue& solution)

- Once selected, the data must be imported.
- Many ways of accessing the data
- SPASE give many hints as of HOW to get the data (AccessInformation)
  - But the actual request to service is not described
  - The tool needs to know each providers/gateway formalism to get the data
  - HAPI is a solution for time series

- SPIS implements interfaces to AMDA and CDAWeb for data request

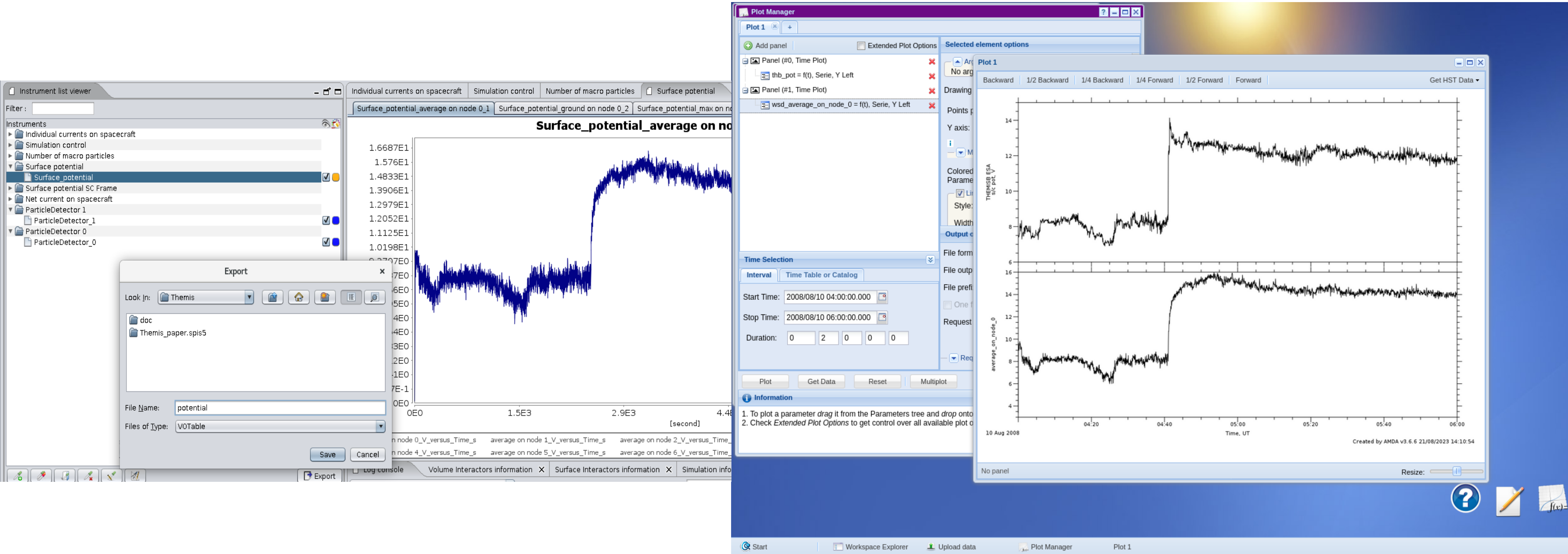
Import the data and run

- Once selected, the data can be imported to SPIS which knows from SPASE who to ask and how
- The imported data are used for the simulation, in which they can be monitored



Import, run and export

- Once selected, the data can be imported to SPIS which knows from SPASE who to ask and how
- The imported data are used for the simulation, in which they can be monitored
- Some instruments results can be exported in VOTable with SPASE description for use in databases, tools ….



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