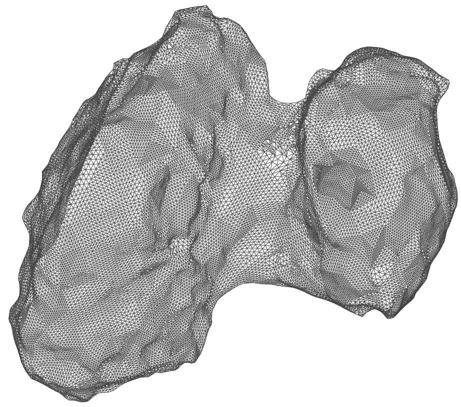
Lab 2
Space Physics

Light mass-loading at 67P

Etienne Behar
etienne@irf.se
2017-05-02

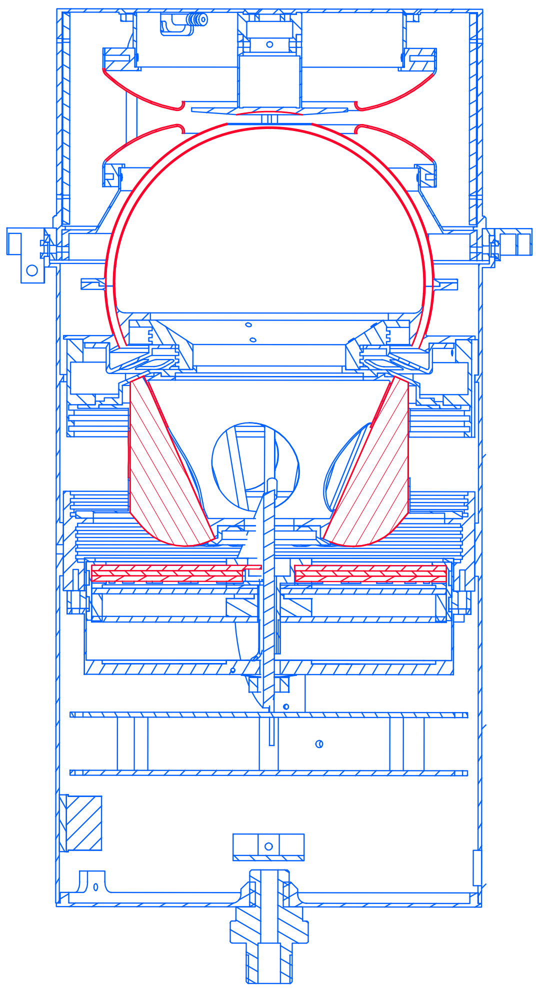
The mission

Rosetta was launched on 2 March 2004, and after a cruising phase of 12 years (31 months in hibernation), reached comet 67P/Churyumov-Gerasimenko on 6 August 2014, at 3.75 au. After rendez-vous, the probe has been closely escorting the nucleus, witnessing its perihelion passage to then get further away from the Sun again. And after two years and two months of active mission, Rosetta landed on the surface of the nucleus on 30 September 2016, ceasing all communication with Earth.



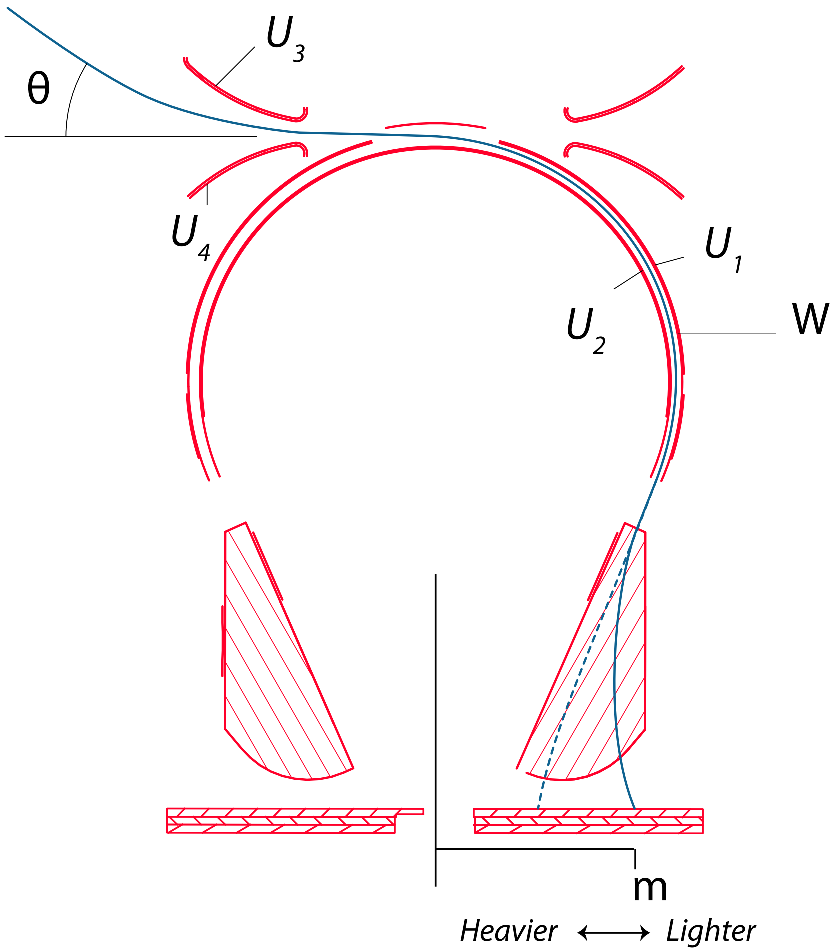
Most of two years worth of data remain to be thoroughly analysed. This volume of data collected by the dozen of instruments on board the probe addresses a variety of research topics, but one topic of particular interest for us is the plasma/plasma interaction between the partially ionised coma and the solar wind.

The instrument



The Ion Composition Analyzer ICA is a positive ion imaging spectrometer, with mass speration capacities. It was designed and built in IRF Kiruna, and two almost identical instruments have been or are orbiting Venus (Venus EXpress, terminated) and Mars (Mars Express, active). ICA was part of the Rosetta Plasma Consortium.

The instrument can reconstruct 3D velocity distribution functions. It somehow answers the question «what flux of what species was flowing with what velocity at what time».



RPC-ICA, IRF, Rosetta

30 eV - 40 keV in <u>96 steps</u>
$\Delta E/E = 7\%$
1H^+, He^+, [H_2O^+, CO_2^+, ...]
90° x 360° <u>16x16 bins</u>
5° x 22.5°
192 s full scan

With settings U_1, U_2, U_3, U_4:

if a particle is detected, ***then*** this particle has an energy *per charge* W and an elevation angle θ .

All azimuthal angles (<u>16 bins</u>) and all masses (<u>32 bins</u>) are measured simultaneously.

The data set

The file 20141128.mat contains data from the 28th of November 2014, as the comet was 2.88 au away from the Sun. The activity was low, but high enough to form a thin atmosphere. This coma is then partially ionised and these new-born ions are mass-loading the initially undisturbed solar wind. We will first identify the different species present in the observations, to then try to characterise them in terms of energy, mass, and most of all flow direction along time. The aim is to understand and describe qualitatively the interaction between the solar wind and the ionised coma, in this precise regime (see lecture notes).

Guidelines

0 – Load the data, look at the different variables of the structure, their size, their meaning. Compare this sizes/dimensions with the instrument description above.

What type of physical values are stored in each variable?

Explain the shape of the variable 'spectra'.

1 – Plot the spectrogram of the data set (energy vs time) as a color map (see pcolor). Use the energy vector (or energy table) for the y axis. Try to plot with and without the time vector for the x axis.

Why does it look different?

2 – Plot the energy-mass matrix (integrated over time): mass as x-axis, energy as y-axis, color map with counts as color. This time, without using the energy table.

3 – On the previous plot, identify the species, and explain their position in terms of both energy and mass.

Report their position in terms of mass bins [m_1, m_2] and energy bins [e_1, e_2]

Try to find at what energy *per charge* solar wind components/species should be expected.

What general region of the energy-mass matrix should each species end up?

4 – Plot azimuth versus elevation (Field Of View FOV), integrated over time first. We can discuss here before the following steps.

What is the dark area covering ~1/4 of the FOV?

5_1 – Plot the 18^{th} FOV for all species, and for protons only (find a way!).

5_2 – Calculate and plot the barycenter of this matrix.

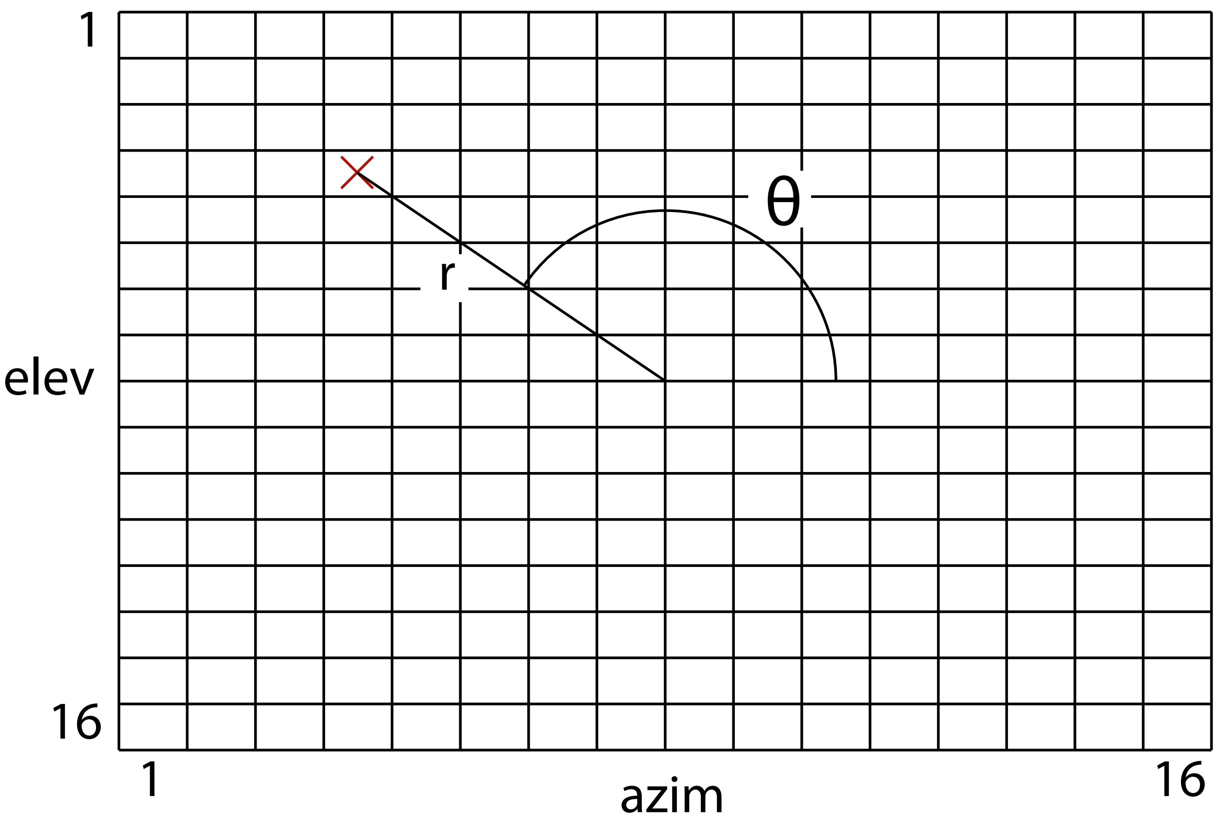
6 – Create an array of FOVs (*ie.* of size nbTime x 16 x 16), one for each species: H^+, He^{++}, accelerated H_2O^+.

7 – Important step of this lab! In one 16 by 16 FOV, we define a polar coordinate system originating between bins 8 and 9 on both dimension (see figure below). From the previous array, calculate series of r and θ for

barycenters of each species.

Plot θ_{H+} versus time together with θ_{H2O+} versus time. We can discuss here.

9 – Summary, and drawing of what is seen and understood from this data set.



Note: for the report, «refined» plots are expected (axis labels with units, right color scale/contrast, etc). Interpreting the plots and results is not literally asked, because it is always expected, if there is any point interpreting anything! Speak about what you are doing and what you are getting, do drawings, figures, to explain how you are handling data, etc.

Matlab samples:

Loading a mat file:

```
load('myFile.mat');
```

Sum an array *a* over one dimension:

```
b = sum(a, 2);
b = squeeze(b);
```

Element-wise multiplication:

```
c = a. * b    or    c = times(a, b)
```

Transpose of an array:

```
a_transpose = a.'
```

A basic pseudo-color plot of array *a* with coordinates *x* and *y*:

```
figure('Name', 'thenameoftheplot')
pcolor(x, y, a)
xlabel( 'xValue [unit]')
ylabel( 'yValue [unit]')
datetick('x', 'dd-mmm-yyyy HH-MM-SS') % Formating the x ticks in case of plotting time.
```