Correction of Low-Energy Ion Measurements from Rosetta-ICA for the Effects of Spacecraft Charging

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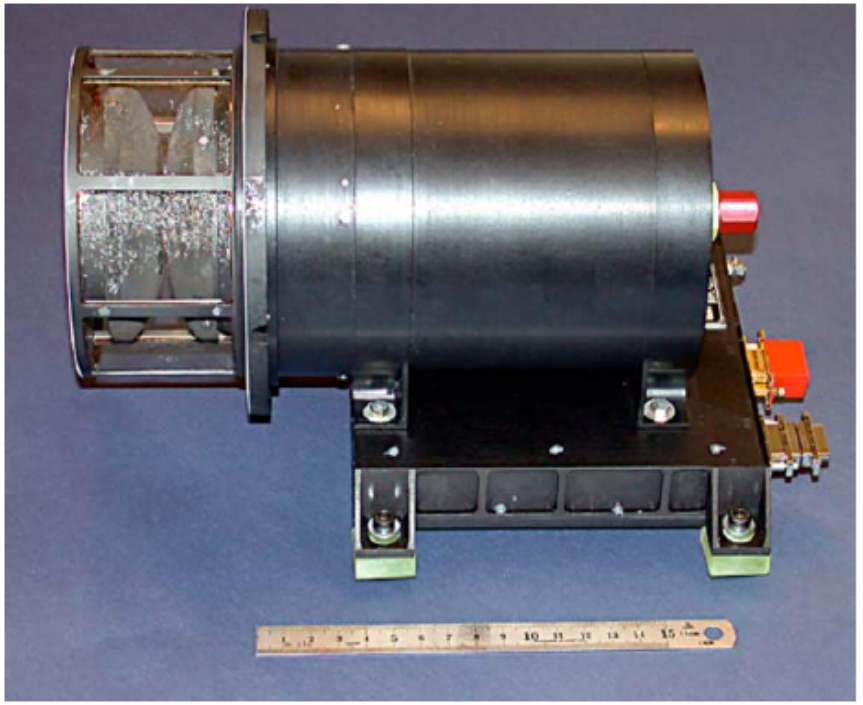
Rosetta Mission

- Launched in March 2004 to study the comet 67P/Churyumov-Gerasimenko
- First spacecraft to orbit a comet
- Mission ended in September 2016 by a controlled impact

Image: ESA

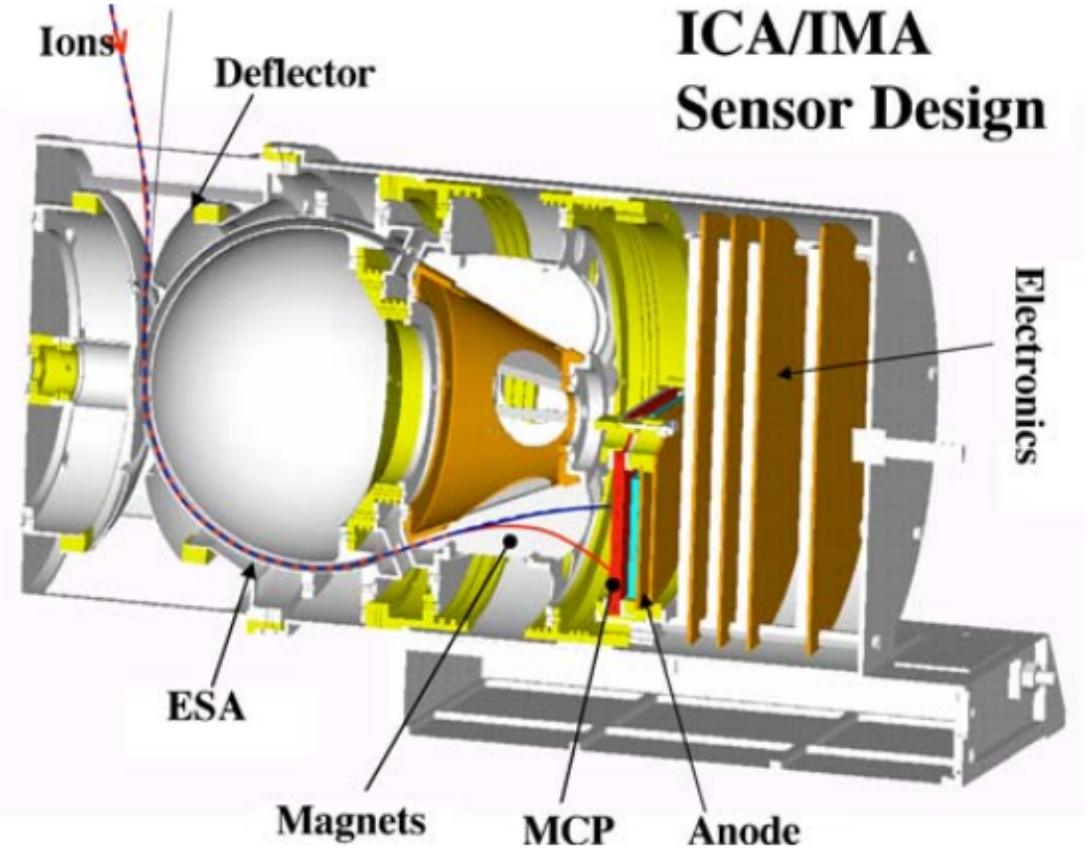
ICA Instrument Description

- Ion Composition Analyzer
- Part of the Rosetta Plasma Consortium
- Ion spectrometer measuring positive ions
- Designed to study the interaction between the solar wind and the cometary particles
- Spherical ”top-hat” electrostatic analyzer



Nilsson et al. (2007).

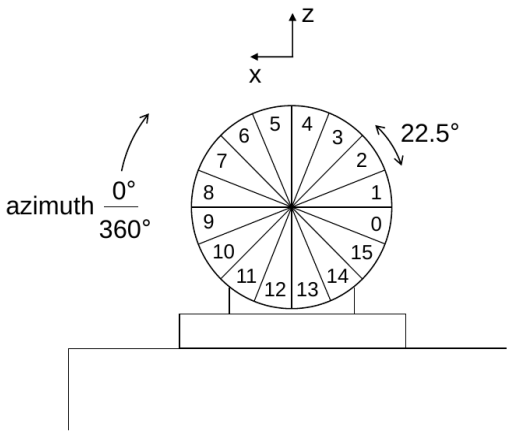
ICA Instrument Description

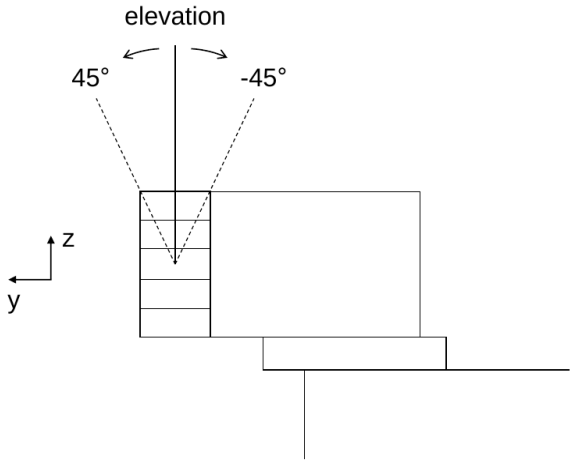


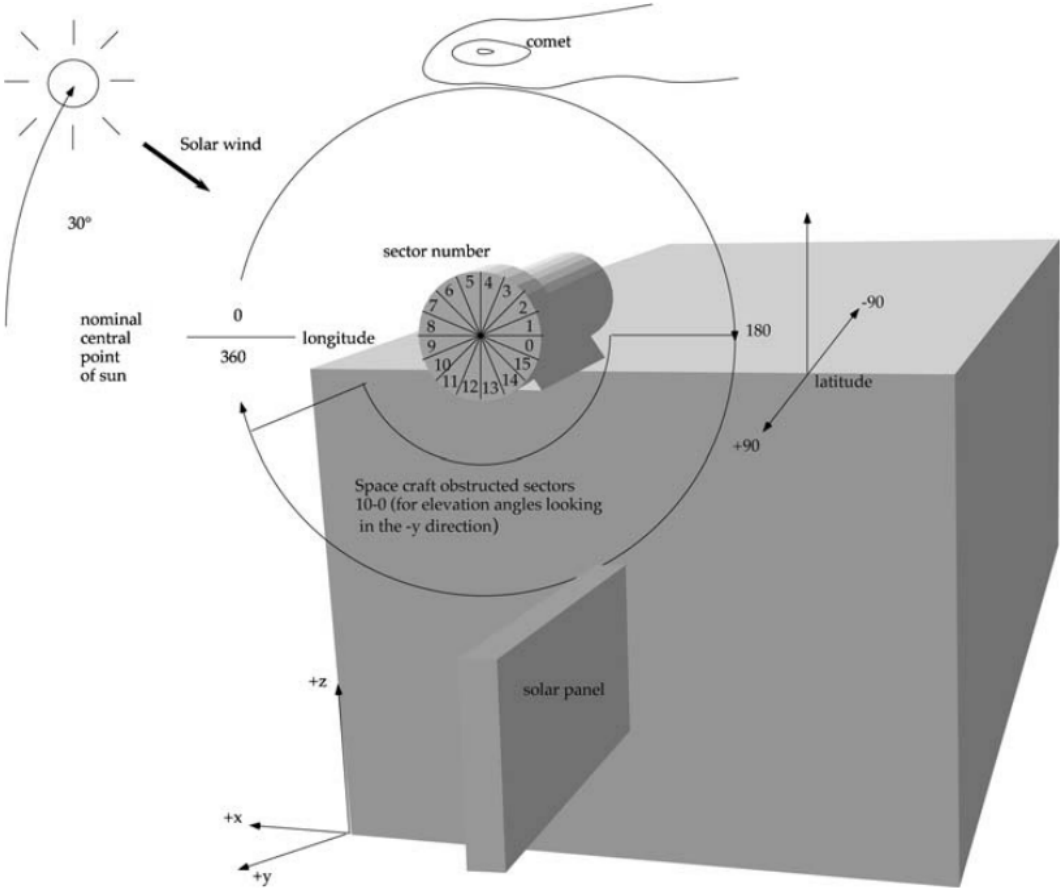
- FOV: 360° × 90°
- Energy range: a few eV – 40 keV
- Energy resolution: dE/E = 0.07
- 96 energy steps
- 16 elevation steps
- One sweep → 192 s

Nilsson et al. (2007).

ICA Instrument Description

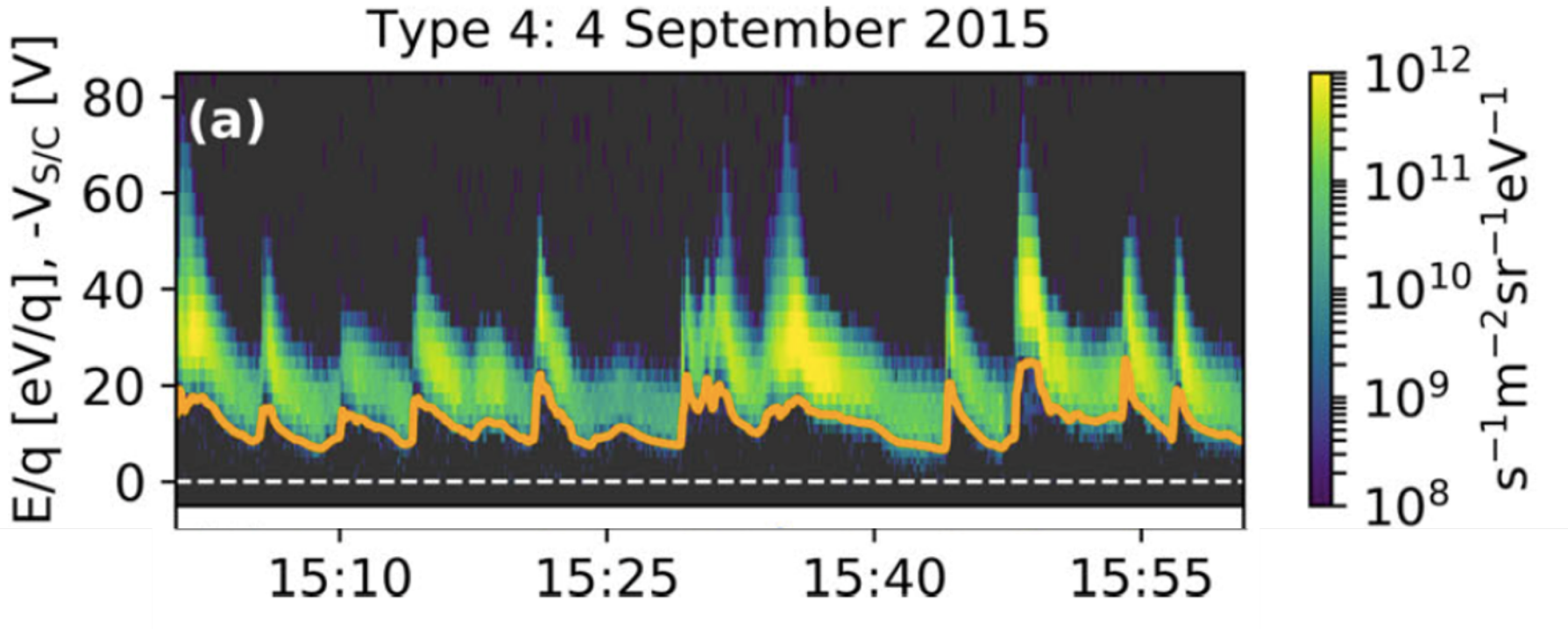






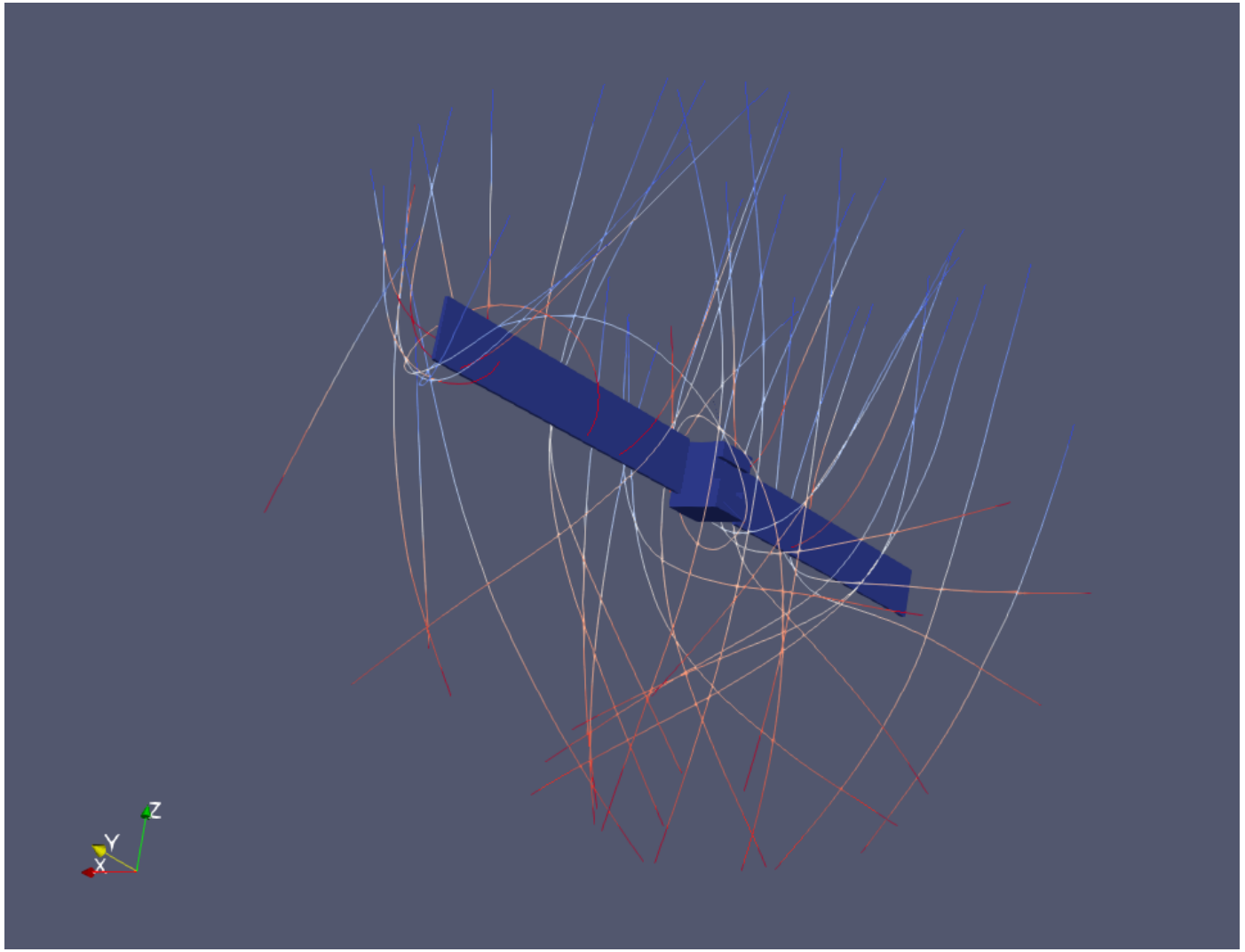
Nilsson et al. (2007).

Spacecraft Potential – Effect on Ion Energy



Stenberg Wieser et al. (2017).

Spacecraft Potential – Effect on Ion Trajectories

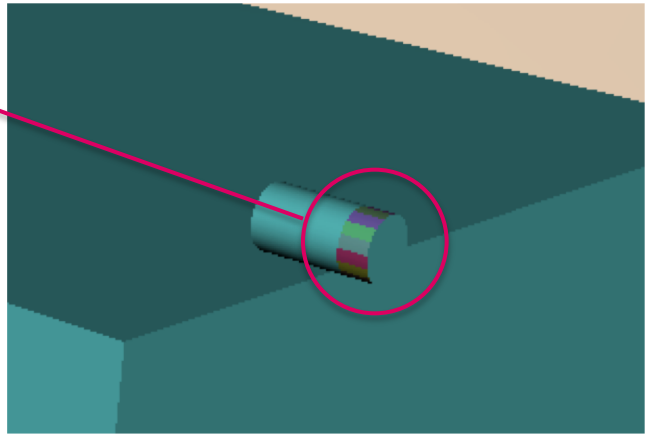


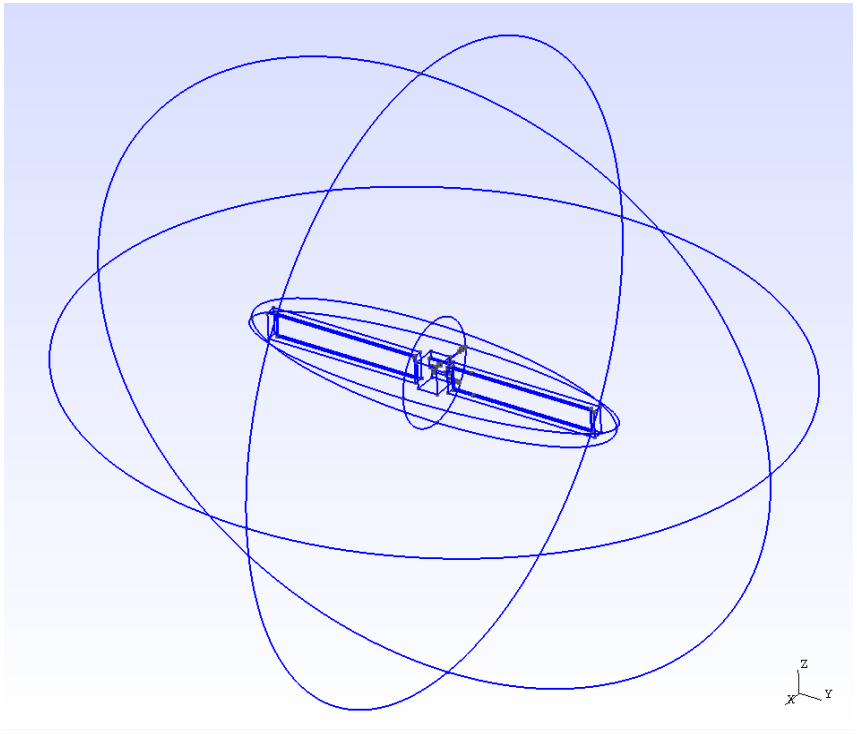
Project Description

- Our low-energy data are heavily distorted by the spacecraft potential
- Important part of the spectrum
- Goal: reconstruct the original ion energies and directions of travel

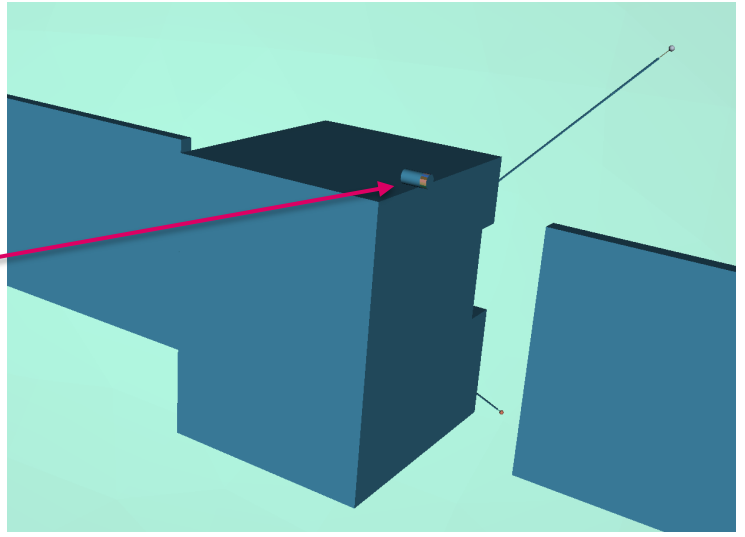
S/C Model

16 particle detectors





ICA



Simulation Environment

e^-	H_2O^+	H_2O^+ (test population)
n = 1000 cm^{-3}	n = 1000 cm^{-3}	n = 0.001 cm^{-3}
T = 10 eV	T = 0.5 eV	T > 20 eV
	v = 4 km/s (-z direction)	v = 0 m/s
Fluid approximation	PIC	PIC

- Floating spacecraft potential
- Whole spacecraft conducting
- ITO material
- Distance to sun = 1.7 AU

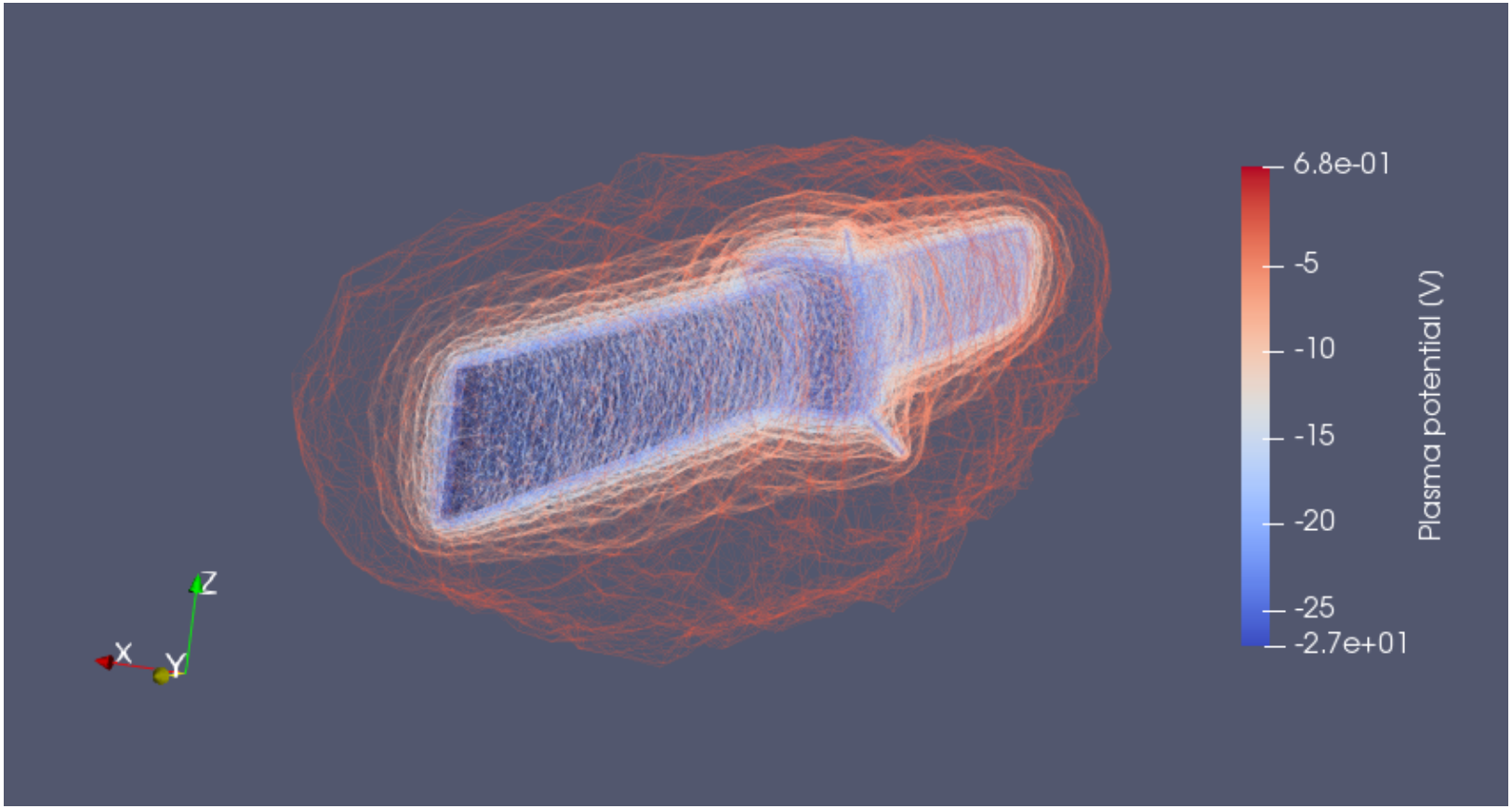
✓ Photo emission

x Secondary electron emission from protons

x Secondary electron emission from electrons

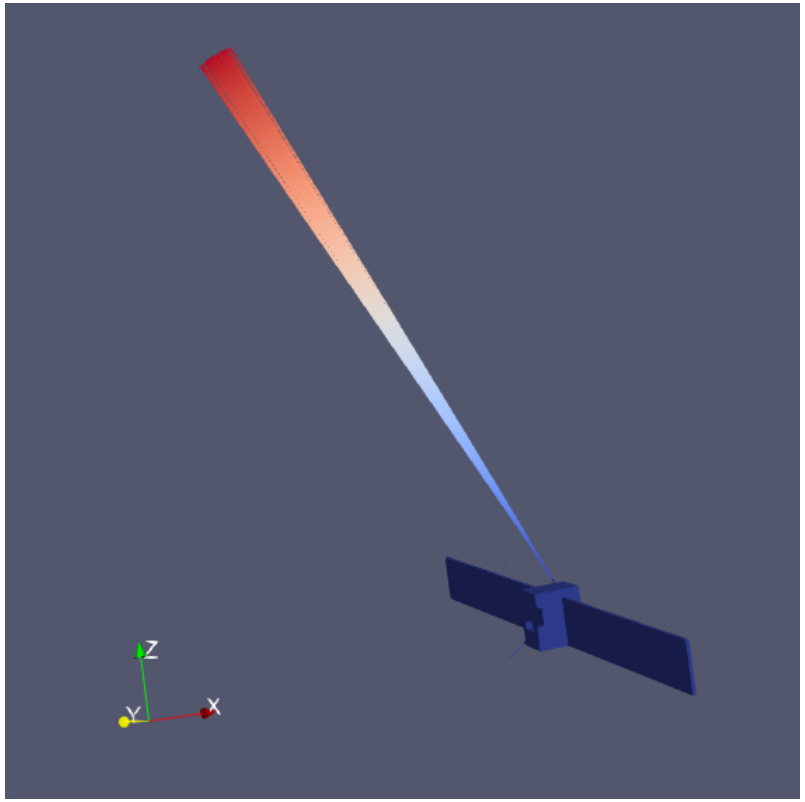
x B-field

Plasma Potential

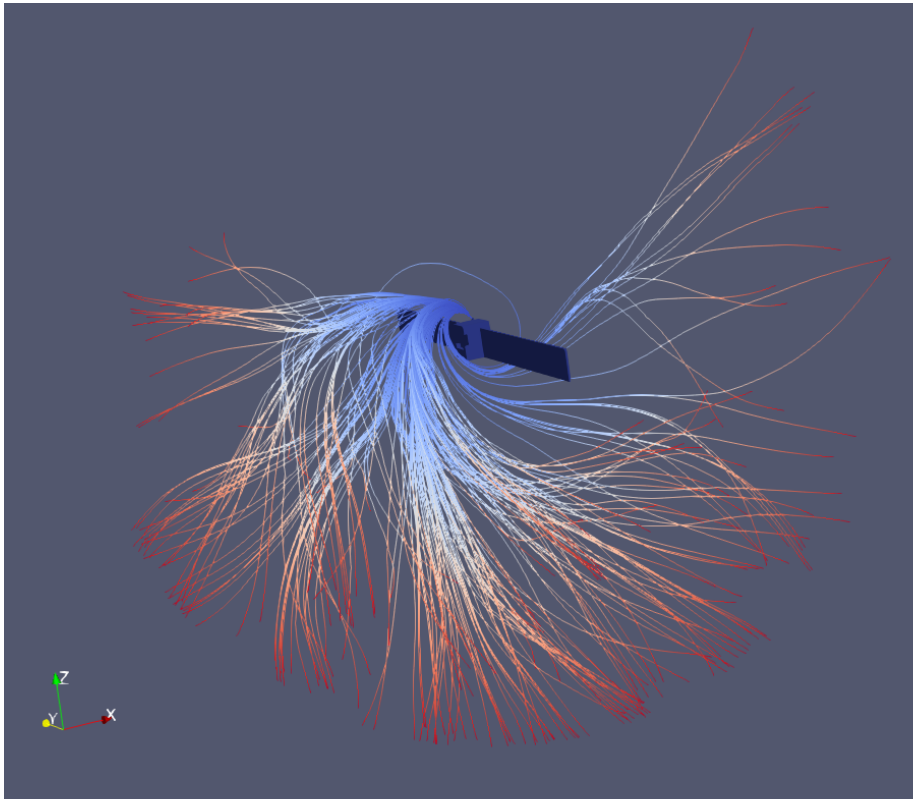


Particle Tracing

Sector 3



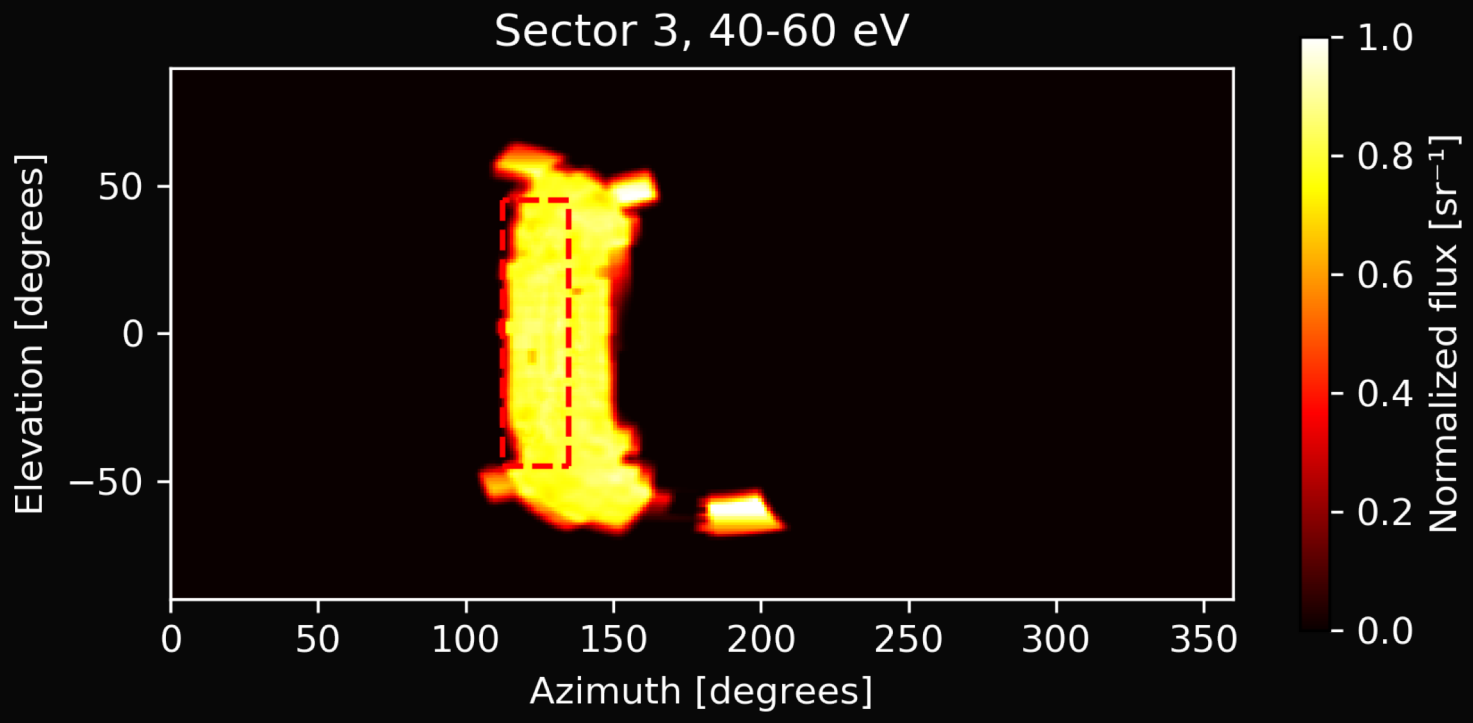
High energy



Low energy

Results

High energy



Processing of SPIS Output

- Velocity distribution ASCII-files
  - Particle_detector_idX_InitialVelocity2DF_at_t=X.XXXXs.txt
  - Particle_detector_idX_Velocity2DF_at_t=X.XXXXs.txt

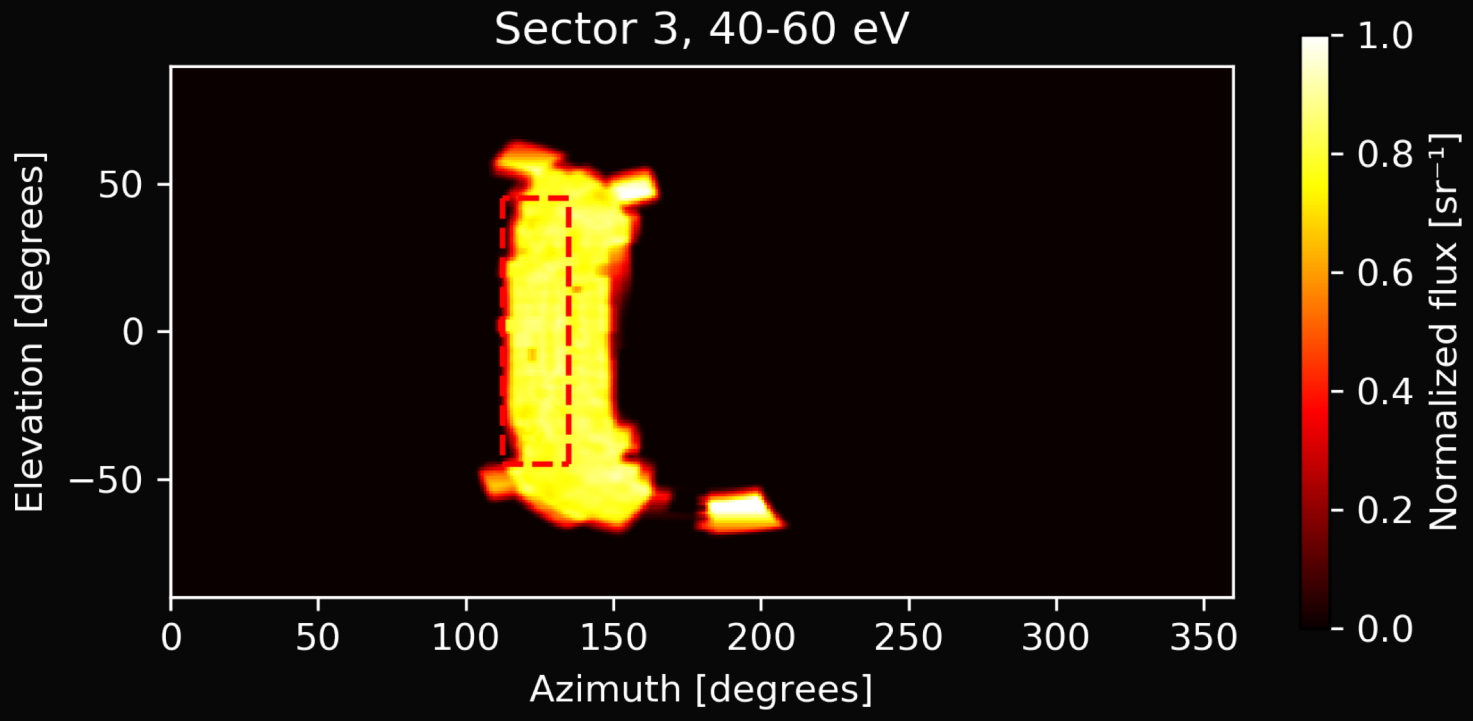
- Directions calculated from velocity vectors
- Particle flux per solid angle for each direction calculated from

$$F = \frac{\int_{v_1}^{v_2} v \cdot f(v) d^3 v}{d\Omega}$$

- Normalized w.r.t. total flux

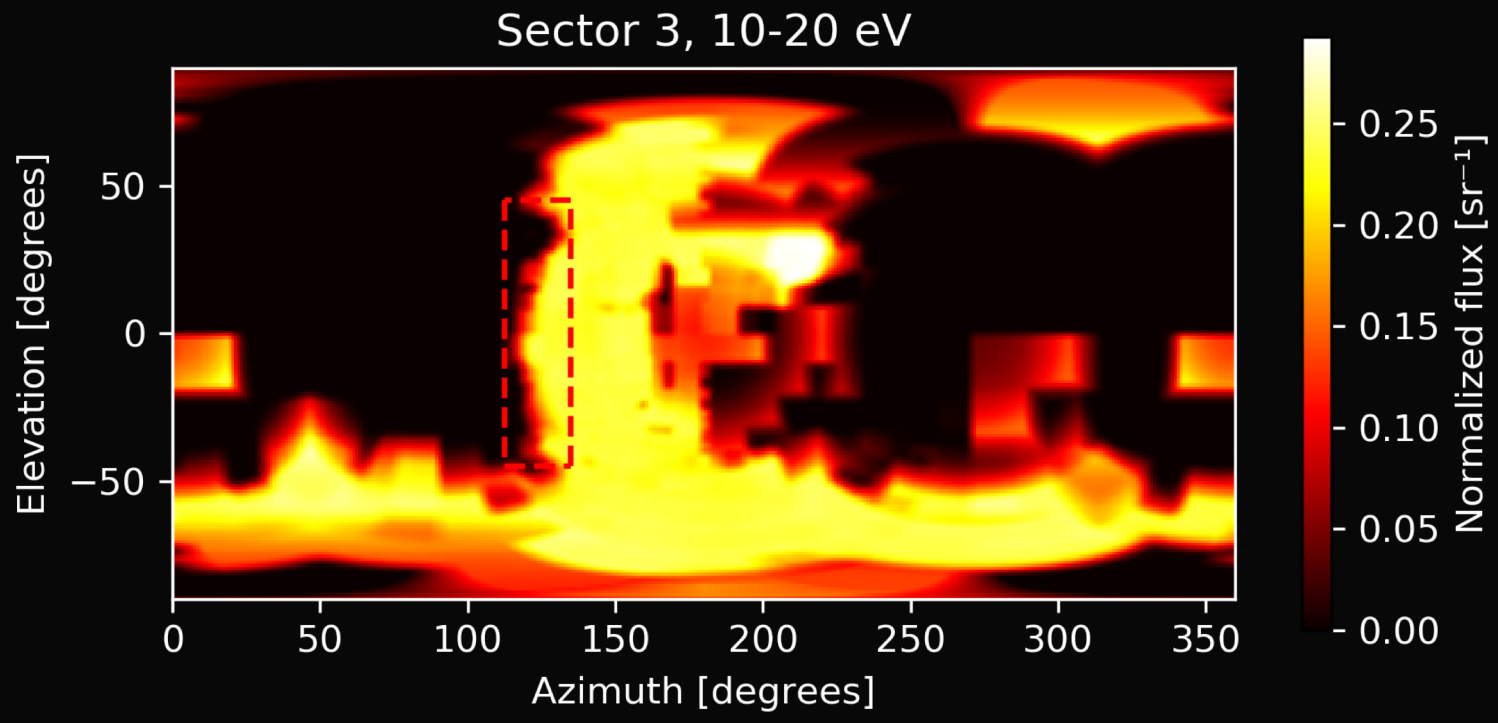
Results

High energy



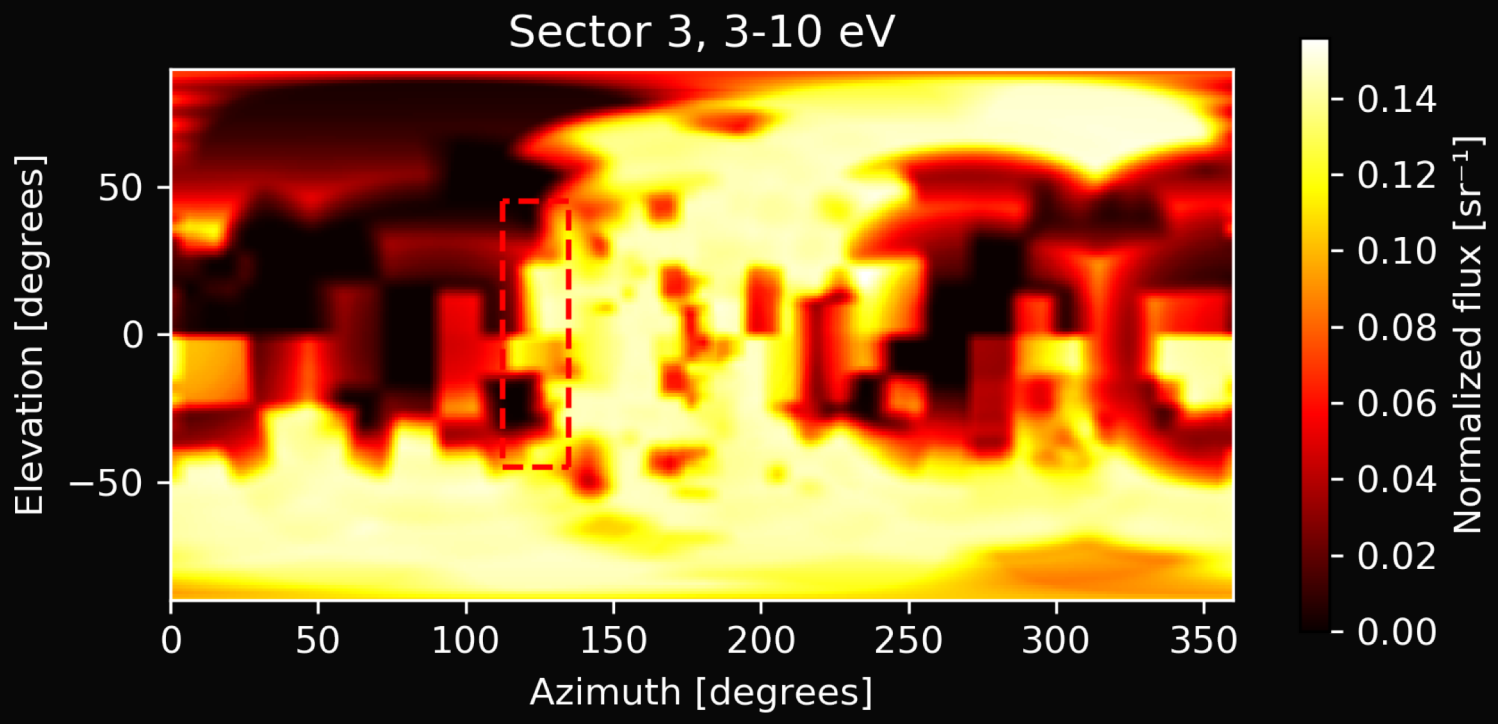
Results

Medium energy

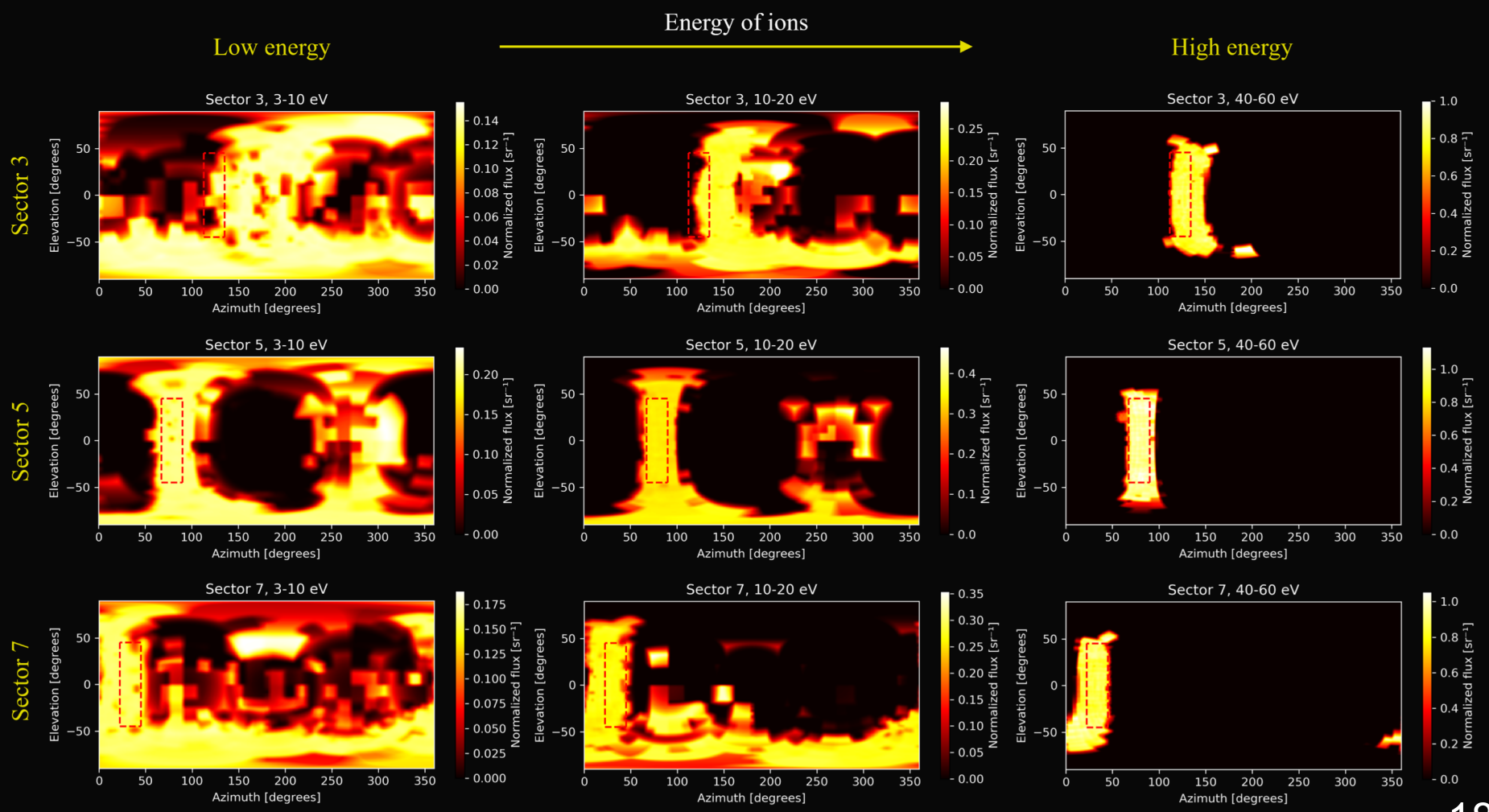


Results

Low energy

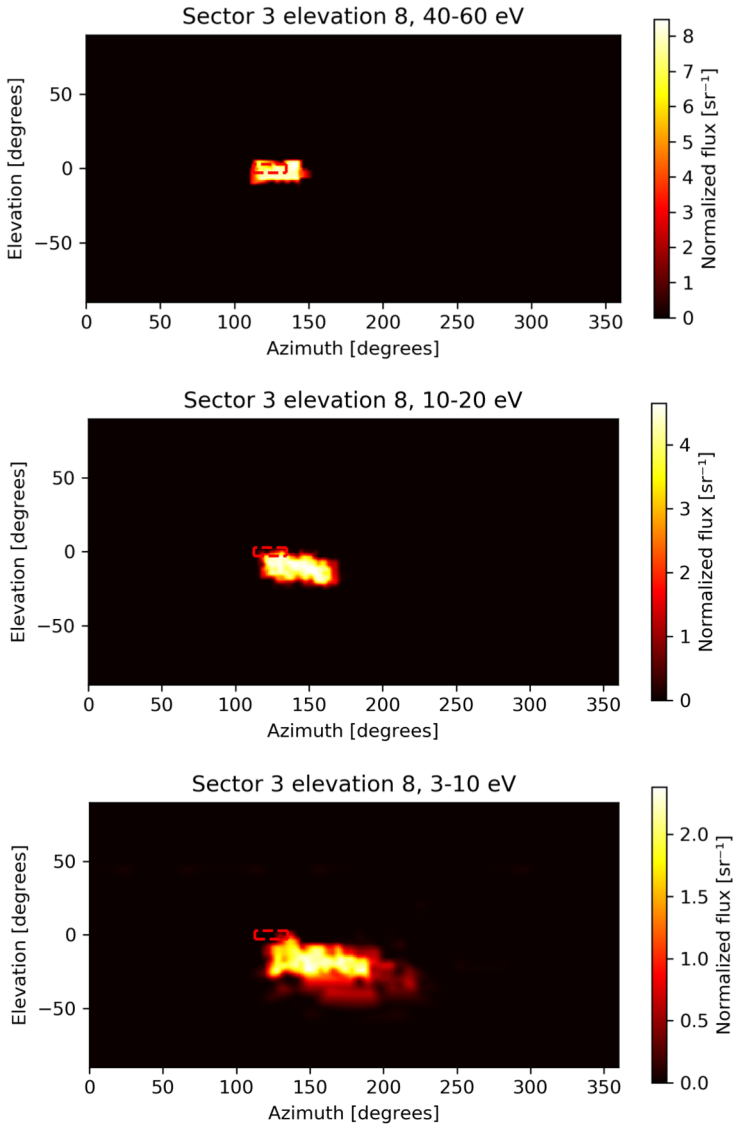


Results

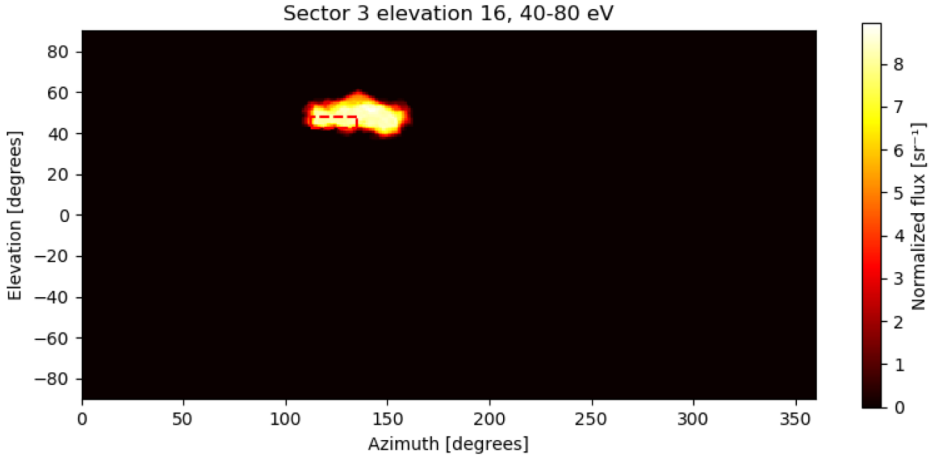

Energy of ions
Low energy
High energy
Sector 3
Sector 5
Sector 7
Sector 3, 3-10 eV
Sector 3, 10-20 eV
Sector 3, 40-60 eV
Sector 5, 3-10 eV
Sector 5, 10-20 eV
Sector 5, 40-60 eV
Sector 7, 3-10 eV
Sector 7, 10-20 eV
Sector 7, 40-60 eV
Elevation [degrees]
Azimuth [degrees]
Normalized flux [sr⁻¹]

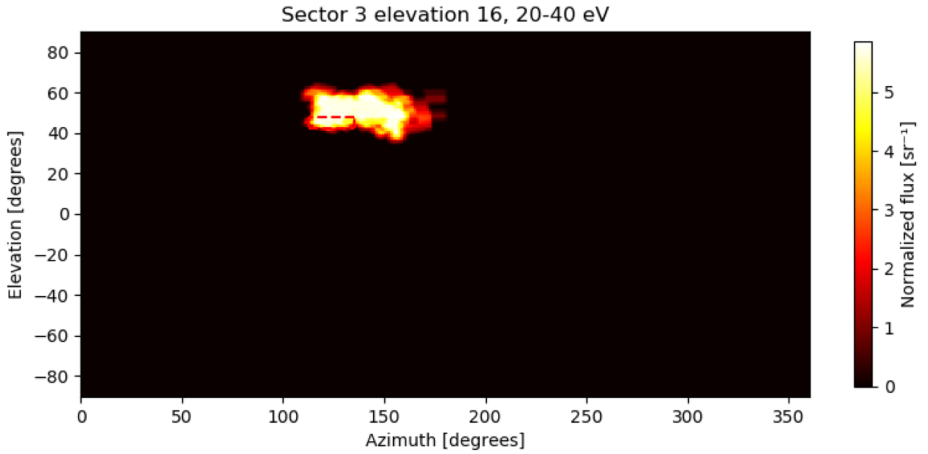
Future Work

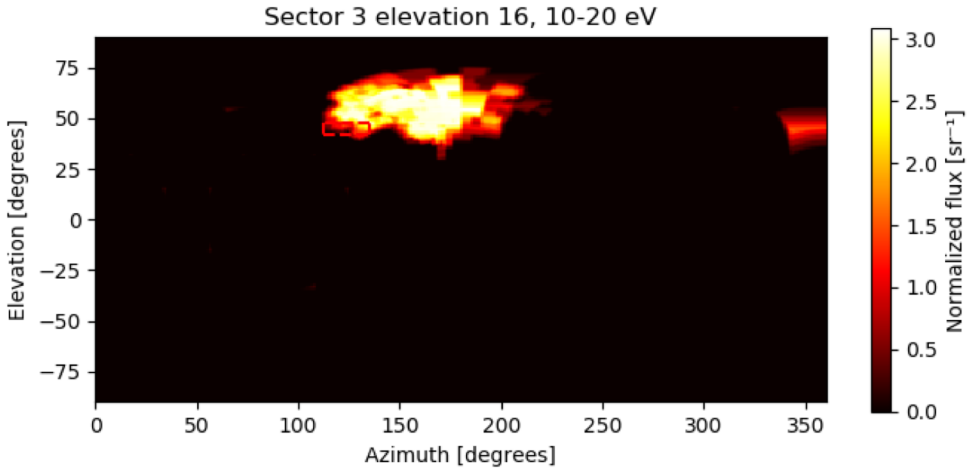
- Elevation separation
- Artefact removal
- Sensitivity analysis (plasma model, s/c model, voltage settings of other instruments, ion mass...)
- Real data inversion

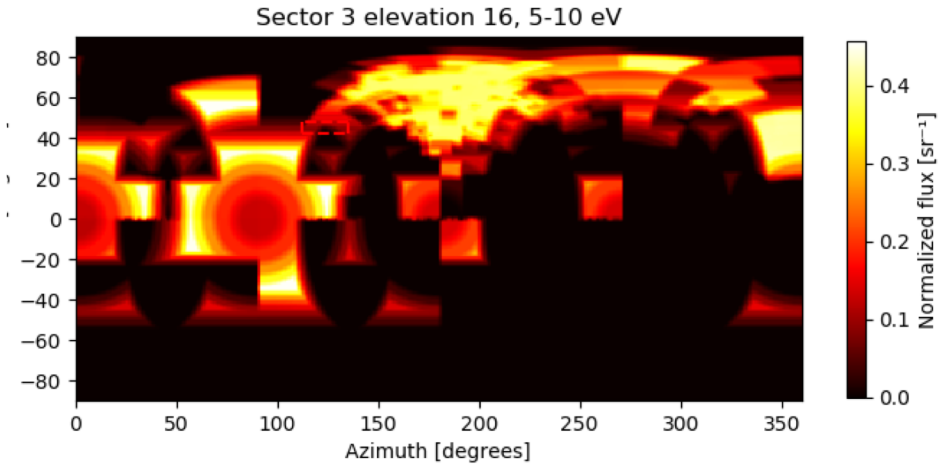


Artefacts


Sector 3 elevation 16, 40-80 eV
Elevation [degrees]
Azimuth [degrees]
Normalized flux [sr⁻¹]


Sector 3 elevation 16, 20-40 eV
Elevation [degrees]
Azimuth [degrees]
Normalized flux [sr⁻¹]


Sector 3 elevation 16, 10-20 eV
Elevation [degrees]
Azimuth [degrees]
Normalized flux [sr⁻¹]


Sector 3 elevation 16, 5-10 eV
Elevation [degrees]
Azimuth [degrees]
Normalized flux [sr⁻¹]

References

Benoît Thiébault, Jean-Charles Mateo Velez, Julien Forest and Pierre Sarrailh (2013), *SPIS 5.1 User Manual*. Version 3. Revision 4.

Nilsson, H., Lundin, R., Lundin, K., Barabash, S., Borg, H., Norberg, O., Fedorov, A., Sauvaud, J.-A., Koskinen, H., Kallio, E., Riihelä, P. and Burch, J. L. (2007), RPC-ICA: The Ion Composition Analyzer of the Rosetta Plasma Consortium. *Space Science Reviews* 128: 671-695.

Stenberg Wieser, G., Odelstad, E., Wieser, M., Nilsson, H., Goetz, C., Karlsson, T., André, M., Kalla, L., Eriksson, A. I., Nicolaou, G, Simon Wedlund, C., Richter, I. and Gunell, H. (2017), Investigating short time-scale variations in cometary ions around comet 67P. *MNRAS* 469: S522-S534.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