Visualization and Analysis of Particle Spectra

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The tasks listed below complement the lectures *Principles of particle spectrometry* and *Interpretation and modeling of particle spectra*. After selecting two Cluster orbits, one in summer and one in winter, CIS ion data are used first to identify the big magnetospheric domains. Next, ion data from the two orbits are explored in detail, by examining moments, spectrograms, and distribution functions. The purpose of this closer investigation is twofold: to illustrate the physical use of the particle data, and to point out instrumental issues that require precautions.

In case you would like to give us feedback, please print and fill in the form here.

1. Orbit plots by Cluster Science Data System
    a. Go to the Cluster Science Data System, CSDS, and select the plot type *Orbit / Configuration Plot*.
    b. Plot a summer Orbit, by selecting the date September 23, 2001 (for this type of plot the exact time is not important).
    c. Plot a winter Orbit, by selecting the date February 3, 2003.
    d. When do you expect Cluster to encounter the solar wind and when the plasma sheet?

2. Ions overview by using the Cluster/CIS web site
    a. Go to the CIS site and select *Data Plots / Public Access Spectrograms*.
    b. Go to the spectrograms for Sep. 22, 2001, and identify the apogee time.
        i. Follow Cluster 1 along a complete orbit, starting at apogee, and identify time intervals spent by Cluster in the plasma sheet, lobe, cusp, radiation belt.
        ii. What can you say about the relative ratio of O^+ / H^+ density in the lobe versus plasma sheet? What feature in the spectrograms can be associated with the (large scale) variation of this ratio?
        iii. List the features that you do not understand.
    c. Go to the spectrograms for Feb. 2, 2003, and identify the perigee time.
        i. Follow Cluster 1 along a complete orbit, starting at perigee, and identify time intervals spent by Cluster in the radiation belt, auroral region, lobe, cusp, magnetosheath, solar wind.
        ii. Give at least one example of signature in the data which does not have a natural origin, but is related to a change in the instrument setup (e.g. a mode change).
        iii. List the features that you do not understand.

3. Closer analysis of a time interval on Sep. 23, 2001, by the *cl* program.
    a. Open three 'Terminal' windows. Go to the directory */mnt/share/particles/config_cl* and start three instances of the program by typing *cl*. Click on 'Ok' in the startup configuration window.
    b. Plot a predefined set of CIS spectrograms and moments, by loading in each *cl* (with *File/Open*) one of the configuration files *STIINTE_20010923_CODIF_H*, *STIINTE_20010923_CODIF_O*, and *STIINTE_20010923_HIA*. For a study of the O+ outflow during the time interval covered by these files you can take a look at Bouhram et al, 2004.

c. Compare the CODIF O+ and H+ plots. What prominent differences do you see? What is the time scale of the O+ outflow?
d. Compare the CODIF H+ and HIA (all ions) density during the cusp crossing. What could be the reason for the difference in density?
e. Compare the CODIF O+ and HIA (all ions) Vz velocity between 12:00 and 12:30. The two velocities appear to be different. What is their ratio and what do you think is the explanation for the difference?
f. Plot a predefined distribution function, by loading the configuration file *STIINTE_20010923_CODIF_O_DF*. What is the approximate energy of the O+ beam seen in the plot? (Hint: a H+ ion moving with 440 km/s has an energy of about 1 keV) Is the energy consistent with the trace in the spectrogram?
g. What could be the acceleration mechanism of the beam ions?

4. Closer analysis of a time interval on Feb. 2, 2003, by the *cl* program.
   a. Restart the three *cl* sessions.
   b. Repeat the procedure 3.b for the configuration files *STIINTE_20030202_CODIF_H, STIINTE_20030202_CODIF_O,* and *STIINTE_20030202_HIA.*
   c. Compare the HIA and CODIF H+ densities at the beginning of the interval. What could be the reason for the large difference?
   d. Note the peaks in the O+ density and velocity between 16:30 and 16:35. Are these peaks compatible with an ion beam of ionospheric origin? (Hint: compare the velocity panel with the magnetic field panel).
   e. Plot the O+ distribution function close to the first peak in density / velocity, by loading the configuration file *STIINTE_20030202_CODIF_O_DF*. What is the energy of the beam? (see the hint at 3.f) Explore the time variation of the distribution function by clicking on *,'Time <='* and *,'Time =>'* (note that in this case the particles are counted every second spin, therefore every second distribution is empty). What is the time scale of the beam? How does it compare with the beam at 3.f ?
   f. Plot the H+ distribution function at the time of the O+ beam, by loading the configuration file *STIINTE_20030202_CODIF_H_DF*. Do you see a beam feature in the H+ data? At what energy? Can you imagine an acceleration mechanism consistent with both the O+ and H+ ions?
   g. How wide in latitude can be the source region of the beam ions? Hint: the satellite velocity is about 5 km/s; for the mapping to the ionosphere compare the magnetic field in the plots 4.b with the value at 100 km, of about 50,000 nT.