Solar Orbiter data access with Amda GUI + Python API

Vincent Génot and the CDPP/AMDA team

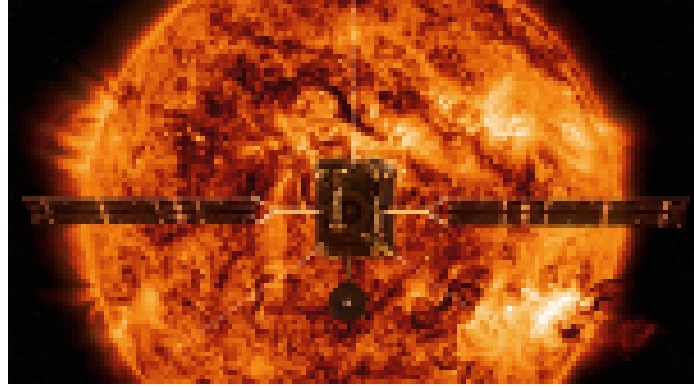
Ecole des Houches / Solar Orbiter

April 2021

http://amda.cdpp.eu/



Data



- Public data from SOAR http://soar.esac.esa.int/soar/
- In-situ instruments: MAG, PAS, EPD, *RPW*
- Time series (scalar, vector, spectro)
- No distribution functions $f(v_x, v_y, v_z)$ → *see presentation by P. Louarn*

- AMDA can accomodate private access to data for designated groups of users (collaborations, projects, …; see the example of Rosetta Plasma Consortium)

Outline

- AMDA general principles
- AMDA GUI
  - Use case #1: plotting Solar Orbiter data (MAG, PAS, derived parameters)
  - Use case #2: plotting PAS spectrograms
    - *Note: distribution functions will be shown at the end of the session by P. Louarn on CLweb*
  - Use case #3: data mining and event lists
  - *Use case #4: plotting RPW data*
  - Use case #5: downloading data
  - Use case #6: plotting EPD data (*by A. Rouillard*)
- AMDA Python interface
  - amdapy
  - Jupyter notebook

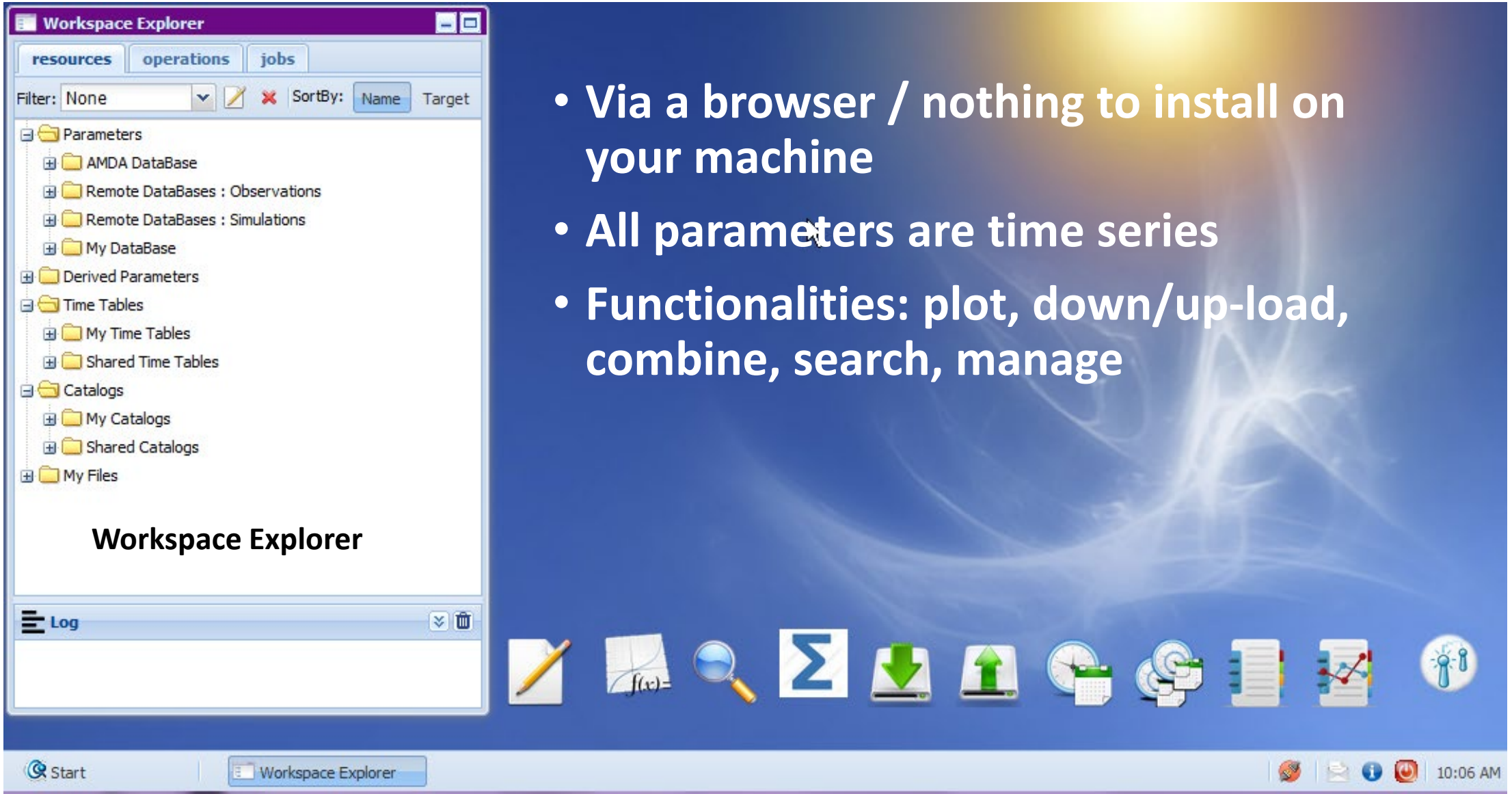


AMDA general principles

Context

- **A**utomatic **M**ulti-**D**ataset **A**nalysis
- Simplifying data access to various data sources in heterogeneous formats
- A plot should only be a few clicks away
- Data mining on long time series to produce catalogues / event lists
- Developped since 2006 by the CDPP, the French Plasma Physics Data Centre http://www.cdpp.eu/
- Support by CNES, CNRS and various collaborative projects
- See *Génot et al.*, 2021 (in press in PSS) for a global overview of functionalities including access to simulations, interoperability, …

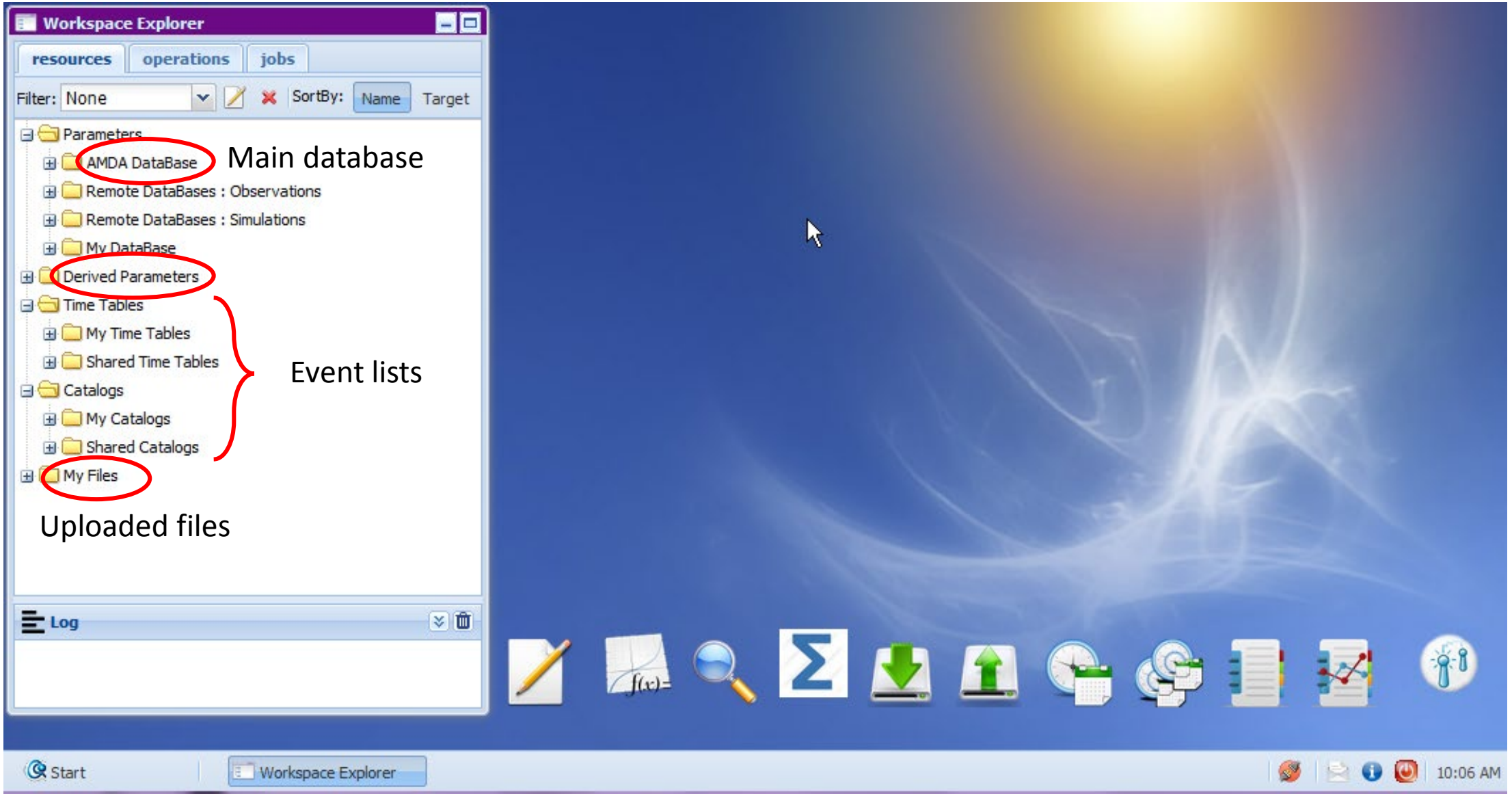
Easy access to science quantities

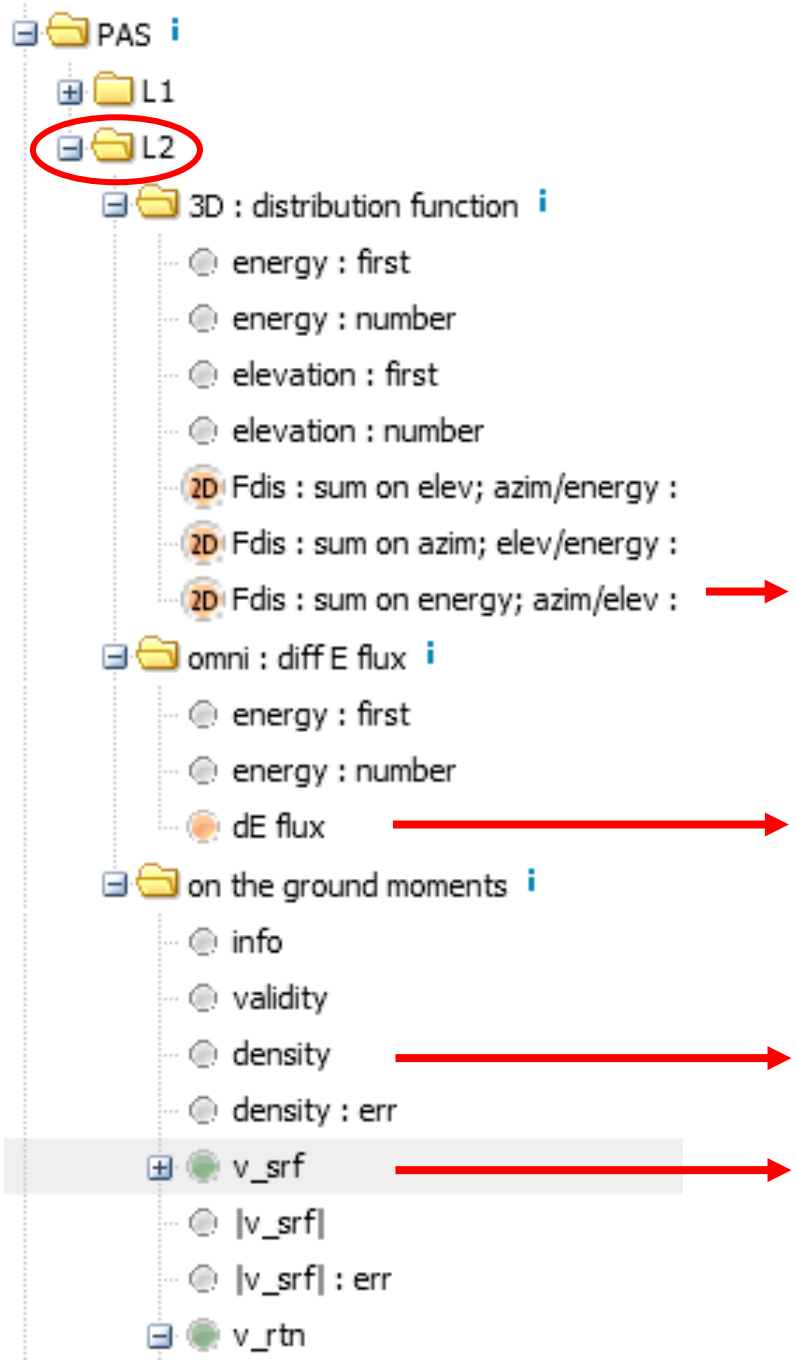


Workspace Explorer

- **Via a browser / nothing to install on your machine**
- **All parameters are time series**
- **Functionalities: plot, down/up-load, combine, search, manage**

Easy access to science quantities





Parameter types

distribution function (see dedicated slides)

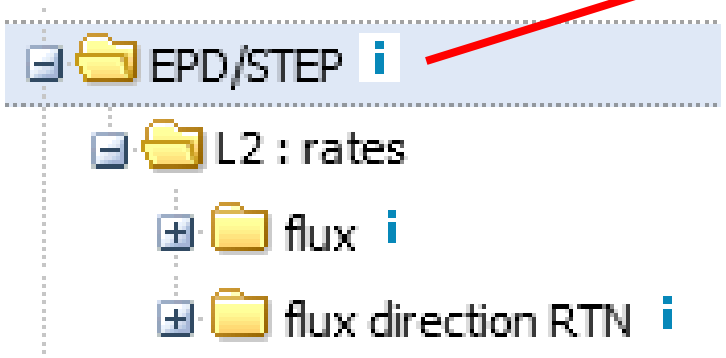
spectrogram (integrated on angleS)

scalar

vector / extend on ‘+’ to access components

Information on instrument

- Help is provided by clicking on the blue i
- Information comes from the archives or laboratories which provide the data



EPD/STEP

Energetic Particle Detector / SupraThermal Electrons And Protons

Description

The Energetic Particle Detector (EPD) is an instrument suite comprising different sensors that have been designed to measure the spectra, composition, time variations, and directional distributions ofenergetic particles. These measurements will be performed over a partly overlapping energy range encompassing a few keV to 450 MeV/n, with sufficient time, energy, angular, and mass resolution to achieve the mission science goals. The EPD consists of the following units :

- SupraThermal Electrons and Protons (STEP).

Designed to measure protons and electrons at supra-thermal energies (between 2 and 80 keV). It employs two co-aligned sensor heads with a parallel field of view. One of the sensor heads contains a permanent magnet that deflects electrons out of the nominal field of view, this is referred to as magnet channel and measures all types of particles except electrons. The other head measures every particle in the energy range including electrons and is called integral channel. Each head contains a solid state detector divided in several pixels to achieve angular resolution. For each channel there are 15 pixels distributed in 3 rows and 5 columns, plus a separate pixel for measuring background.

Information links

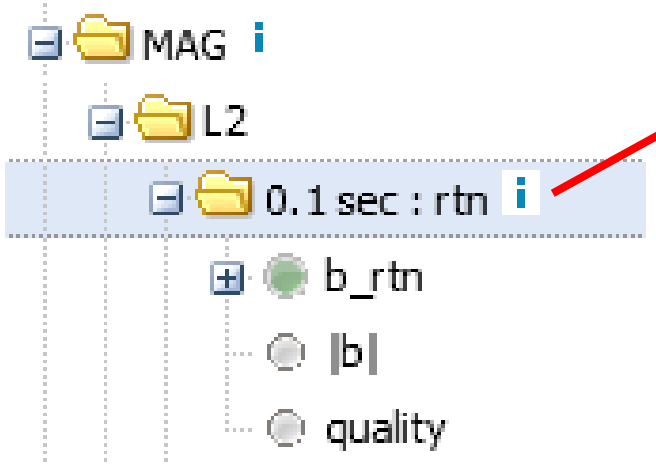
Instrument Description

Contacts

Principal Investigator: Dr. Javier Rodrigues-Pacheco
fsrodriguez@uah.es - Space Research Group, Universidad de Alcala

Information on dataset

- Help is provided by clicking on the blue i
- Information comes from the archives or laboratories which provide the data



0.1 sec : rtn

Magnetic Field In RTN : 0.1 Sec

Last Updated

2021-03-02T04:21:24Z

Description

Publication quality. Take note of Quality Flag and refer to SOL-MAG-DPDD for exceptions (see SolO Archive Support Data)

Information links

SolO home page at Imperial College
SolO Archive Support Data

Caveats

Flag setting:

- 0: Bad data;
- 1: Known problems use at your own risk;
- 2: Survey data, possibly not publication quality;
- 3: Good for publication subject to PI approval;
- 4: Excellent data which has received special treatment; refer SOL-MAG-DPDD for more information on how these flags are generated."

Temporal description

Time range: 2020/04/15 00:00:00 — 2020/12/31 23:59:59
Sampling: 0.1s

Provider

Name: http://soar.esac.esa.int/soar
Resource name:
MAG-RTN-NORMAL

Acknowledgement

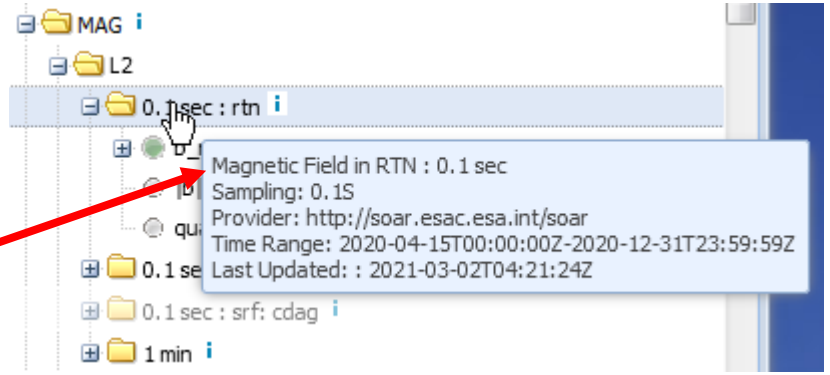
Solar Orbiter magnetometer data was provided by Imperial College London and supported by the UK Space Agency

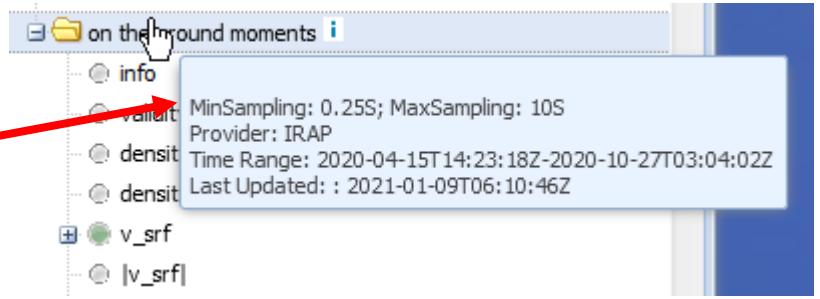
Contacts

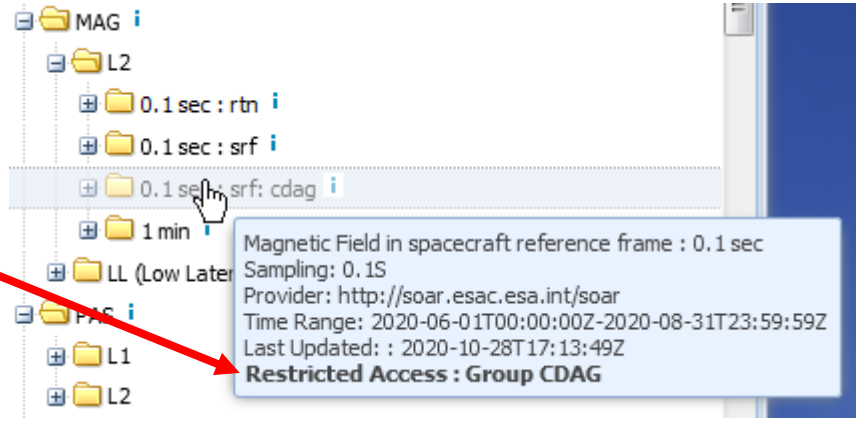
Principal Investigator: Dr. Timothy S. Horbury
t.horbury@imperial.ac.uk - Imperial College, UK

Information on datasets

- Provided in tool tips / info bulles
- Shown « on mouse over »
- Information
  - Description
  - Sampling: single value or min/max
  - Provider: SOAR, IRAP, …
  - Time range
  - Last update by AMDA
  - Restriction to a group of users (grayed directories)

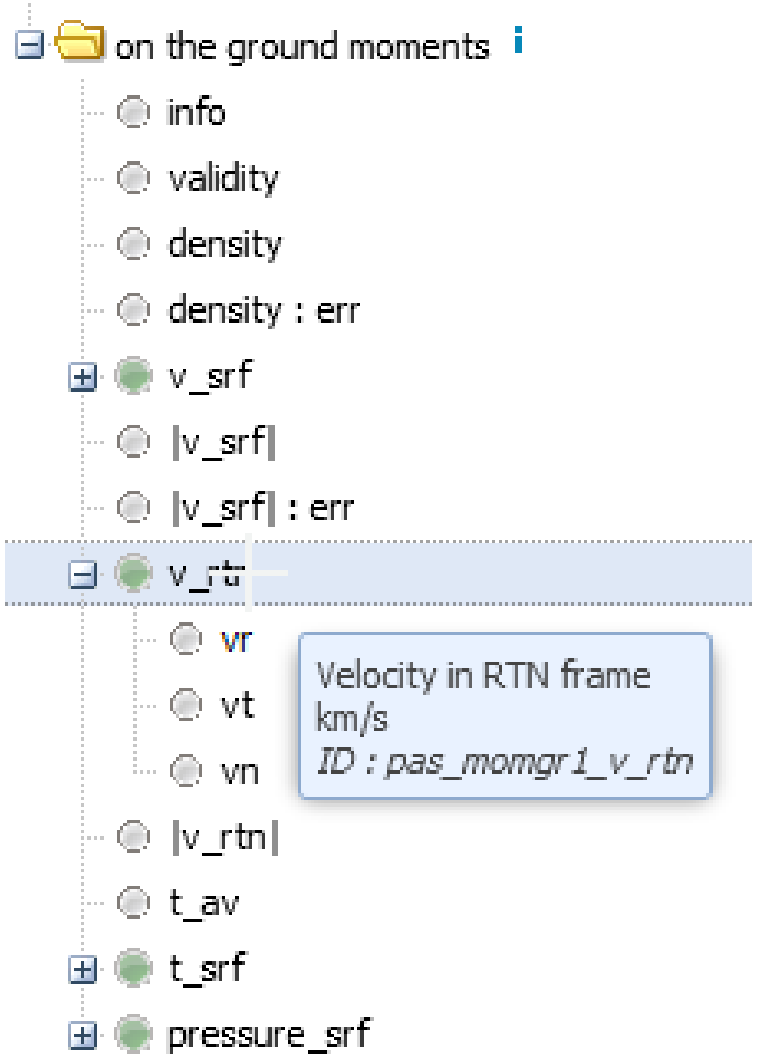






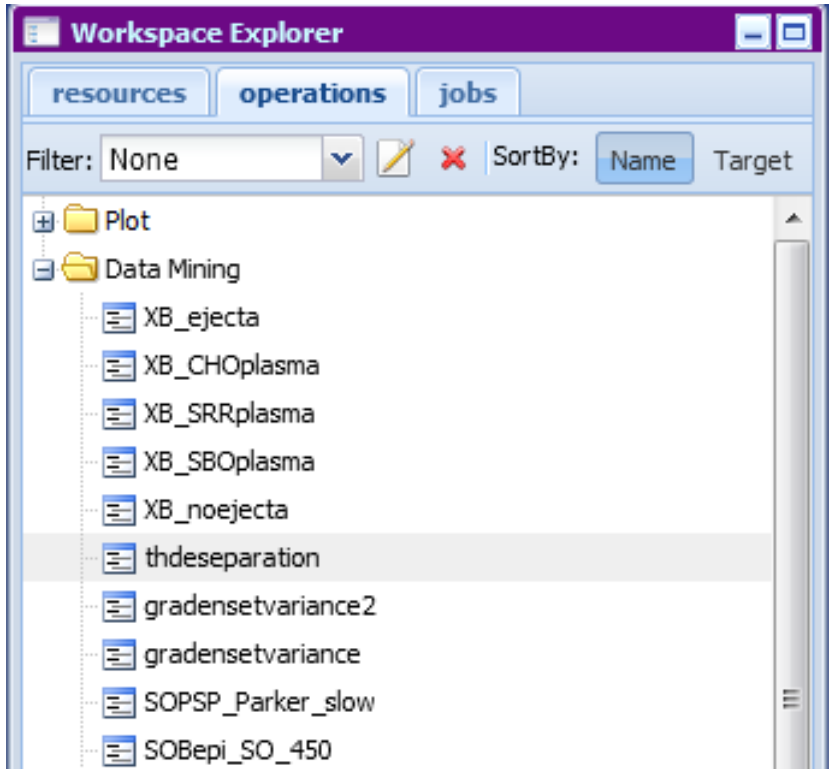
Information on parameters

- Provided in tool tips / info bulles
- Shown « on mouse over »
- Information
  - Description
  - Unit
  - AMDA ID
    - Useful to edit derived parameters
    - Useful for the Python API



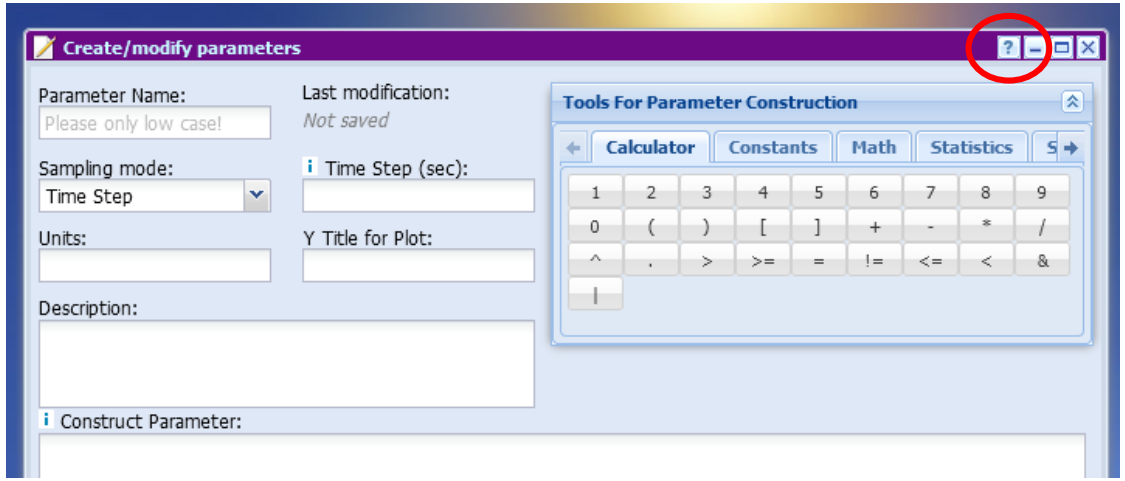
Saving requests for future use

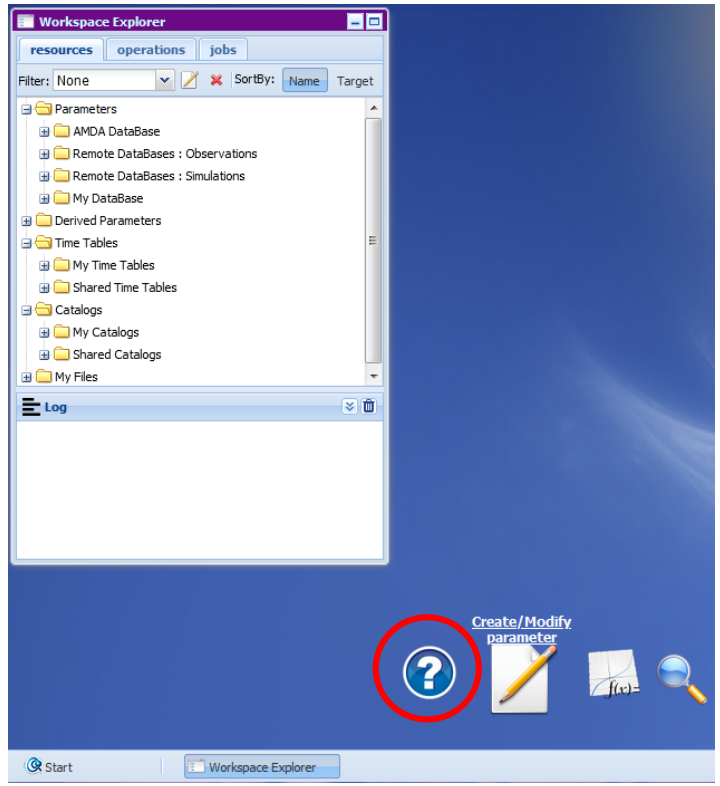
- It is a functionality useful for registered user (for the public access the session is limited)
- ‘Plot request’ and ‘Data mining request’ can be saved on the corresponding window
- They’re all gathered in the ‘operations’ tab of the Workspace Explorer
- Double clicks on the name to retrieve the corresponding window and its settings



Getting help

- Blue i
- **?** on all windows / upper right corner
- General help
- amda@irap.omp.eu





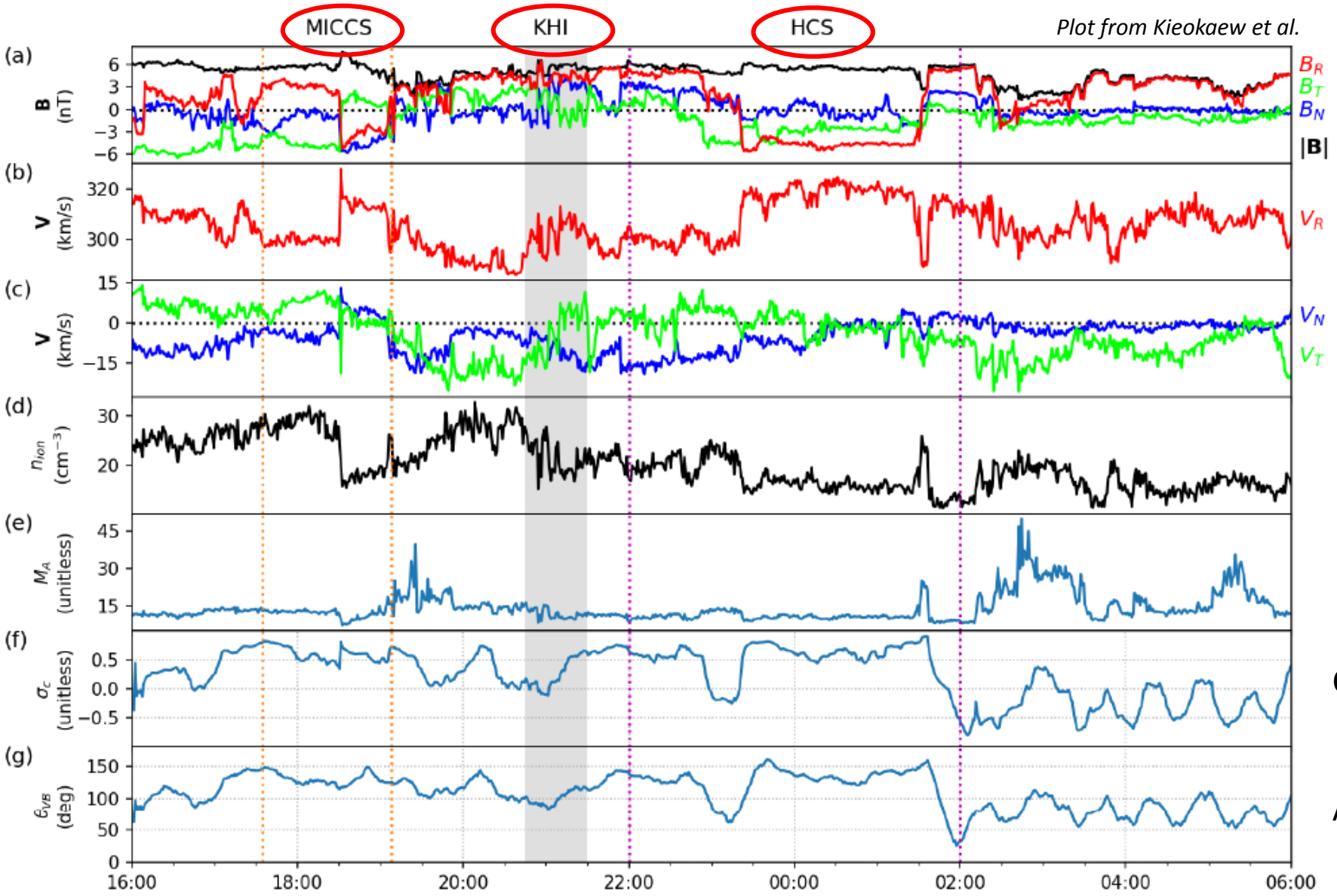
AMDA GUI

AMDA use case #1

AMDA use case #1

- Objectives:
  - Plotting Solar Orbiter data
  - Combining data
  - Downloading data
- Based on : *Kieokaew et al.*, submitted to A&A for the Solar Orbiter special issue
- Time period:
  - 23/07/2020 16:00 – 24/07/2020 06:00

3 interesting events in 14h / slide A



KHI : Kelvin Helmholtz Instability

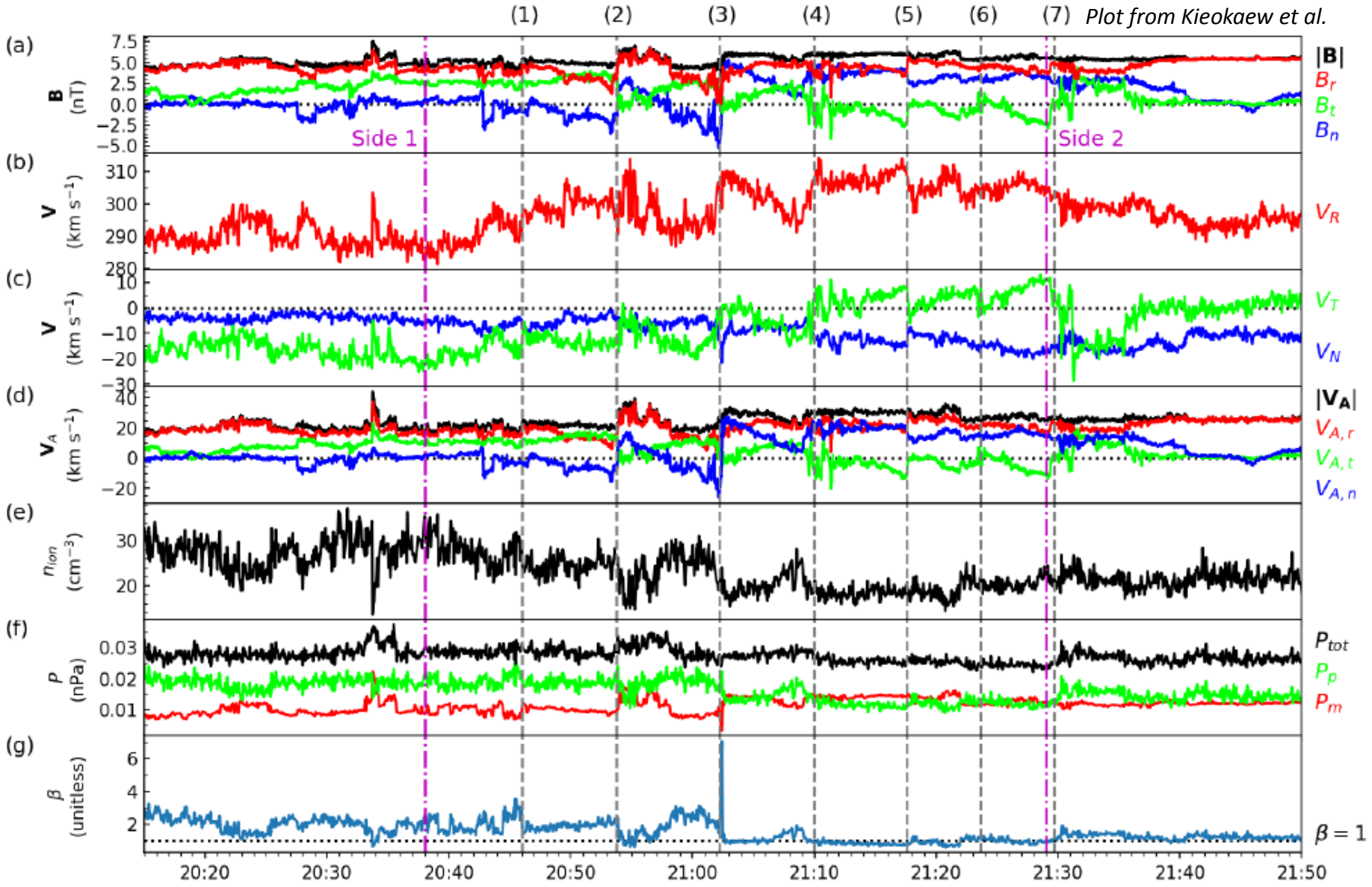
MICCS : Magnetic Increases with Central Current Sheets
See https://doi.org/10.1051/0004-6361/202039191

HCS : Heliospheric Current Sheet
See https://doi.org/10.3847/2041-8213/ab8d2d

Cross-helicity

Angle (B,V)

Focus on the KHI event / slide B

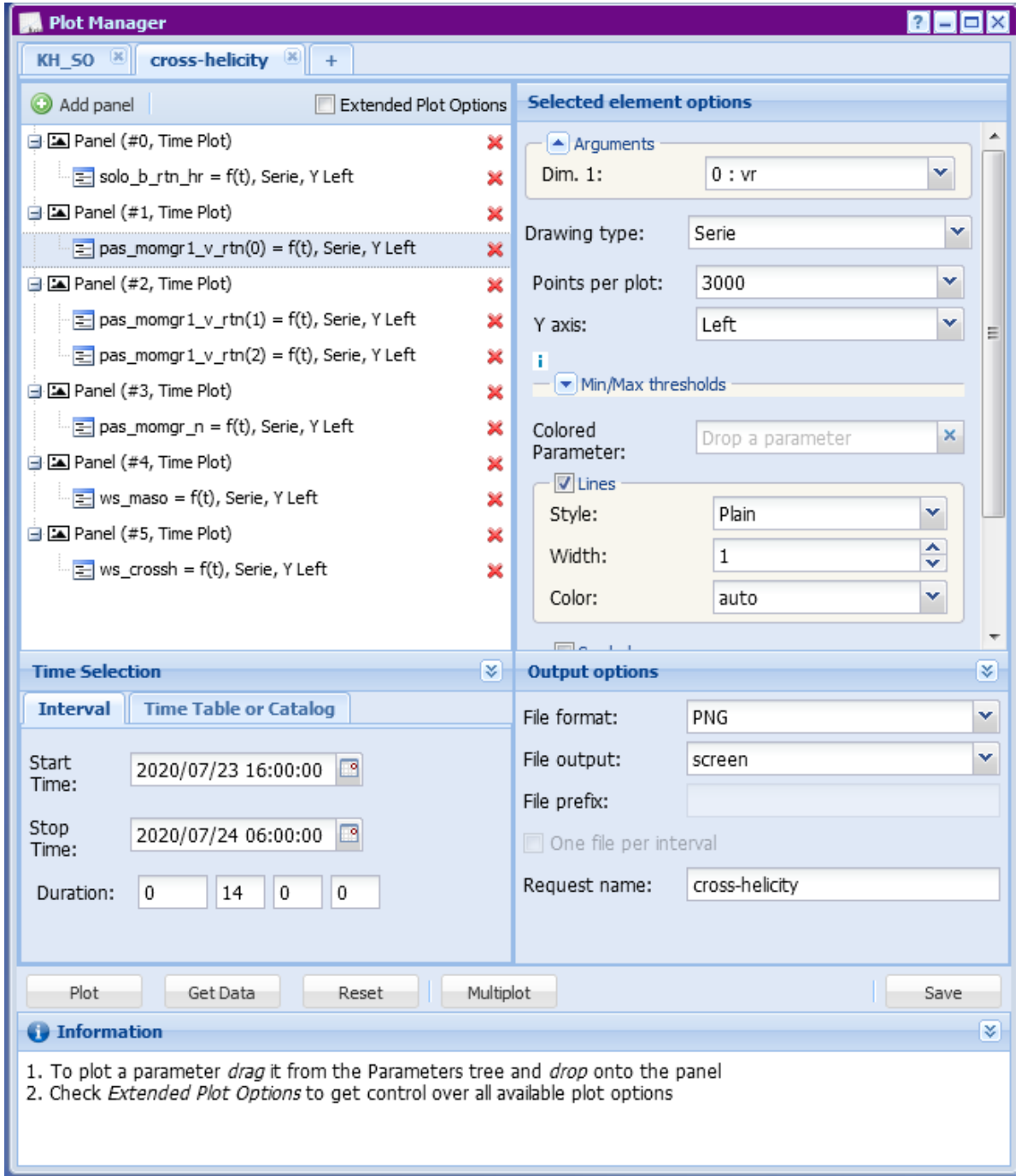


Alfvén velocity

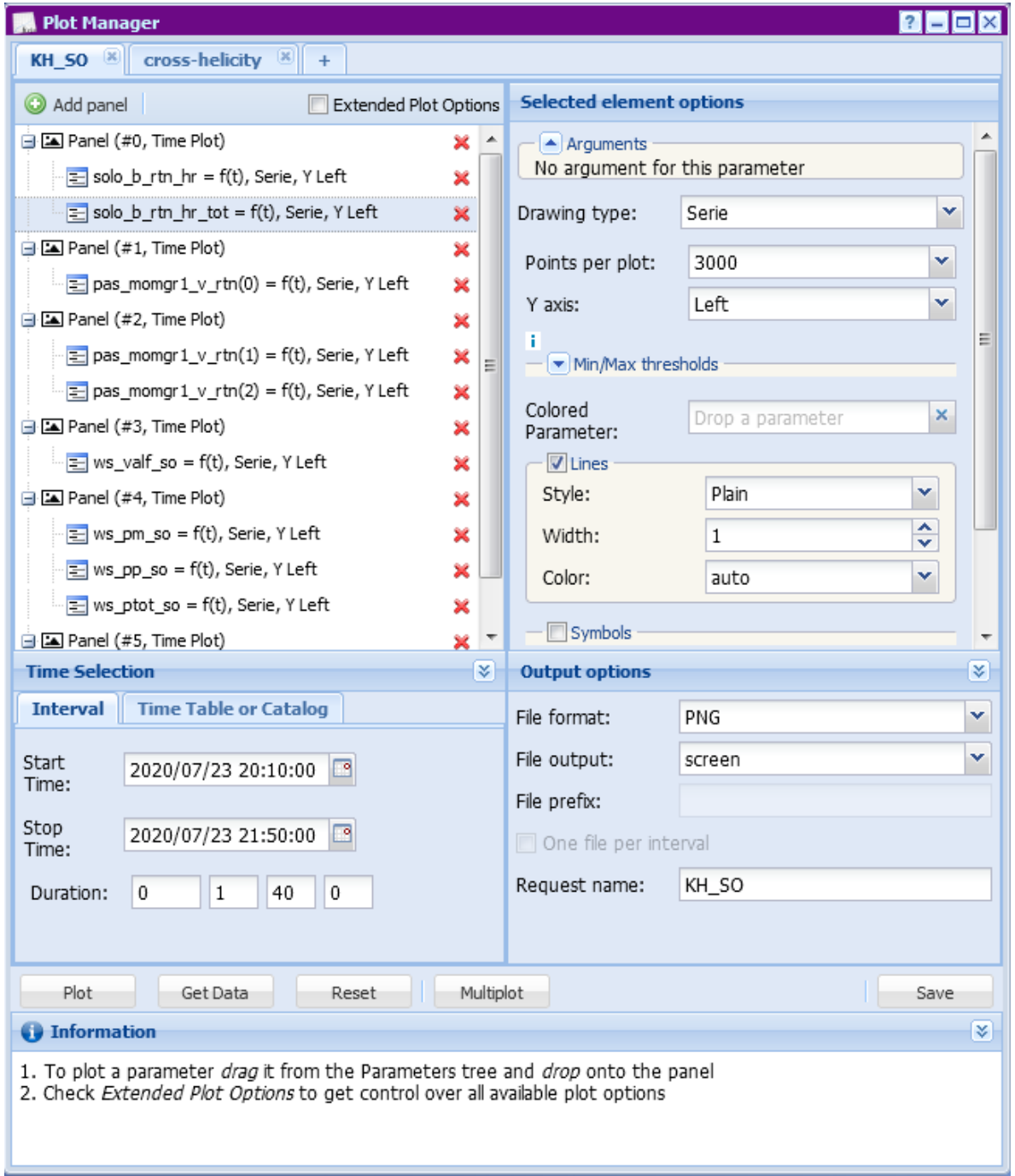
Pressure terms

Beta

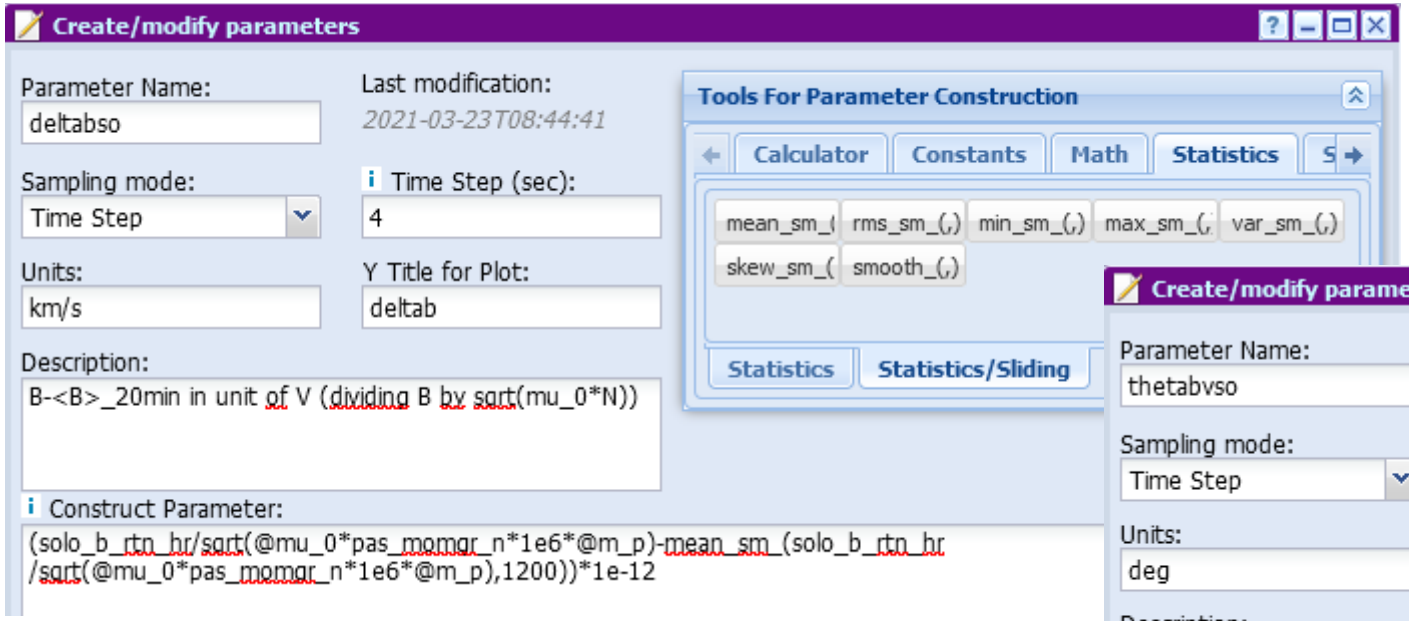
Slide A



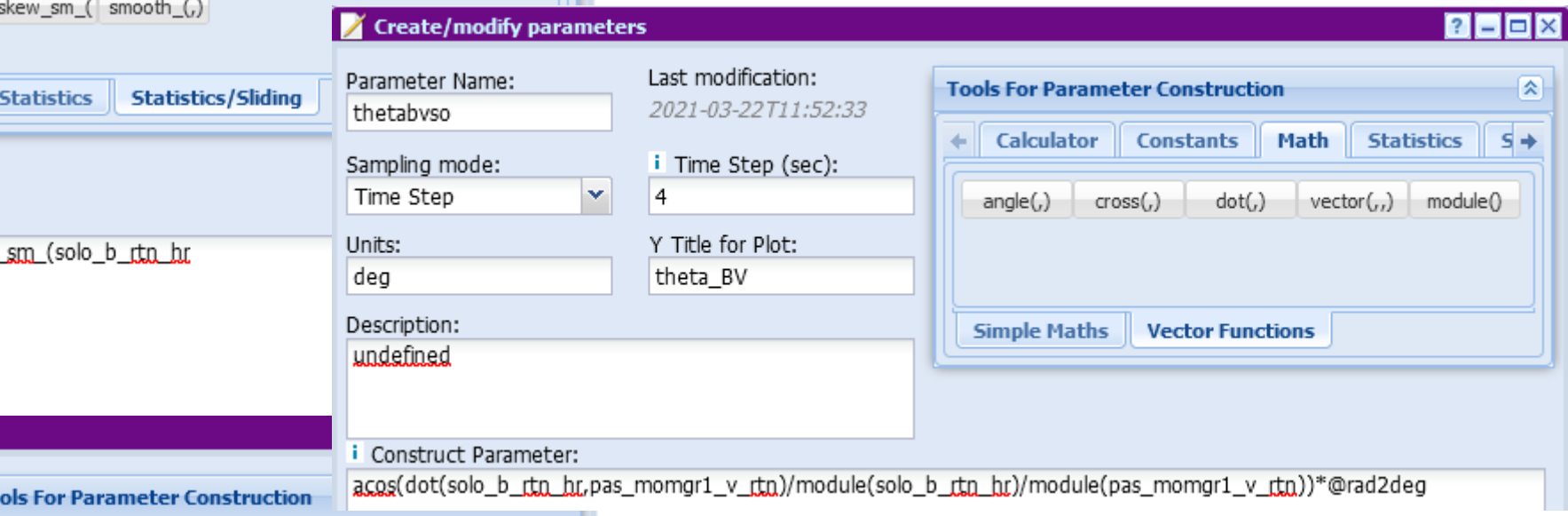
Slide B



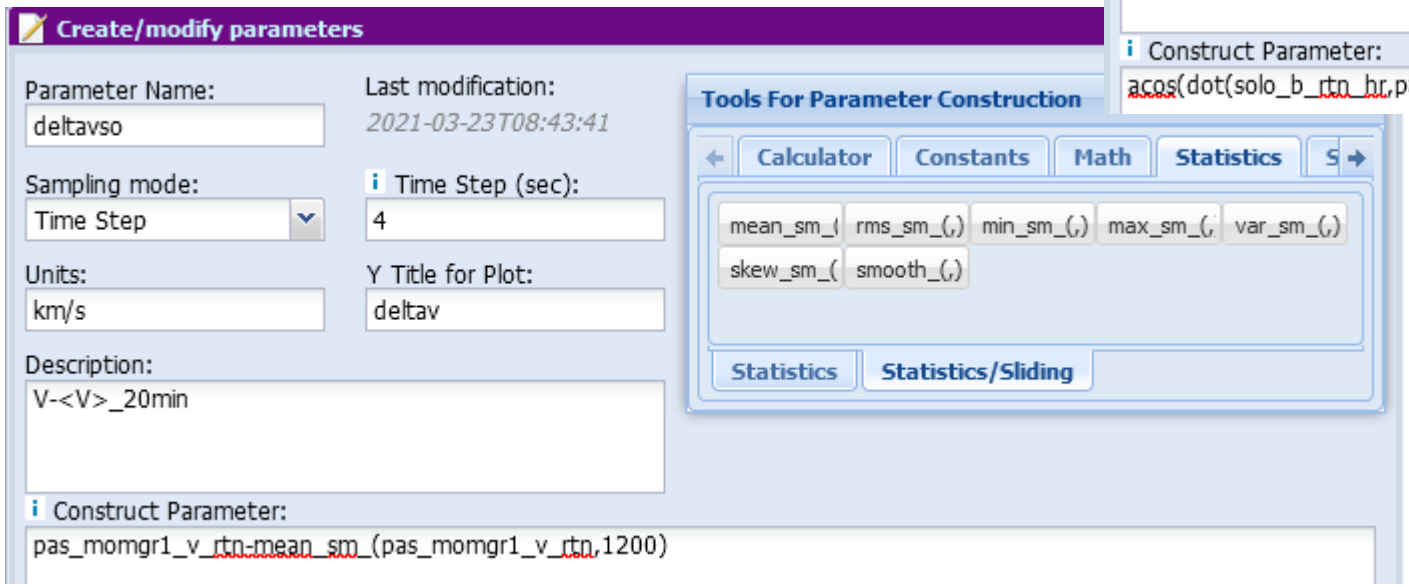
Delta_b



Angle (B,V)

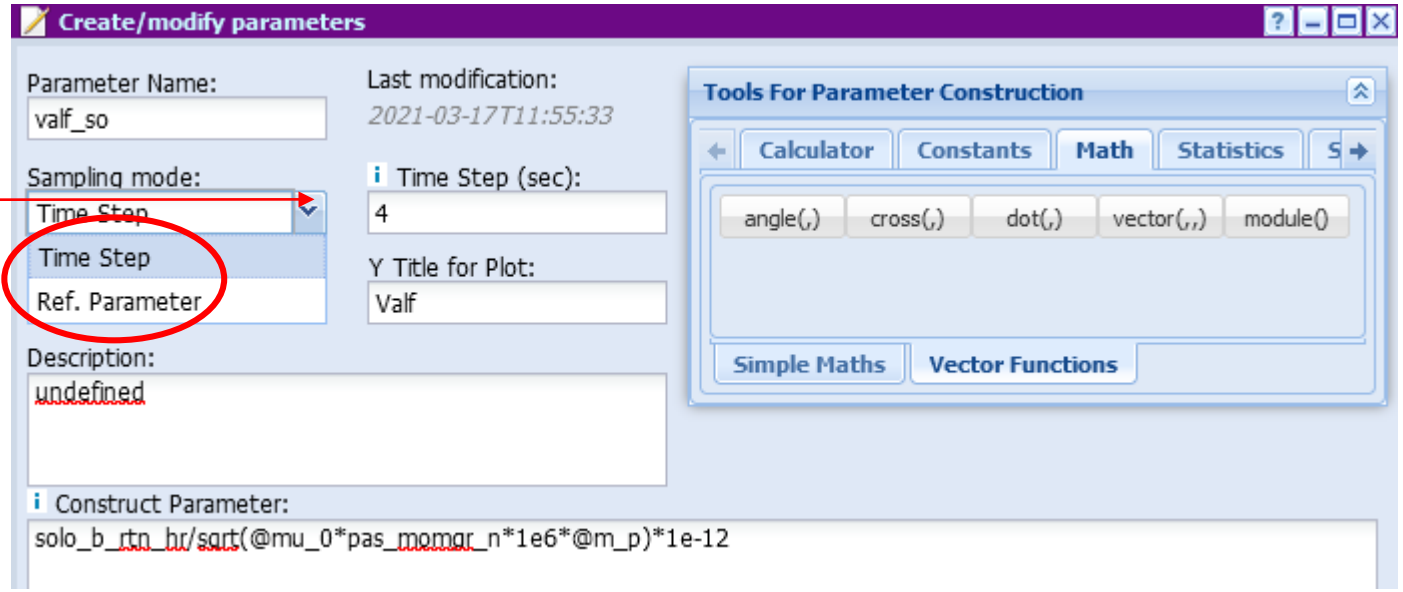


Delta_v



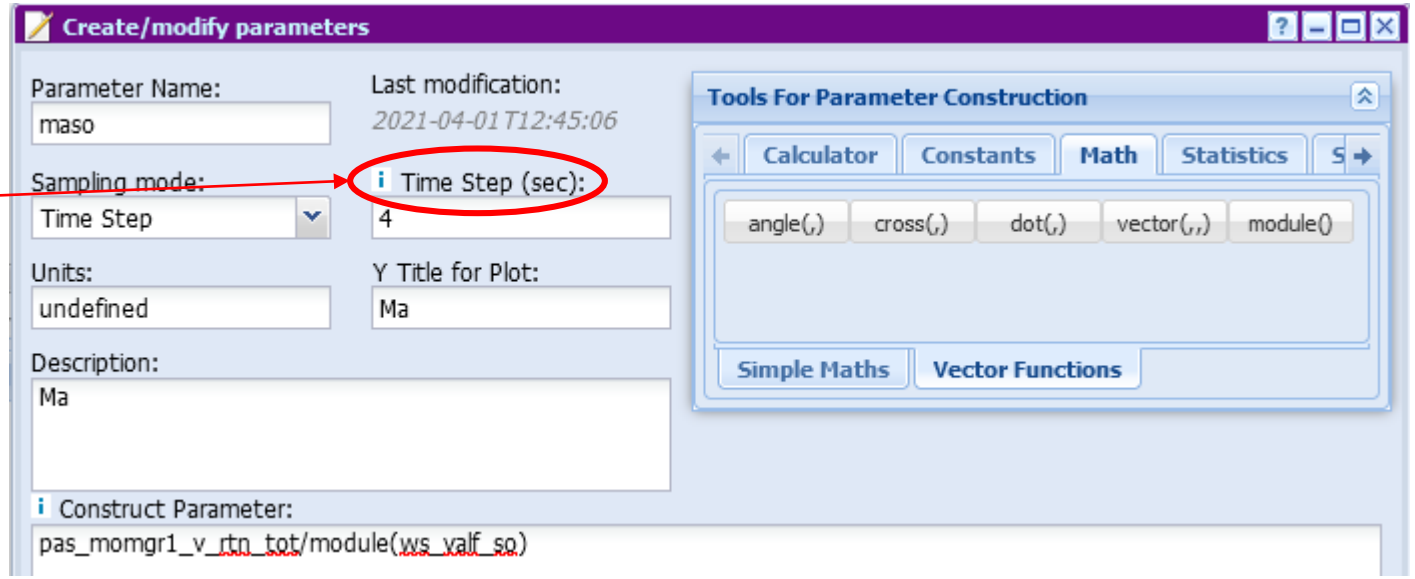
Depending on original samplings, AMDA parameters used in the expression will be averaged or interpolated to create new parameter with the requested time resolution

Time Step
or **Reference Parameter**
can be used



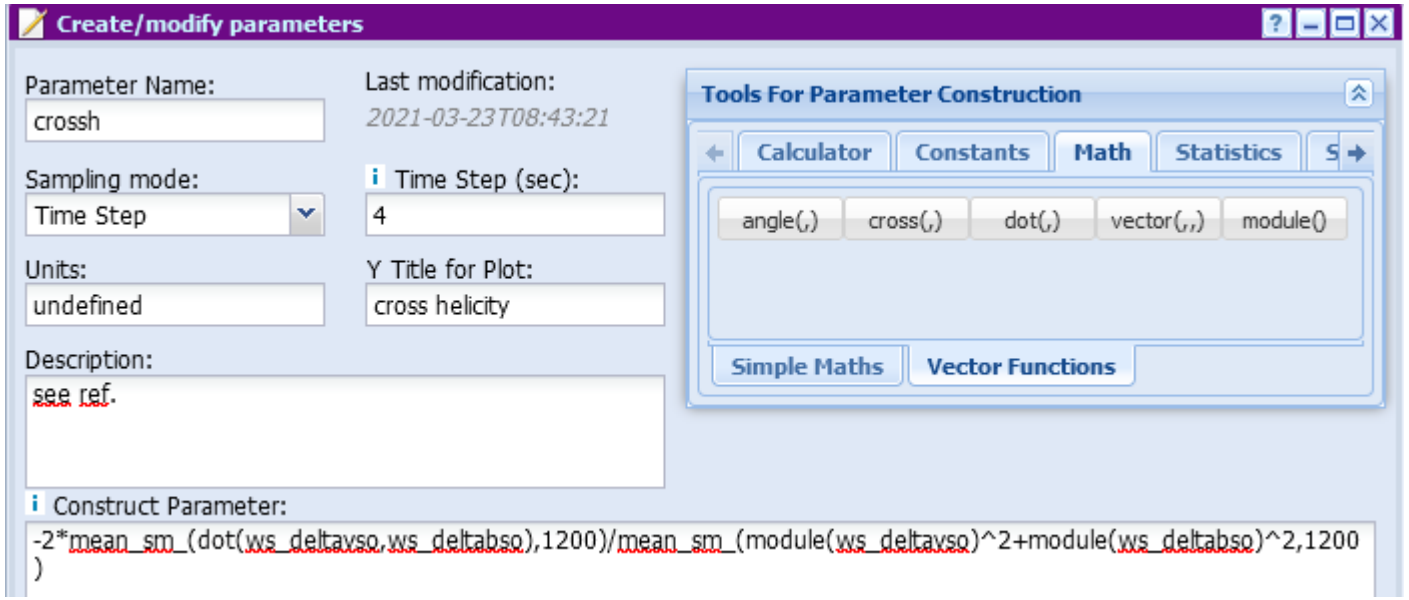
Alfvén velocity

Time Step
All AMDA parameters used in your expression are resampled (averaged/interpolated) with this time step before calculations.



Ma

Cross-helicity: a proxy for the Alfvénicity



- *Matthaeus and Goldstein, 1982*
- *Roberts et al., 1992*
- *Stansby et al., 2019*

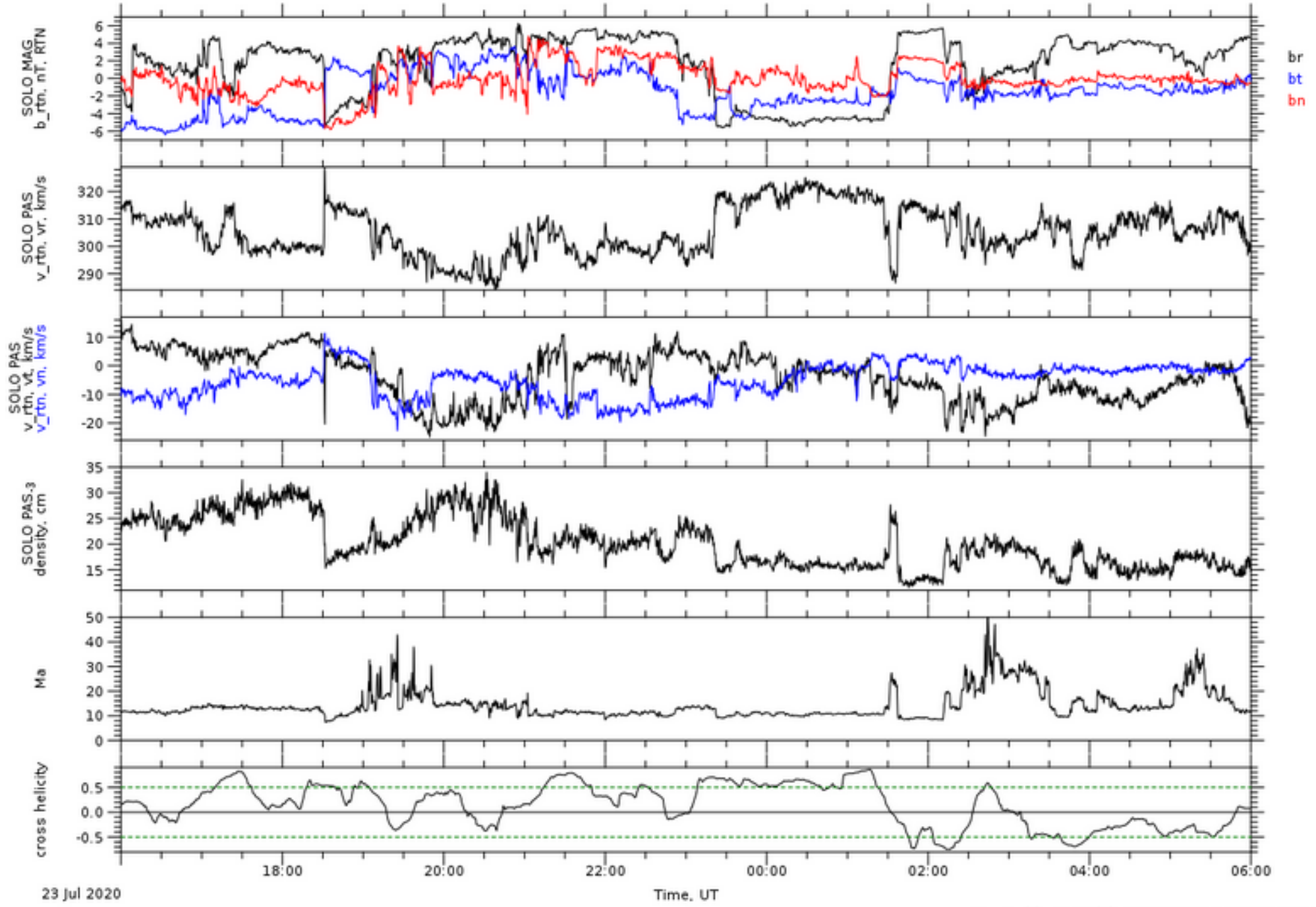
$$\sigma_c = 2\frac{\langle \boldsymbol{v}\cdot\boldsymbol{b}\rangle}{\langle |\boldsymbol{v}|^2 + |\boldsymbol{b}|^2\rangle}$$

v=V-<V> : deltavso (km/s)
b=B/sqrt(μ_0*N)-<B/sqrt(μ_0*N)> : deltabso (km/s)
< > : local average over 20 min. In AMDA use the sliding / boxcar average *mean_sm_*

AMDA plot

14h

(same as slide A without theta_BV)



Ma

Cross helicity

AMDA plot

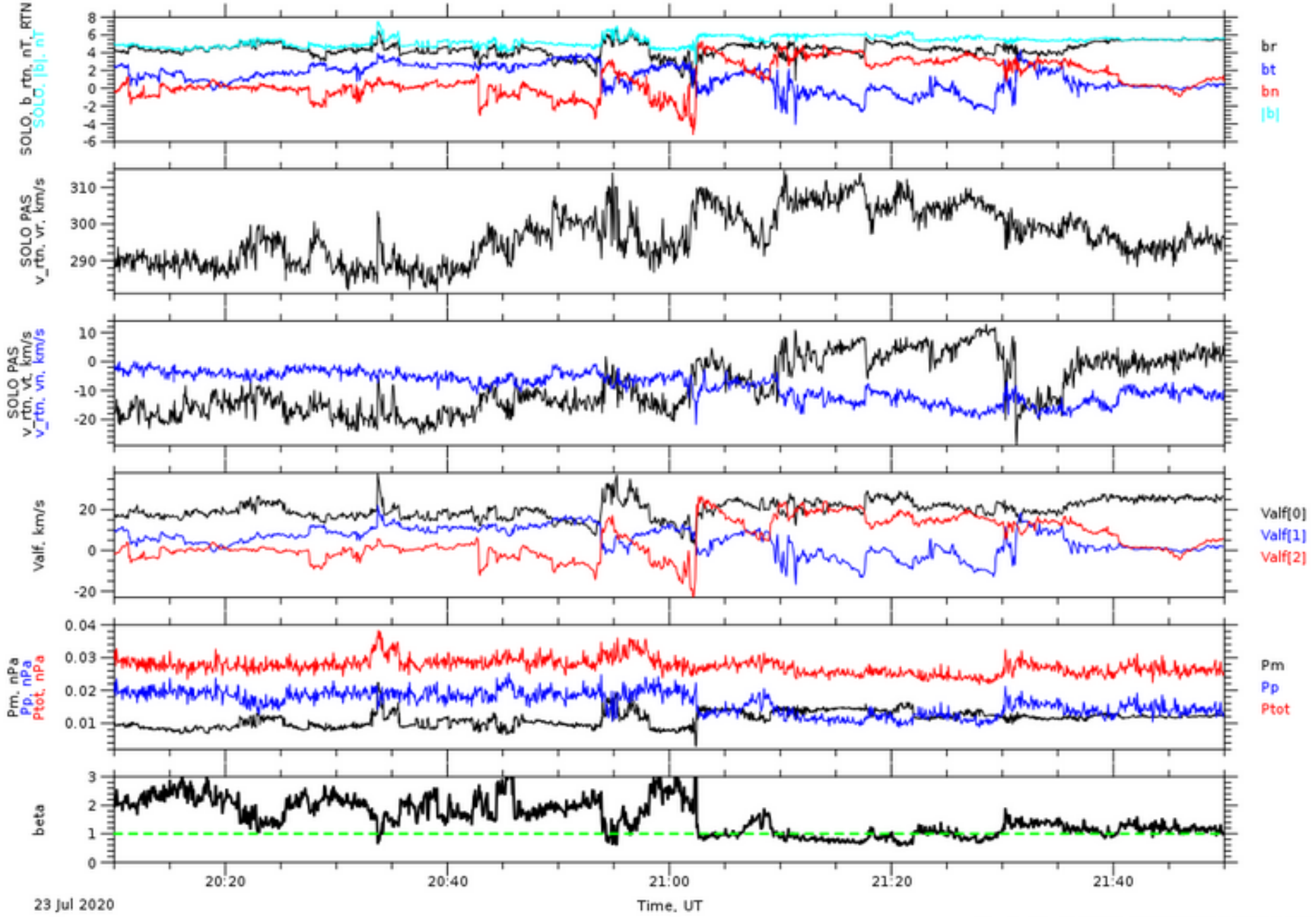
Focus on the KHI event

(same as slide B without the density)

Alfvén velocity

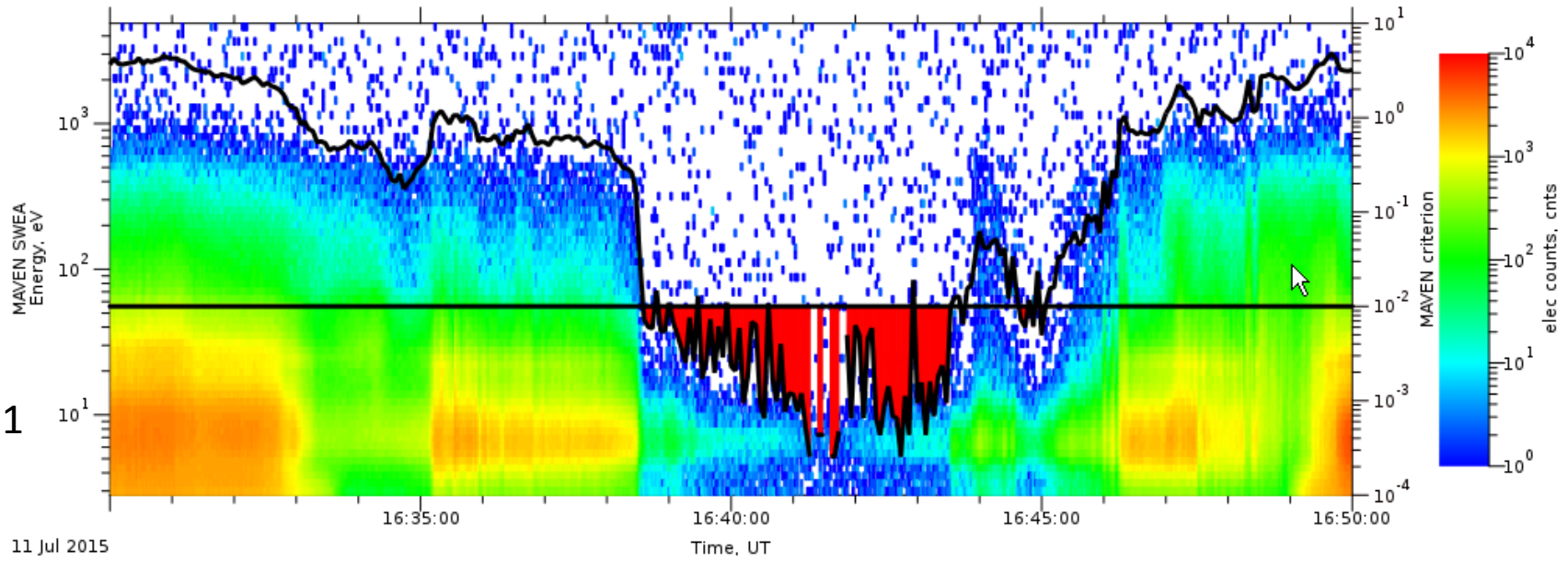
Pressure terms

Beta



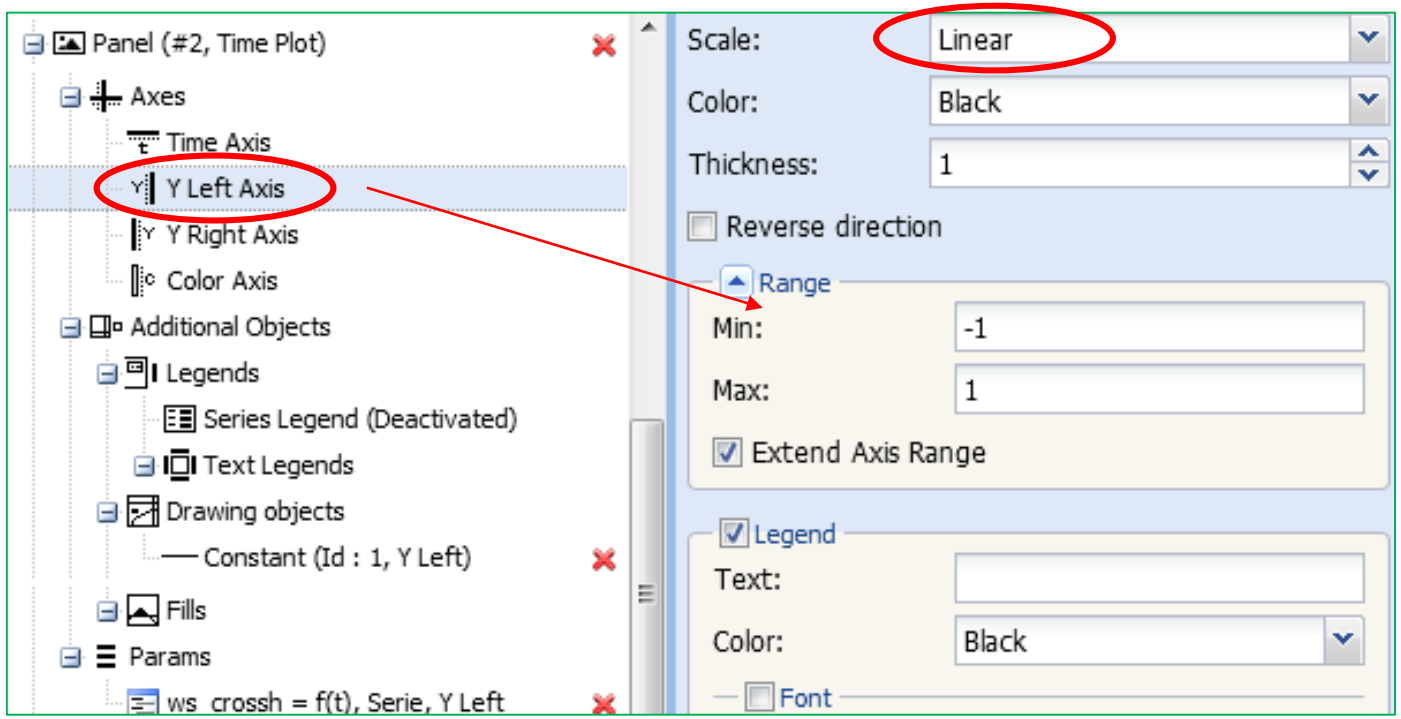
Some tips

- Click on *Extended Plot Options* to access more options
  - Ranges on the axis (next slide)
  - Add a constant (next slide)
  - Color a part of the plot between 2 curves/constant (see below)

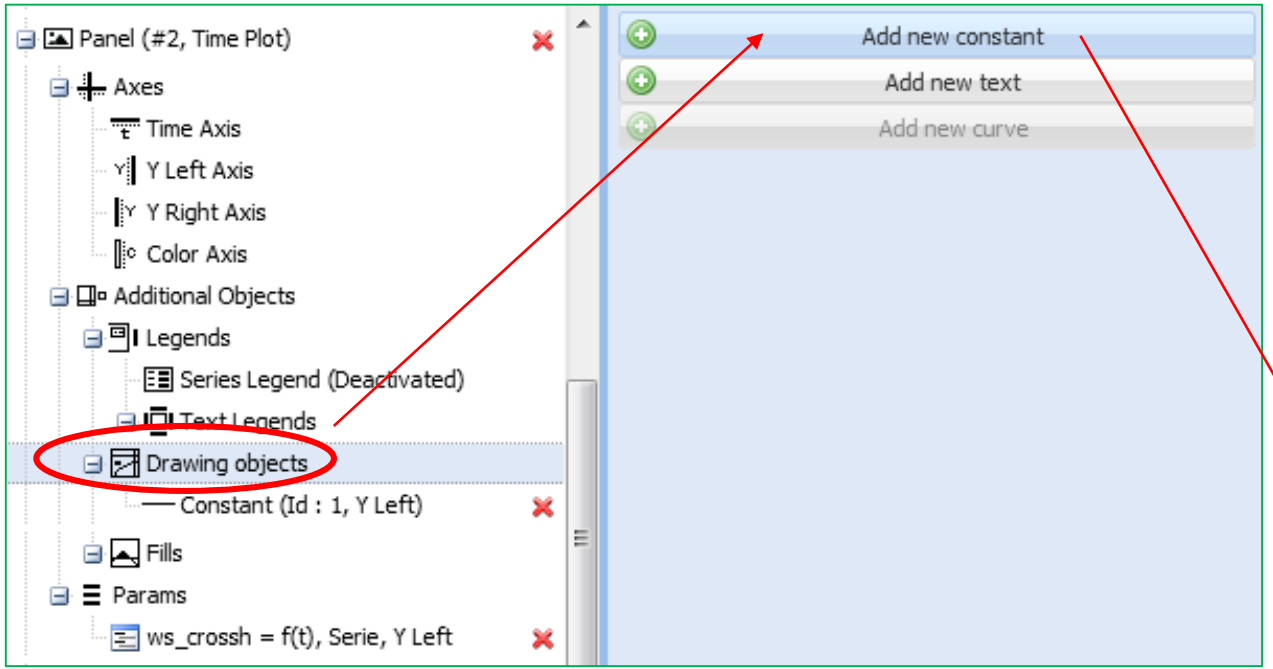


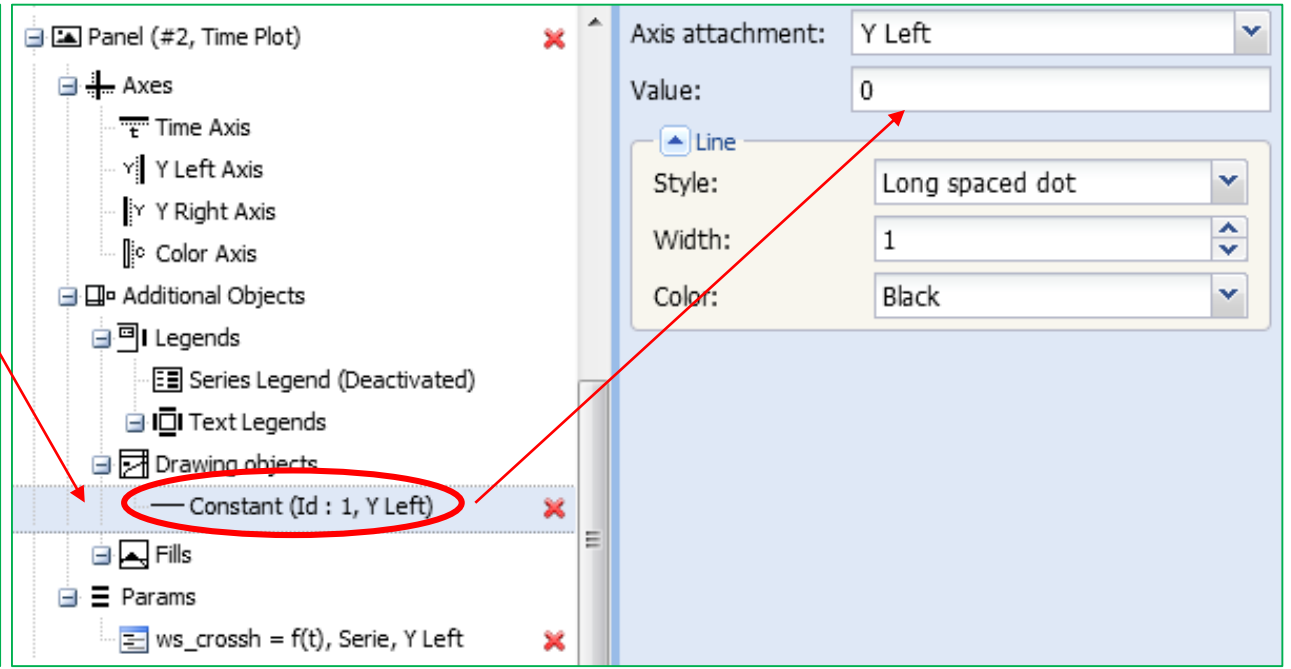
Electron depletions at Mars seen by MAVEN (figure 10 from *Génot et al.*, 2021 in press)

Setting the
Y axis range

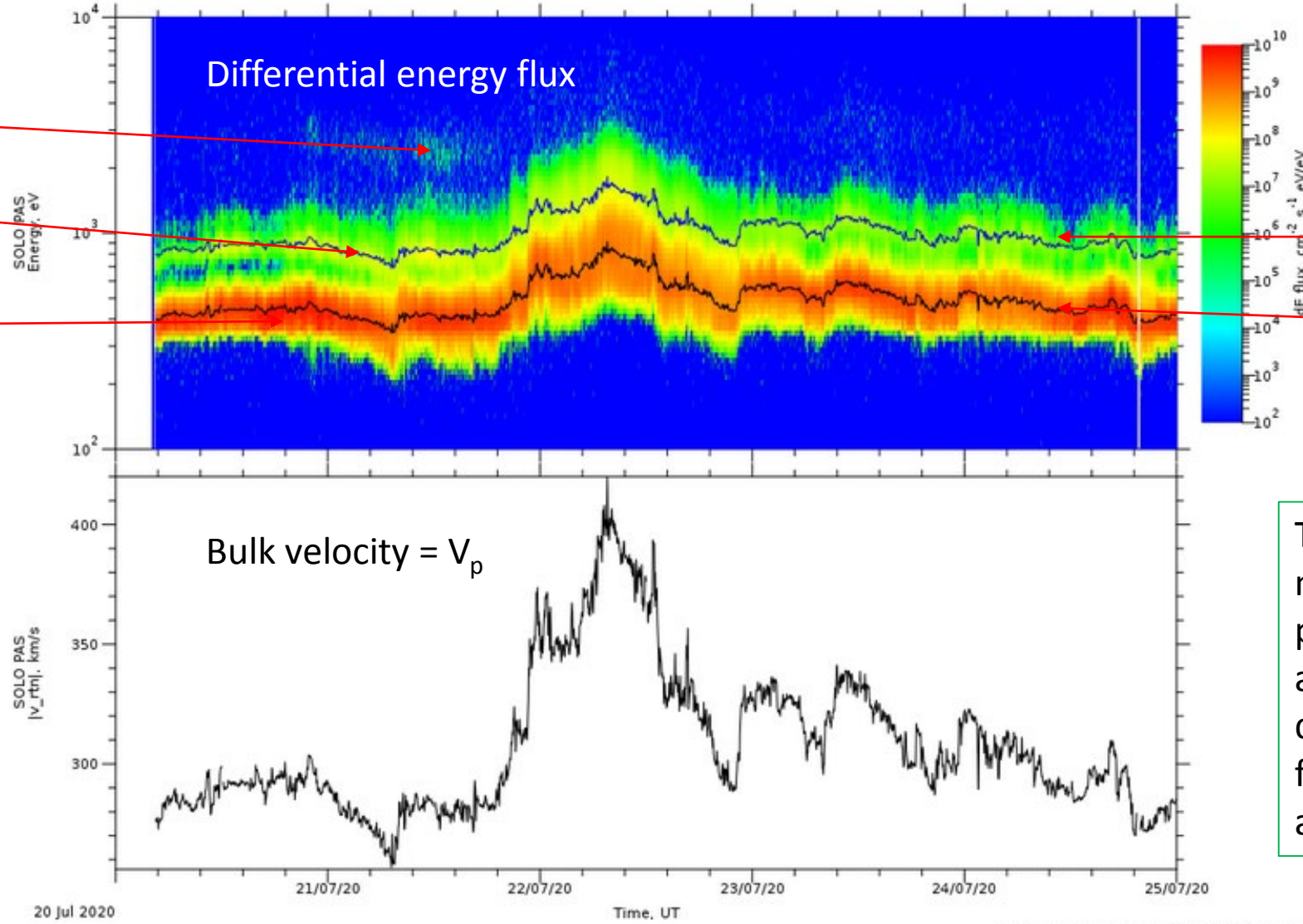


Extended Plot Options





Last minute addition following P. Louarn's presentation on PAS



O^{6+}

Alphas (He^{++})

Protons

$E_a=2E_p$

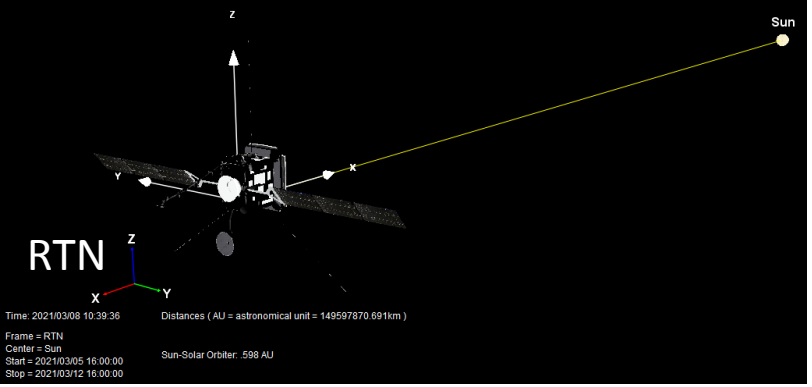
$E_p=0.5*m_p*V_p^2$

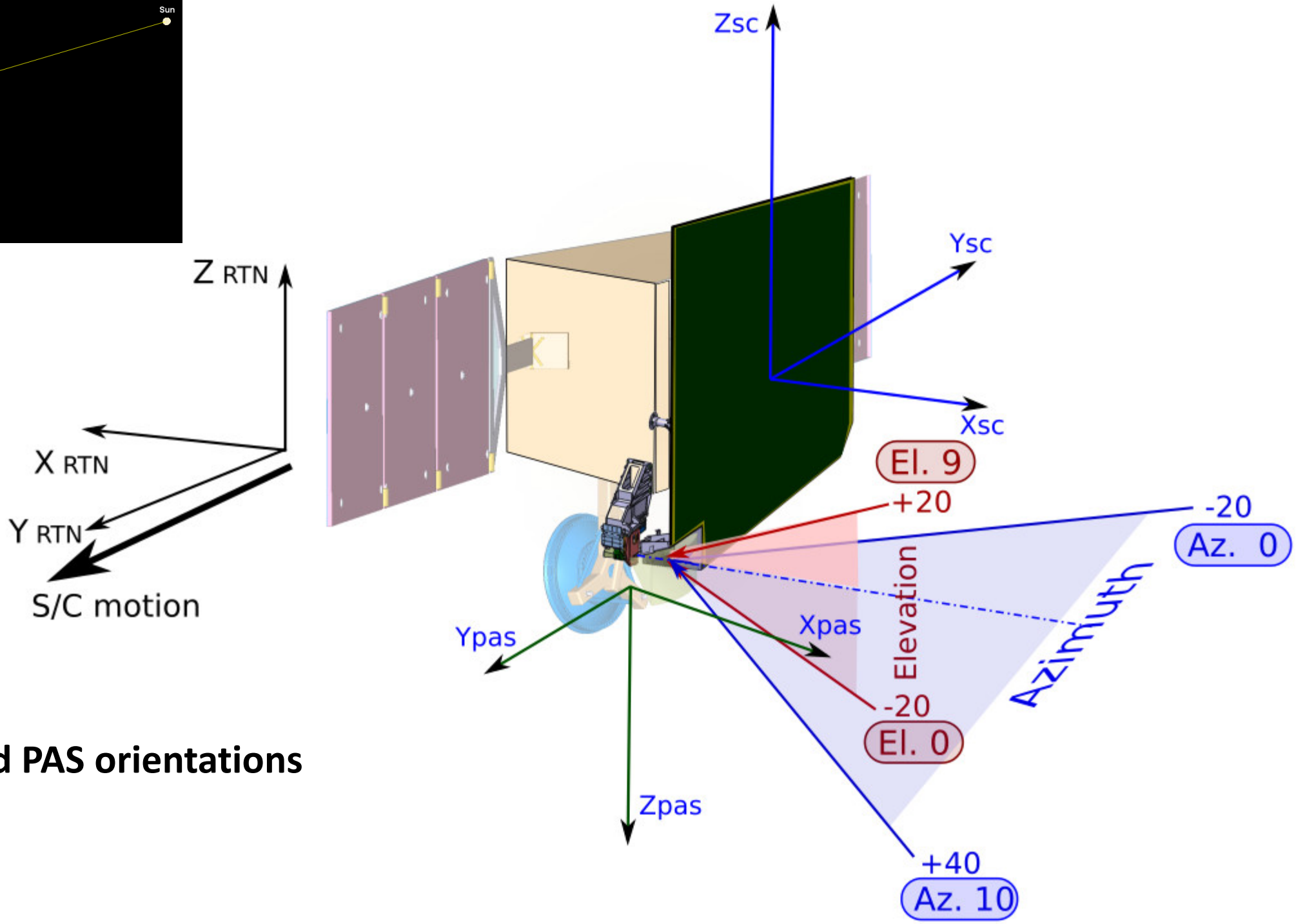
The instrument measures the 'energy per charge', so for the alphas $m_a=4m_p$ and $q_a=2q_e$ hence the factor 2 in the plot above ($E_a=2E_p$)

AMDA use case #2

AMDA use case #2

- Objectives:
  - Plotting PAS distribution functions as times series
  - Getting instant cuts
- Time period:
  - 23/07/2020 16:00 – 24/07/2020 06:00





Solar Orbiter and PAS orientations

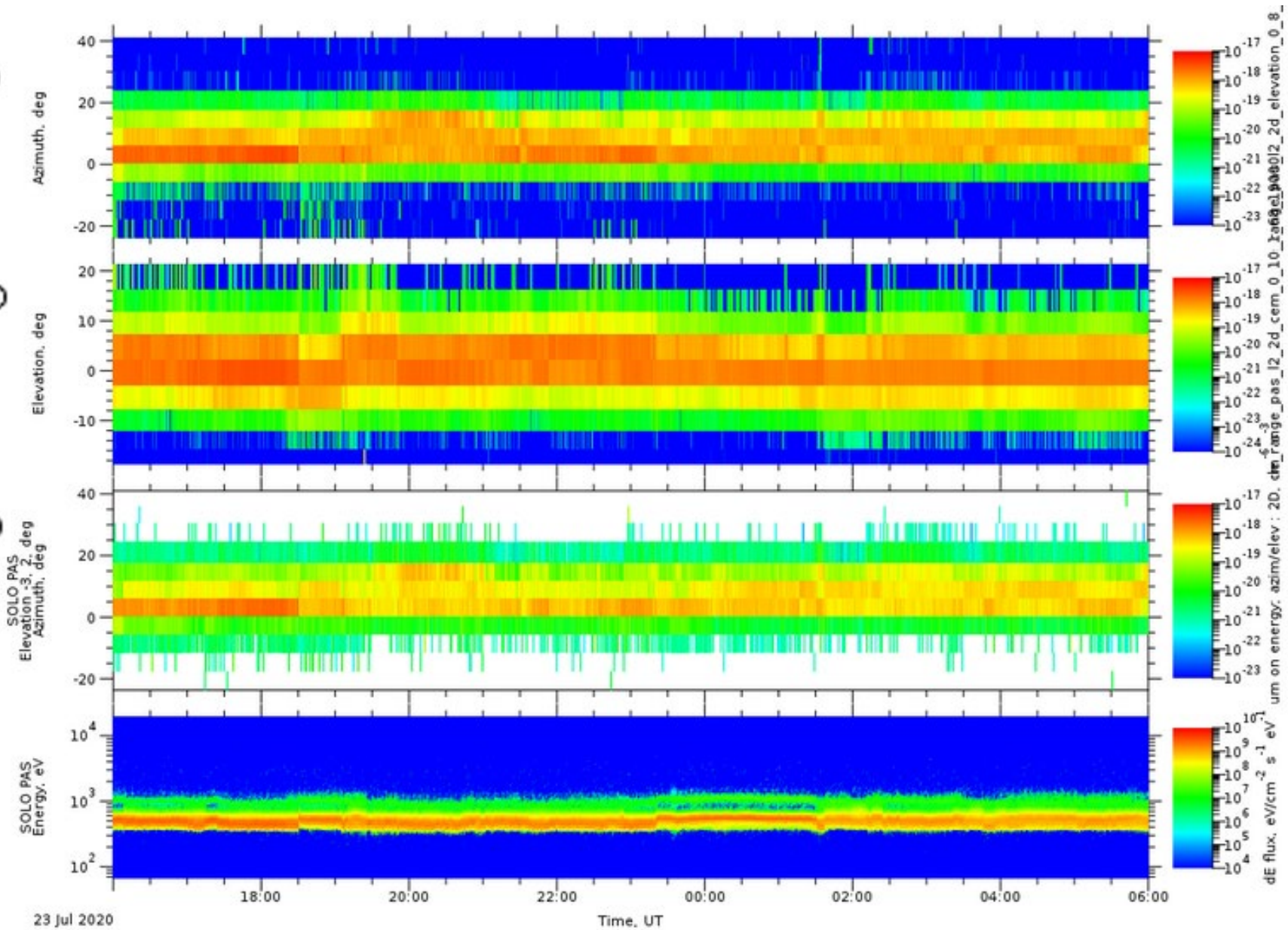
Courtesy A. Fedorov

2D Fdis : sum on elev; azim/energy : 2D

2D Fdis : sum on azim; elev/energy : 2D

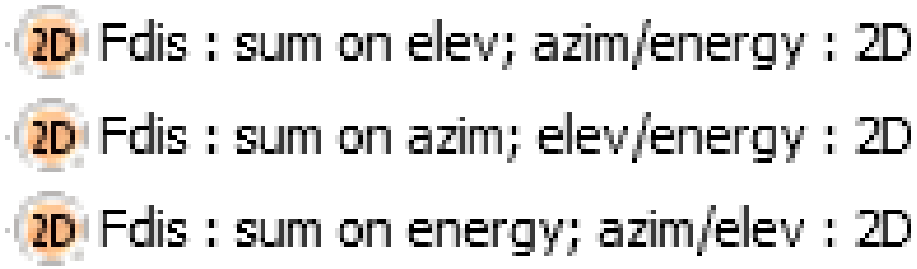
2D Fdis : sum on energy; azim/elev : 2D

OMNI diff. energy flux

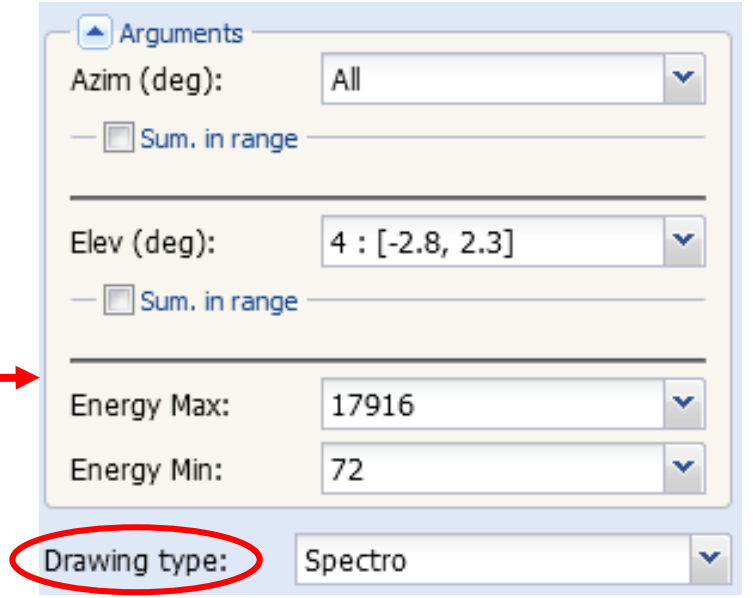


PAS distribution functions

- Fdis = array [elevation, azimuth, energy]
- AMDA shows Fdis summed on one dimension

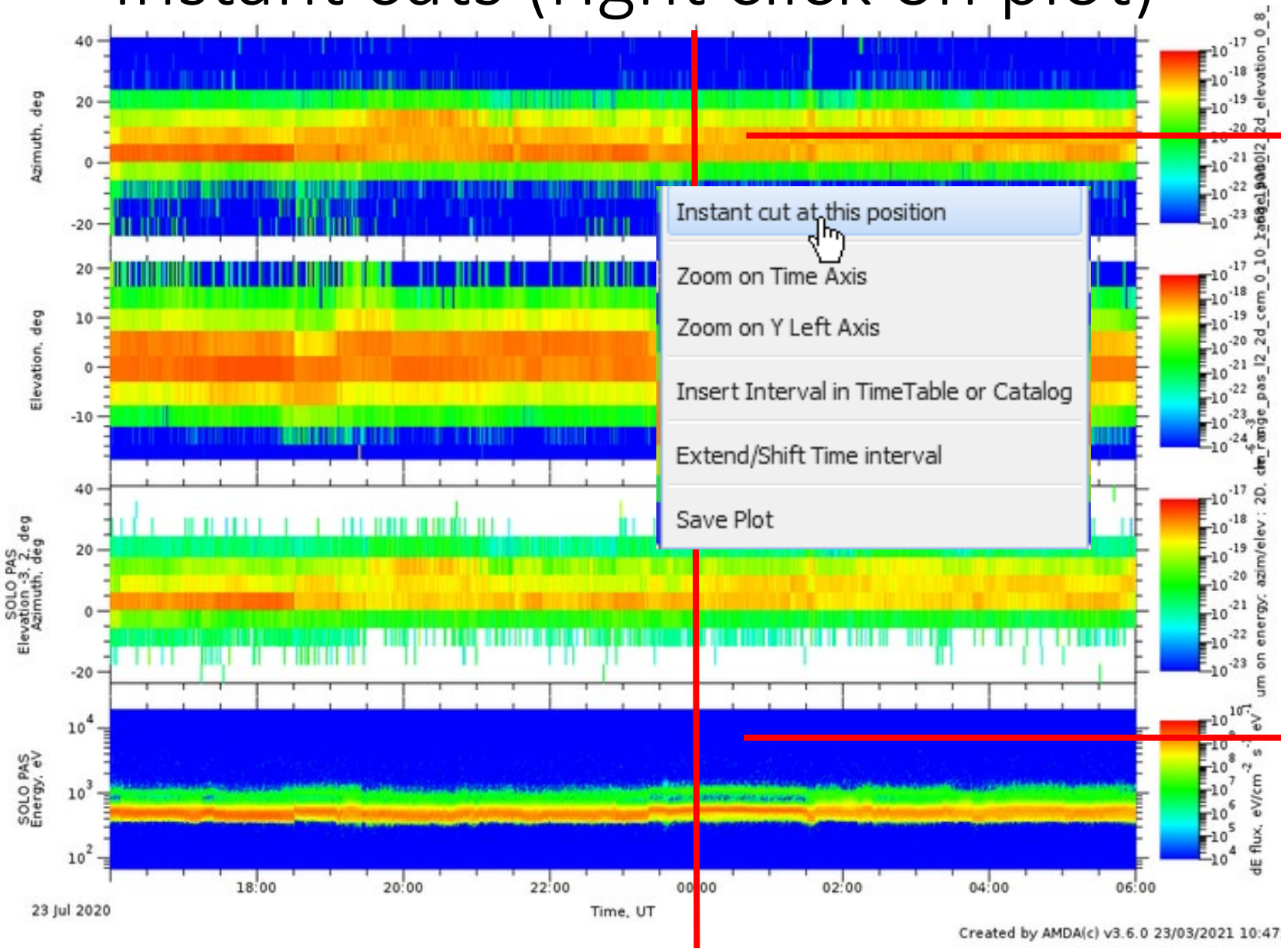


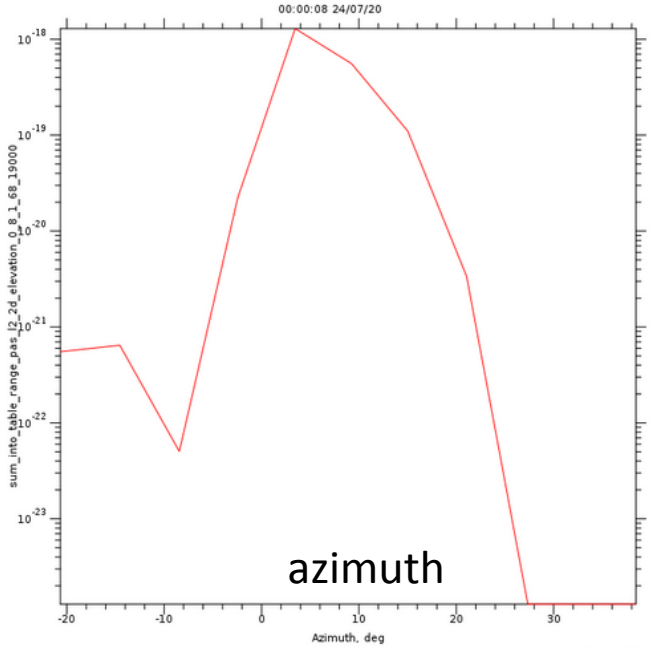
- [elevation, azimuth, energy] ranges can be chosen
- For ex. the 3rd plot is obtained from this setting
  - *Azim = all* means azimuth is the Y axis
  - *Elev = [-2.8; 2.3]* is the chosen elevation channel
  - *Energy min/max* is the range over which energy is summed



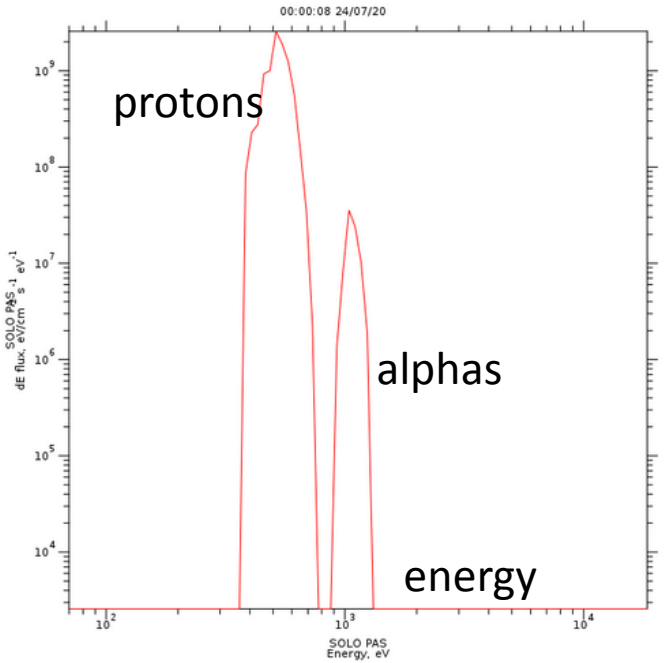
- If Fdis is summed over all dimensions change « Spectro » to « Serie »
- Change *log* to *lin* for angle on the Y axis as needed (not automatic)

Instant cuts (right click on plot)





Vsw=320 km/s



Notes

- On the summation: it is really a ‘sum’ of f (phase space density) not a proper integration that must take into account energy bands and solid angle sectors
  - The unit therefore remains ‘$cm^{-6}\ s^{3}$’ (or ‘$s^{3}\ m^{-6}$’)
- On OMNI differential energy flux
  - The unit is ‘$eV/(cm^{2}\ s\ eV)$’
  - For a typical plasma instrument this quantity is directly proportional to its count rate
- See http://www.issibern.ch/forads/sr-007-01.pdf for a quick recap on these different quantities
- On instant cuts: they are provided as they are; there is no option to parameterize the plots (size, color, range, …) or download the data directly

AMDA use case #3

AMDA use case #3

- Objectives:
  - Find orbital conjunctions between Solar Orbiter, BepiColombo and PSP
  - Construct and manage a catalogue of events
- Based on the work done for the BepiCoordObs group
  - See *Hadid et al.*, in preparation for *Frontiers in Astronomy & Space Sciences*



Magnetic footprints

- “Magnetic alignments” between 2 or more bodies, i.e. when the footprints of Parker field lines passing through the bodies are in a latitude/longitude neighborhood at the source surface of the Sun
- The longitude of the footpoint Φ_s is given by

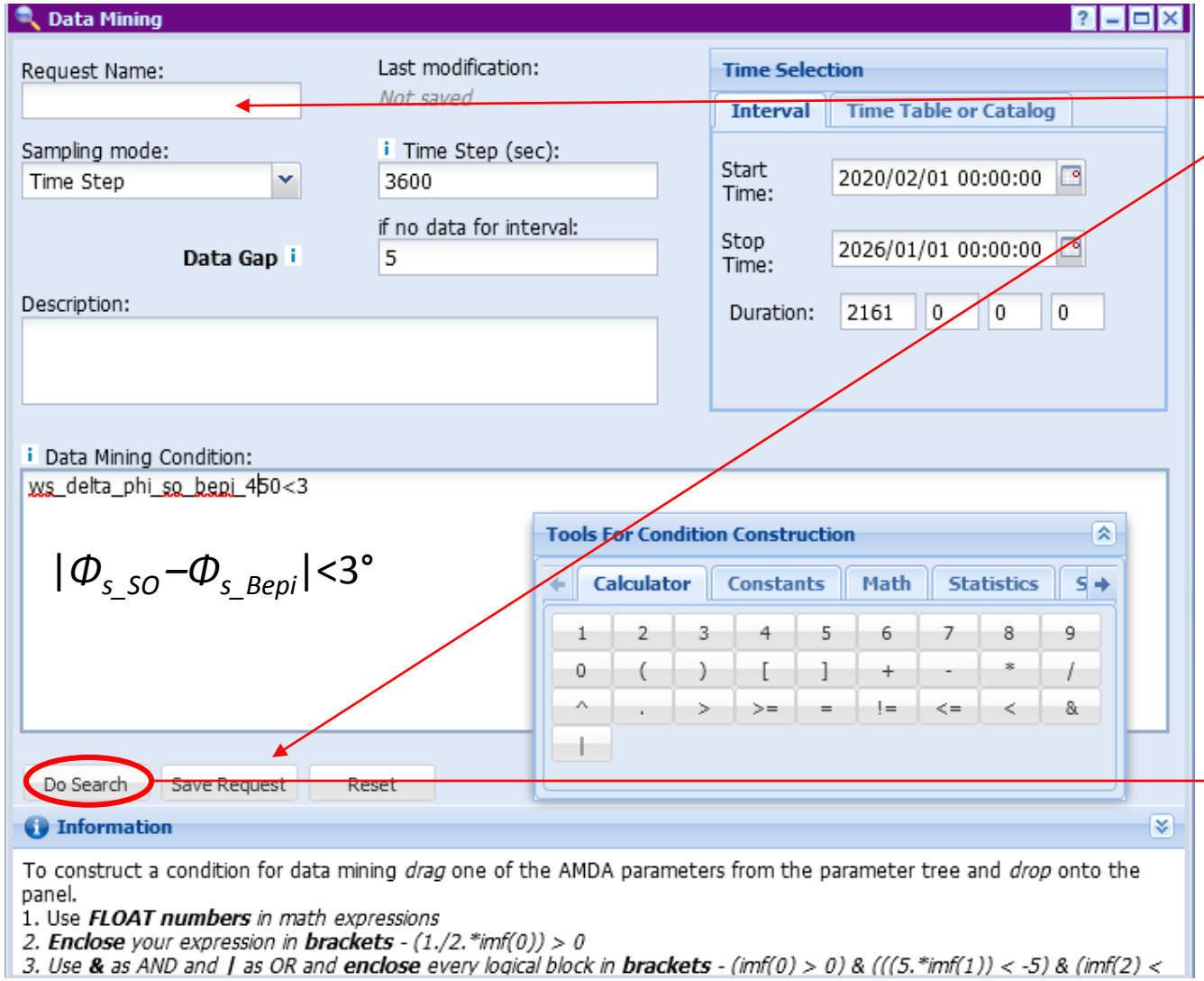
$$\phi_s = \phi(r) + \Omega(r - R_s)/u_{SW}$$

  - $\Phi(r)$ is the spacecraft heliocentric longitude at distance r
  - $\Omega = 2\pi/25.38\text{days}$
  - $Rs = 2.5\ R_{sun}$
  - u_{SW} is the solar wind velocity
- The latitude is equal to the one of the spacecraft as a Parker field line is inscribed on a cone of constant latitude

Parker alignments between spacecraft

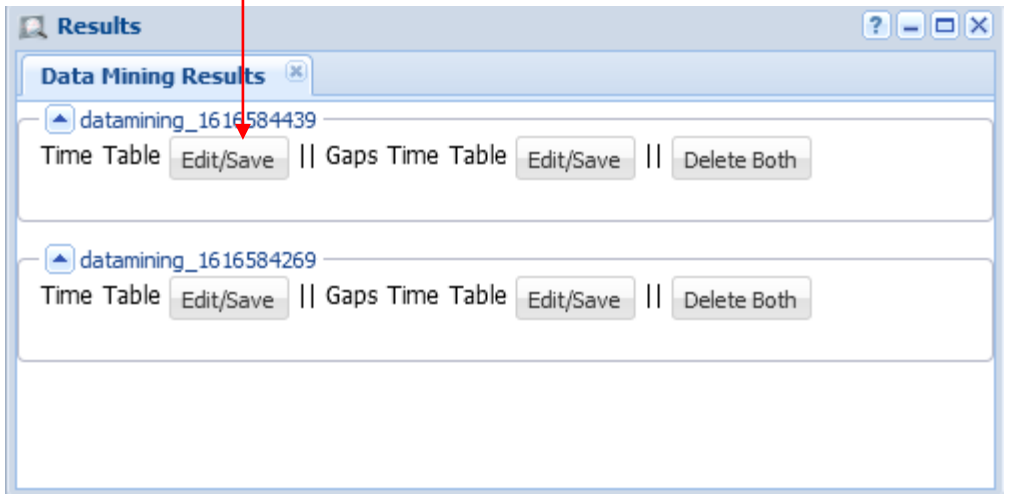
- Use AMDA data mining to determine time intervals when Solar Orbiter and BepiColombo have their magnetic footprints « close enough »
  - For instance $|\Phi_{s_SO} - \Phi_{s_Bepi}| < 3°$
- Time interval: Feb. 2020 - Dec. 2025
- The solar wind velocity is an unknown
  - Start with u_{SW}=450 km/s
  - See how time intervals are modified for different velocities

Data mining / conditional search



Name and save the ‘request’ for future use

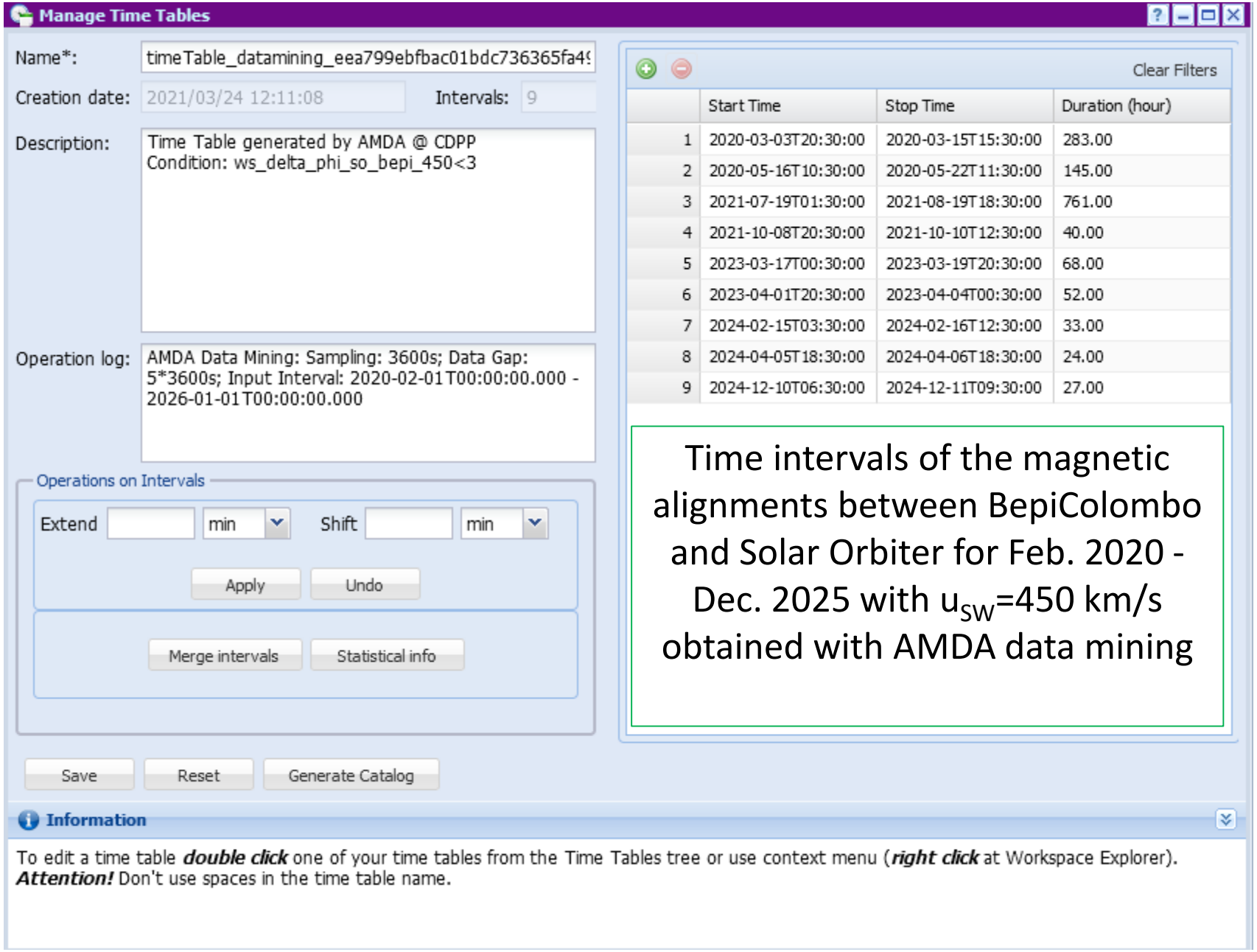
Edit the time table



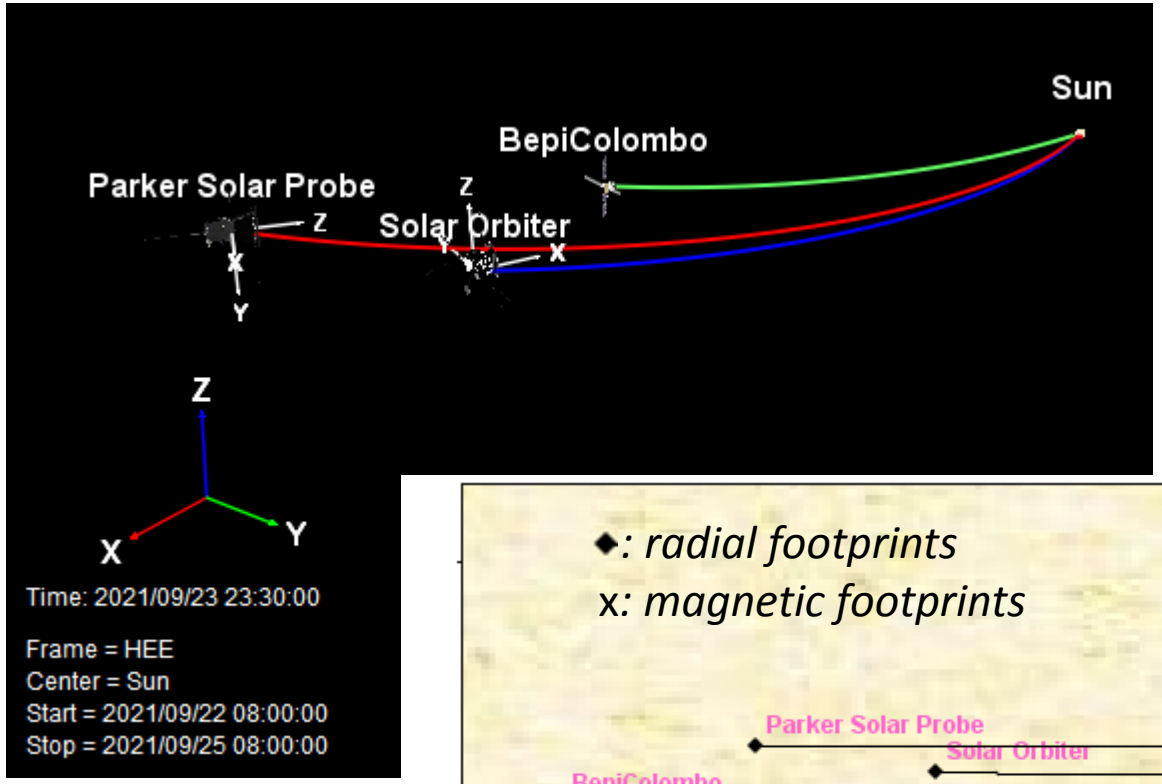
Default name

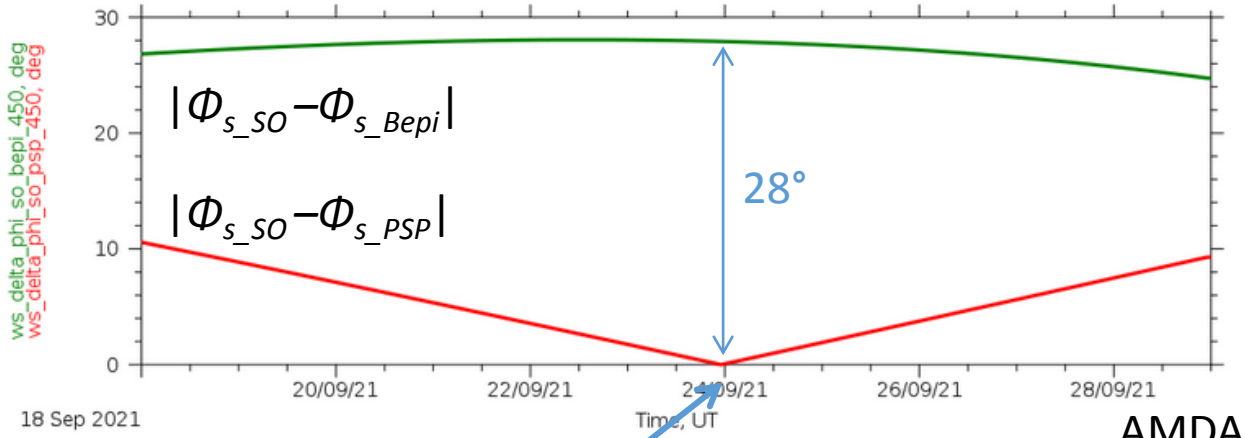
Change the defaut name and Save

day/hour/min/sec can be set

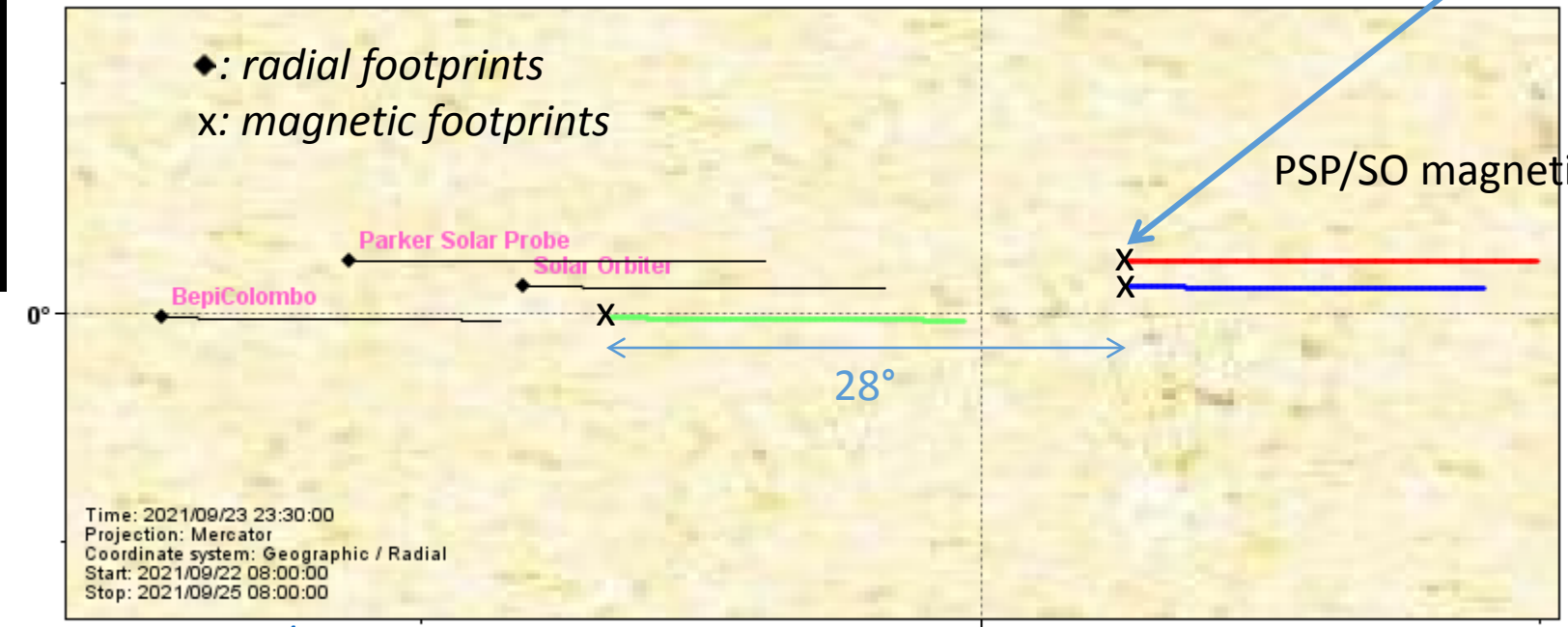


Solar Orbiter / PSP « Parker » conjunction (u_{SW}=450 km/s)





AMDA



PSP/SO magnetic conjunction

3DView

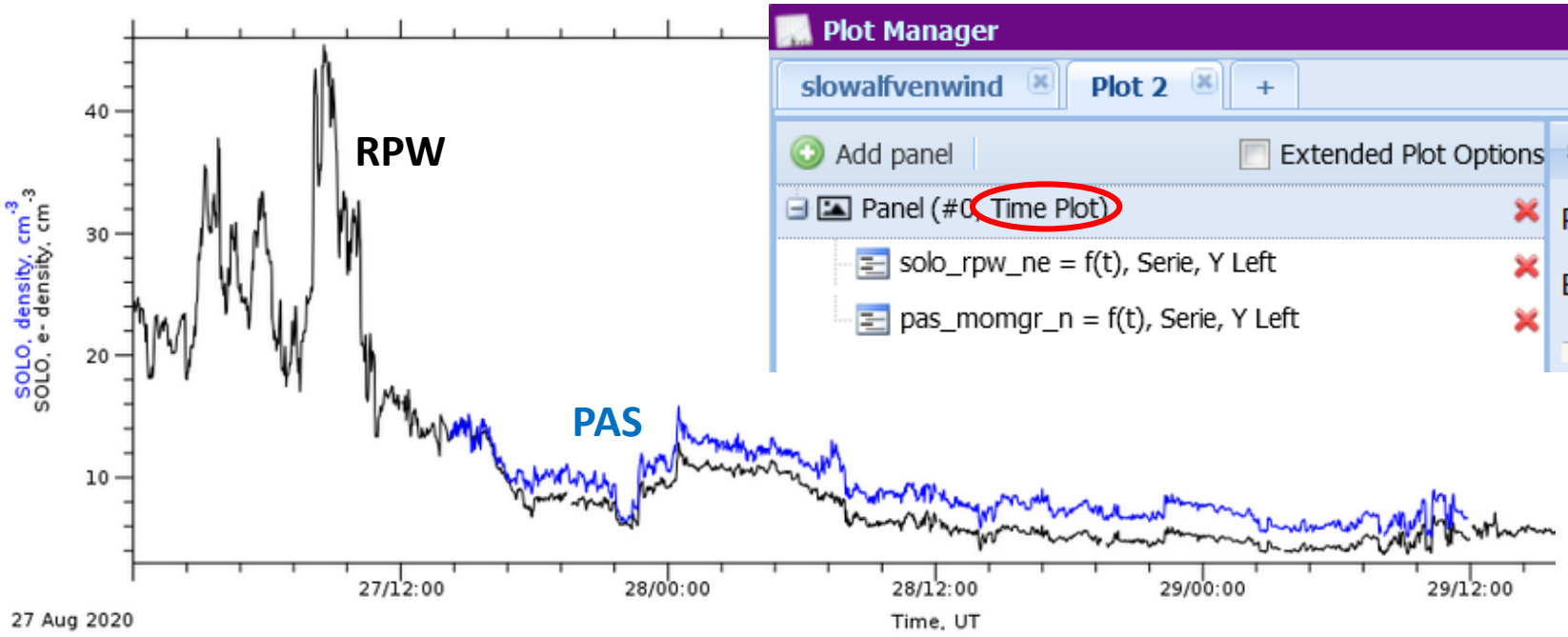
done with http://3dview.cdpp.eu/ ; more on Friday morning

AMDA use case #4

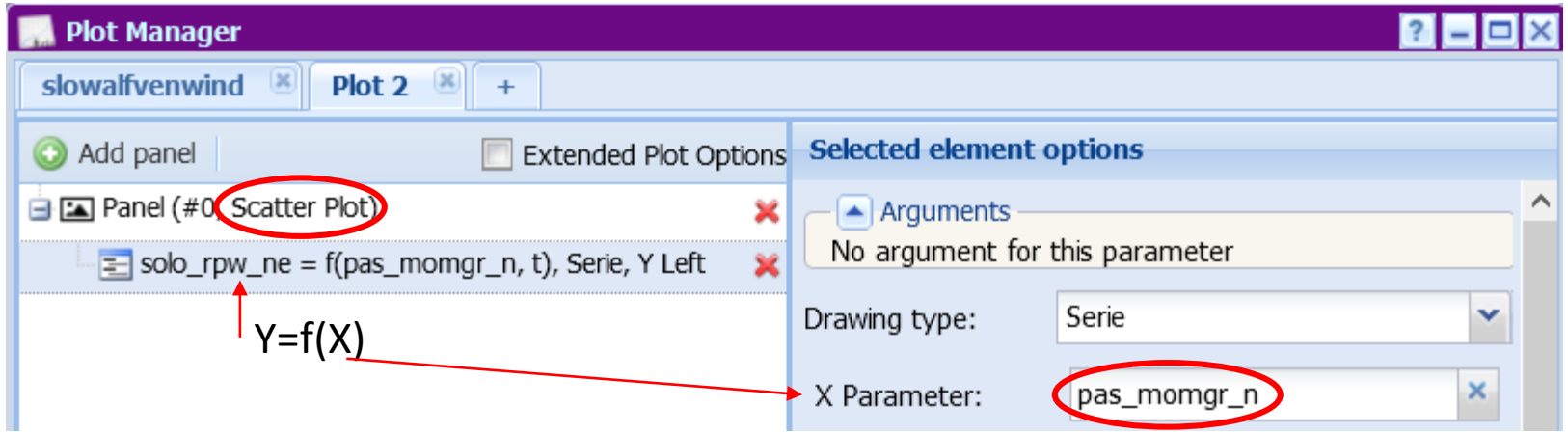
AMDA use case #4

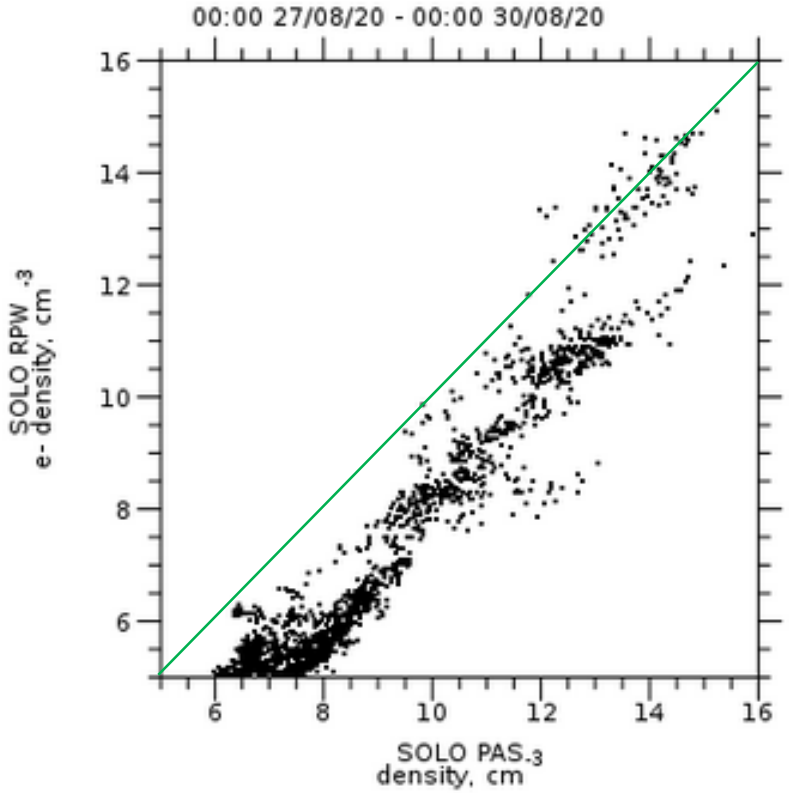
- Objectives:
  - Plot RPW data / only the density is available
  - Make a scatter plot

- *Data restricted only to the « PAS group » for calibration purposes*
- *More RPW public data will be integrated soon*


RPW
PAS
SOLO, density, cm-3
SOLO, e- density, cm-3
40
30
20
10
27/12:00
28/00:00
28/12:00
29/00:00
29/12:00
27 Aug 2020
Time, UT

Plot Manager
slowalfvenwind
Plot 2
+
Add panel
Extended Plot Options
Panel (#0, Time Plot)
solo_rpw_ne = f(t), Serie, Y Left
pas_momgr_n = f(t), Serie, Y Left
Selected element options
Plot type:
Time Plot
Background Color:
None
Preferred Dimensions

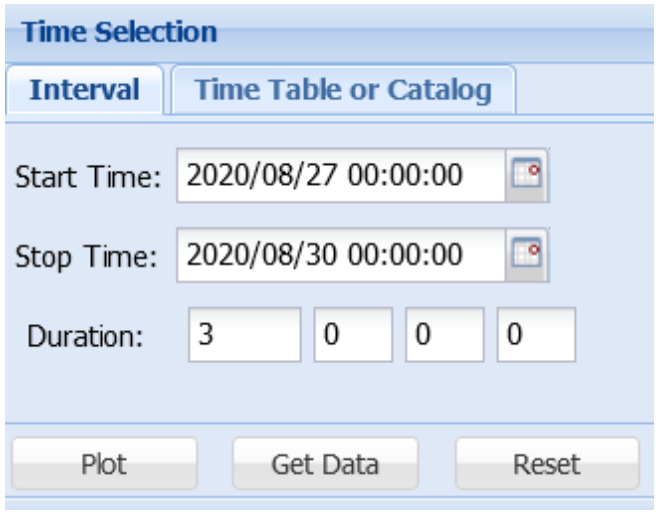

Plot Manager
slowalfvenwind
Plot 2
+
Add panel
Extended Plot Options
Panel (#0, Scatter Plot)
solo_rpw_ne = f(pas_momgr_n, t), Serie, Y Left
Y=f(X)
Selected element options
Arguments
No argument for this parameter
Drawing type:
Serie
X Parameter:
pas_momgr_n


00:00 27/08/20 - 00:00 30/08/20
SOLO RPW -3
e- density, cm
16
14
12
10
8
6
6
8
10
12
14
16
SOLO PAS-3
density, cm

AMDA use case #5

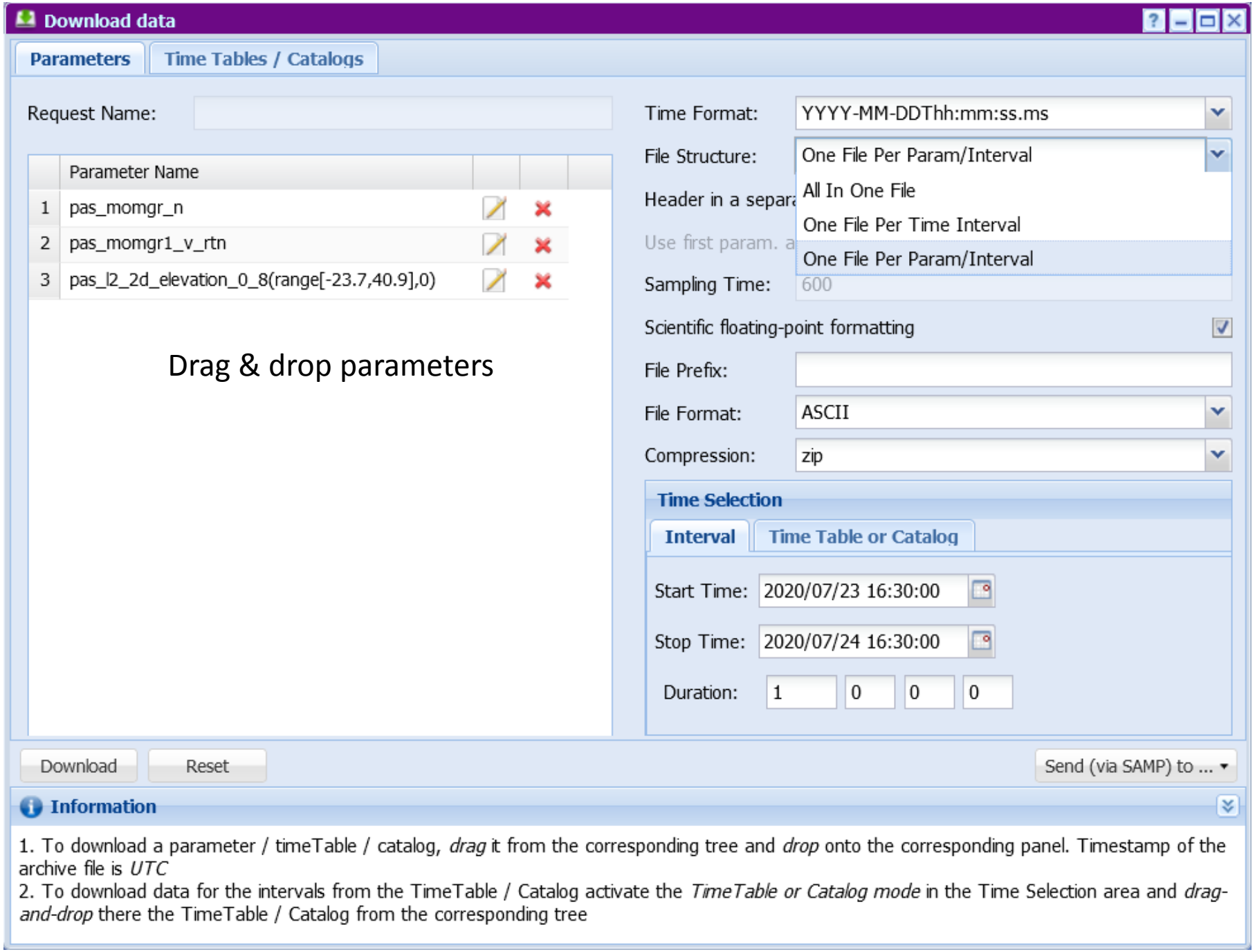
AMDA use case #5

- Objectives:
  - Download data
  - 2 ways
    - From a plot: « Get data »



    - From the Download menu



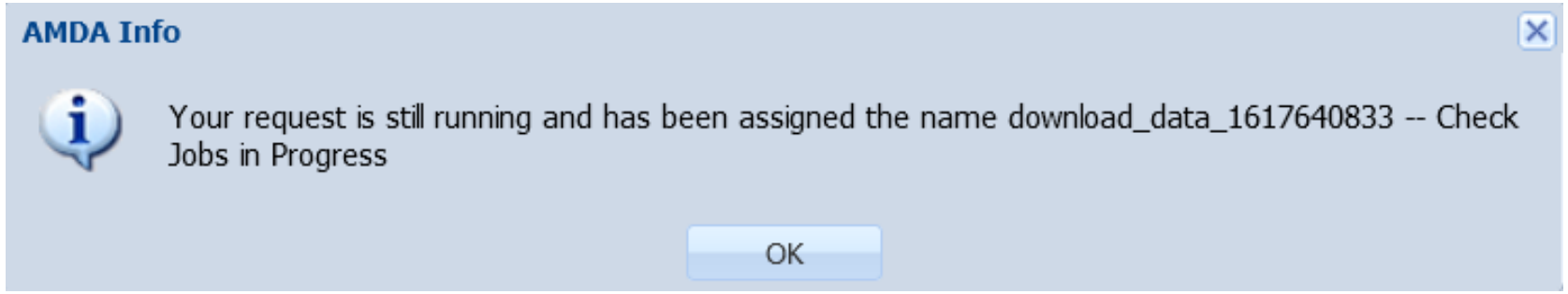


Choose the file structure

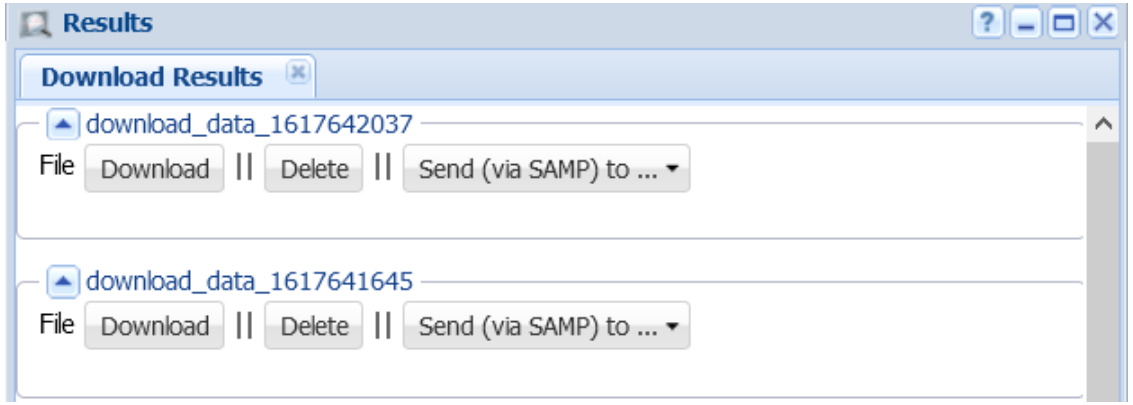
Choose time interval or Time Table

Download process

- If the request takes too long, it goes in ‘batch mode’ and a message pops up



- A tar/zip file is created containing one or multiple files, click on download to get it



```
# -----------
# AMDA INFO :
# -----------
# AMDA_ABOUT : Created by AMDA(c)
# AMDA_VERSION : 3.6.0
# AMDA_ACKNOWLEDGEMENT : CDPP/AMDA Team
#
# --------------
# REQUEST INFO :
# --------------
# REQUEST_STRUCTURE : all-in-one-file-refparam
# REQUEST_TIME_FORMAT : ISO 8601
# REQUEST_OUTPUT_PARAMS : pas_momgr_n,pas_momgr1_v_rtn,sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
#
# --------------------
# DERIVED PARAMETERS :
# --------------------
#
# PARAMETER_ID : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9_17228245143598613721
# PARAMETER_NAME : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
# PARAMETER_SHORT_NAME : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
# PARAMETER_UNITS : unspecified
# PARAMETER_PROCESS_INFO : Resampling of 'sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.
# PARAMETER_PROCESS_DESC : sum_into_table_range(pas_l2_2d_elevation_0_8, 0, -23.7, 40.9)
# PARAMETER_LINKED_PARAMS : sum_into_table_range_5014350929172425849,sum_into_table_range_pas_l2_2
#
#
# PARAMETER_ID : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
# PARAMETER_NAME : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
# PARAMETER_SHORT_NAME : sum_into_table_range_pas_l2_2d_elevation_0_8_0_-23.7_40.9
# PARAMETER_UNITS : unspecified
# PARAMETER_PROCESS_INFO : Derived parameter from expression '#sum_into_table_range($pas_l2_2d_ele
# PARAMETER_PROCESS_DESC : sum_into_table_range(pas_l2_2d_elevation_0_8, 0, -23.7, 40.9)
# PARAMETER_LINKED_PARAMS : sum_into_table_range_5014350929172425849
#
```

```
# -----------------
# BASE PARAMETERS :
# -----------------
#
# MISSION_ID : SolO
# MISSION_NAME : SolarOrbiter
# MISSION_DESCRIPTION : Solar Orbiter
# MISSION_URL : http://sci.esa.int/solar-orbiter
#
#   INSTRUMENT_ID : SolO_pas
#   INSTRUMENT_NAME : PAS
#   INSTRUMENT_DESCRIPTION : Proton-Alpha Sensor
#   INSTRUMENT_PI : spase://SMWG/Person/Philippe.Louarn
#   INSTRUMENT_TYPE : ParticleDetector
#
#     DATASET_ID : so-pas-momgr1
#     DATASET_NAME : on the ground moments
#     DATASET_SOURCE : CDPP/DDServer
#     DATASET_GLOBAL_START : 2020-04-15T14:23:18.322
#     DATASET_GLOBAL_STOP : 2020-10-27T03:04:02.063
#     DATASET_MIN_SAMPLING : 0
#     DATASET_MAX_SAMPLING : 10
#     DATASET_CAVEATS : Info :
#                                   * 0: Ground
#                                   * 1: Normal
#                                   * 2: Snapshot
#                                   * 3: Burst
#                                   * 4: Engineering
#
#                                   Validity :
#                                    * 1: V lt 270 km/s
#                                    * 2: V gt 270 km/s , V lt 380 km/s
#                                    * 3: V gt 380 km/s
#
#       PARAMETER_ID : pas_momgr1_v_rtn
#       PARAMETER_NAME : pas_momgr1_v_rtn
#       PARAMETER_SHORT_NAME : v_rtn
#       PARAMETER_COMPONENTS : vr,vt,vn
#       PARAMETER_UNITS : km/s
#       PARAMETER_TENSOR_ORDER : 0
#       PARAMETER_FILL_VALUE : nan
```

The header is a bit verbose but retains all info on the production of the file (original dataset, resampling, processes, …)

AMDA use case #6

AMDA use case #6

- Objectives:
  - Plot EPD data

- *Presentation by Alexis Rouillard*

AMDA Python API

AMDA Python API

- Objectives:
  - Get Solar Orbiter data in a Python environment
    - From Spyder or any other Python interface
      - http://amda.irap.omp.eu/help/amdapy/
    - From a Jupyter notebook
      - Get the file ExemplePlotAMDA.ipynb
      - http://amda.irap.omp.eu/help/amdapy/amdapy-notebook-1.html
- This is brand new and any feedback/bug/suggestion will be very much appreciated !

https://www.davidstansby.com/soda/

