5 science nuggets from Cluster

S. Haaland[(1)], E.A. Kronberg, P.W. Daly, L. Degener [(1)], E.Georgescu, M.Fränz

[(1)] also at University of Bergen, Norway

MAX-PLANCK-GESELLSCHAFT

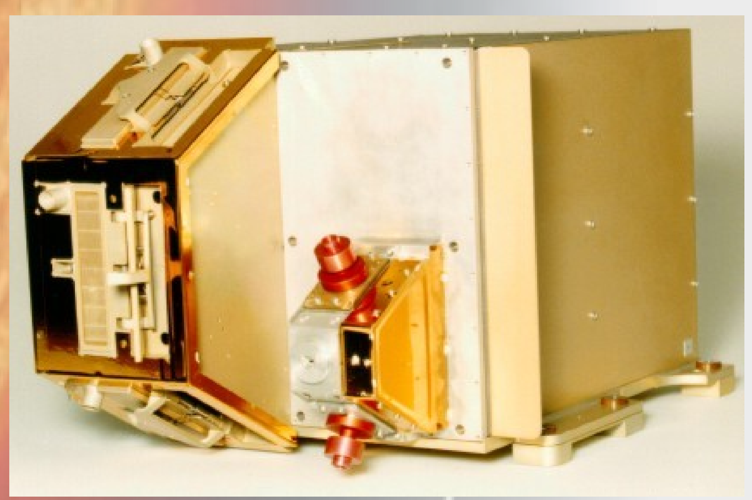
MPS Max-Planck-Institut für Sonnensystemforschung

Introduction

Cluster is a four-spacecraft ESA satellite mission. The 4 satellites, launched in 2000 and still operatio nal, fly in a nearly 90 deg inclination elliptical polar 4 x 20 Re orbit (1 Re = Earth radii = 6370 km).

Some of the primary science objectives of Cluster are:
- investigation of boundaries in space
- study of plasma transport in the magnetosphere
- study of physical processes, such as reconnection

In this poster, we present 5 science nuggets - science results where MPS has been responsible and provided a significant contribution.



MPS has been involved in the Cluster mission both on the hardware side and with science interpretation,

The image to the left shows the Research with Adaptive Particle Imaging Detectors (RAPID) instrument, which was designed, built and calibrated at MPS.

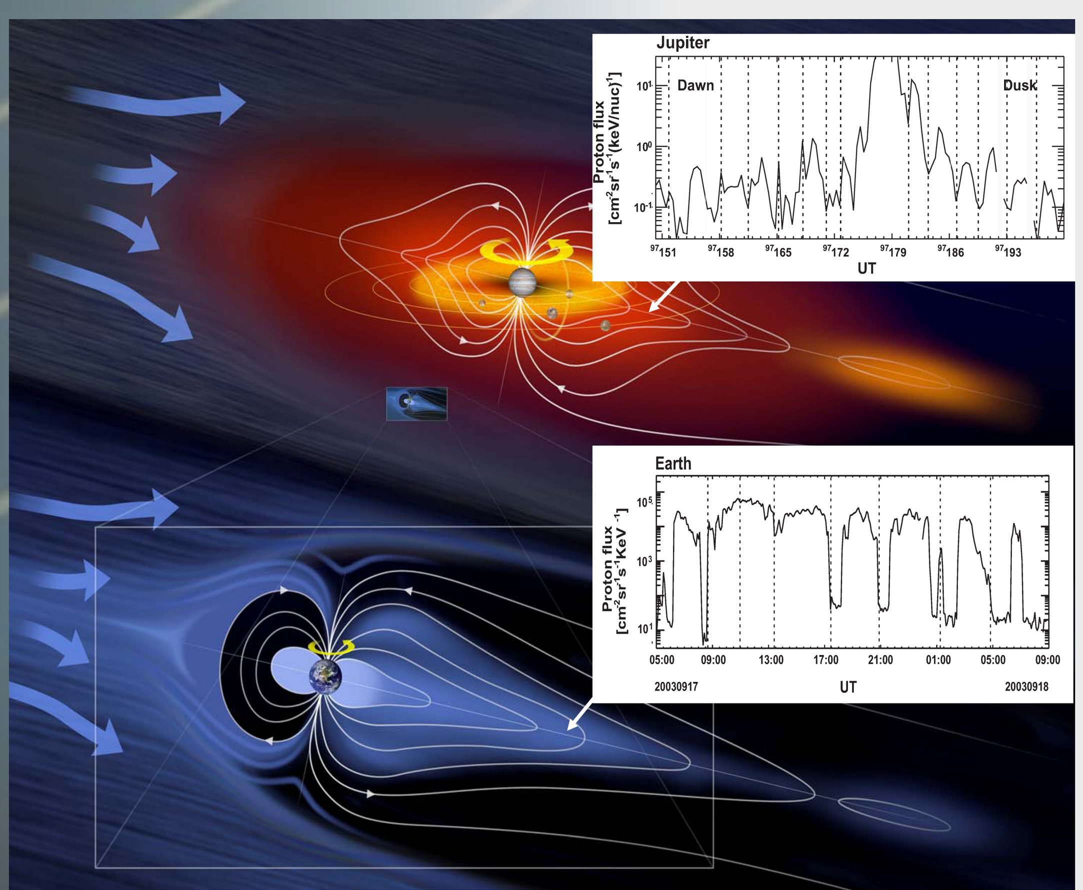
MPS has PI responsibility for the RAPID experiment, and much of our work is focused on data from this instrument.

Periodic substorms at Jupiter and Earth

In the terrestrial magnetosphere periodic substorms have been observed during magnetic storms. Data from Cluster mission, particularly from particle instruments RAPID and CIS help us to study behavior of ions during these magnetospheric disturbances.

The energetic particles detector and magnetometer measurements from Galileo have shown that the Jovian magnetosphere also undergoes quasi-periodic (~ 3 days) reconfiguration processes which are very similar to the characteristics of a terrestrial substorm. A comparison of the periodic disturbances at Jupiter and Earth shows that they are similar in dynamic features, but have different energy sources.

The particle data show periodic intensity fluctuations and plasma pressure variations. In addition, recurring signatures of stretching and dipolarization are observed in the magnetic field. Furthermore, the release process is associated with an intensification of auroral emissions. The typical phases for terrestrial substorms like growth, expansion and recovery are also found in the periodic substorms at Jupiter.

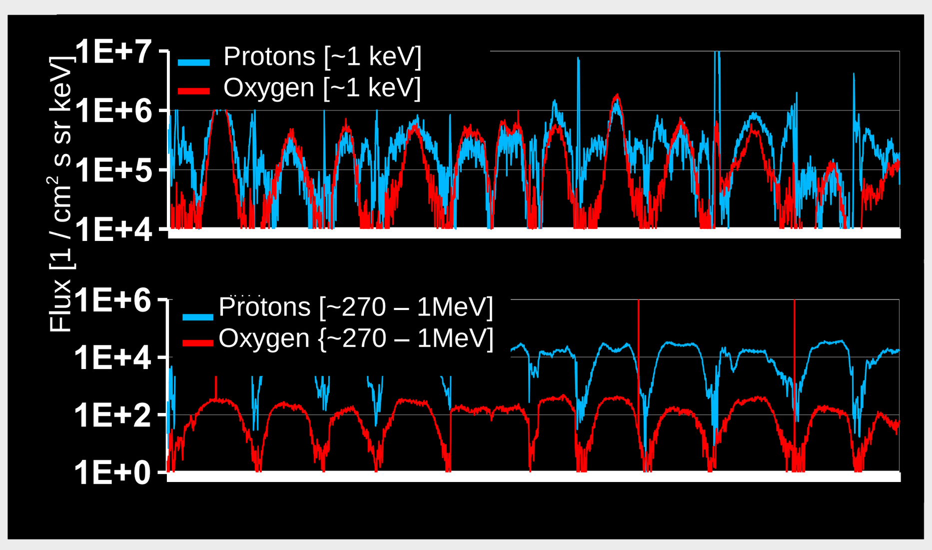


The figures to the left shows energetic protons (220 - 540 keV/nuc) observed on Galileo orbits G8 and G9 in the Jovian magnetotail (top panel) and energetic protons (28 - 64 keV) measured by Cluster in the terrestrial magnetotail (bottom panel). Vertical lines denote the times when substorms occur.

As a lesson taken from the Jovian magnetosphere it is proposed that under certain conditions periodic substorms at Earth can be driven by mass-loading from the plasmasphere. From [Kronberg et al, 2008]

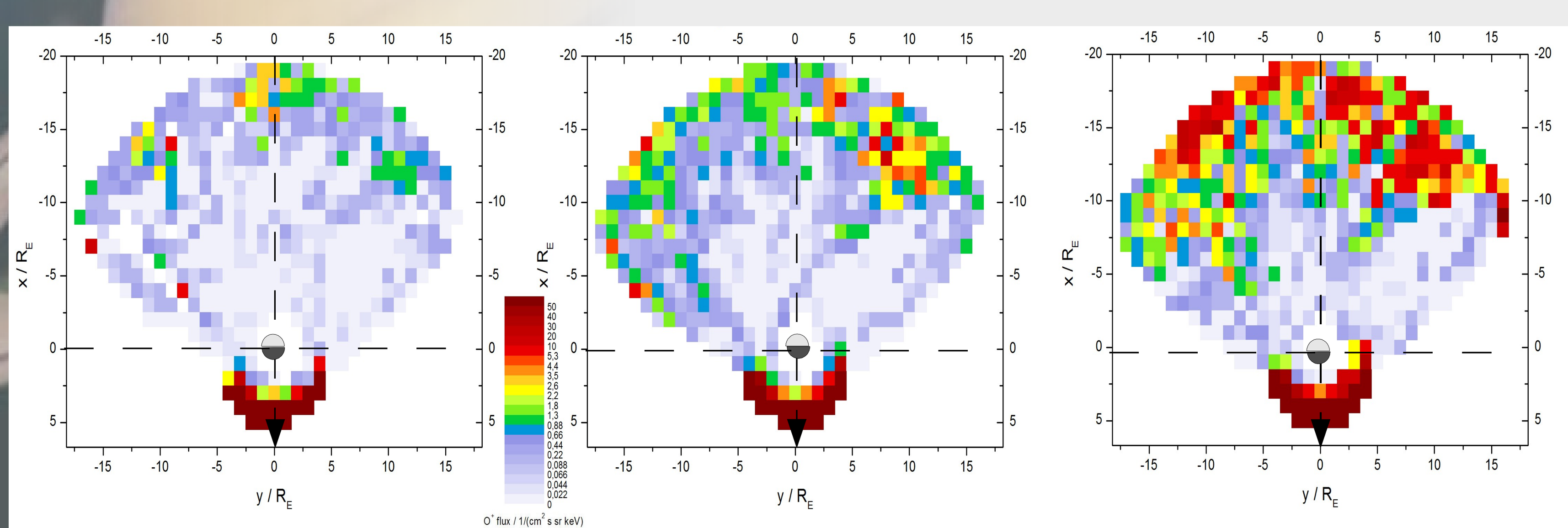
O^+ abundance in the magnetotail

The mass composition, and in particular the abundance of oxygen in the Earth's magnetosphere plays an important role for many plasma processes. A small abundance of oxygen significantly increases the average ion mass. Fundamental plasma properties such as the Alfvén speed and average gyro radius, are then changed changed. Another important consequence of enhanced oxygen abundance is that that the threshold levels in many known plasma instabilities are altered,

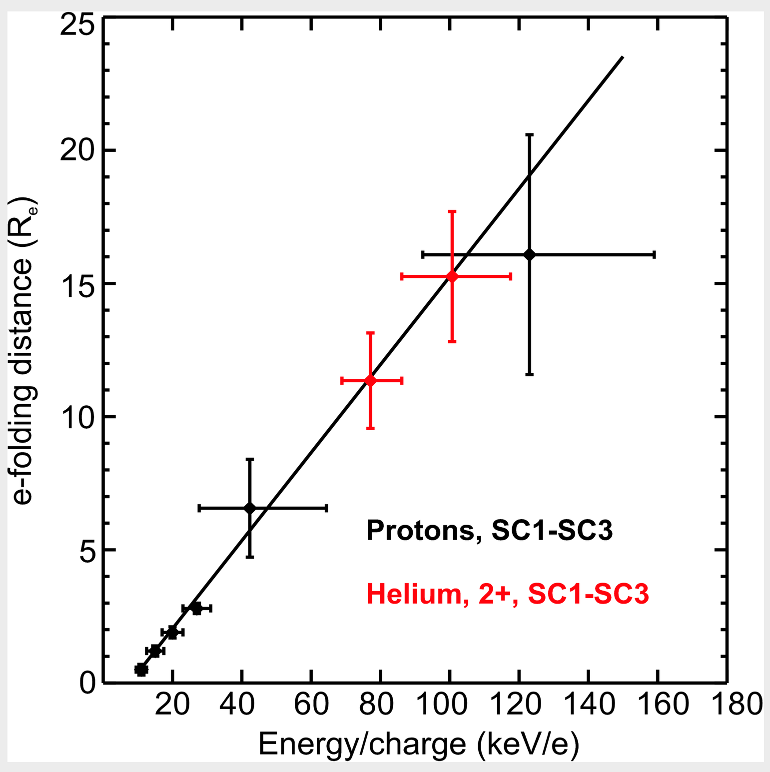


The figure to the right shows one month of Cluster proton and oxygen data for two energy ranges. During some times, and for some regions of space, the flux of oxygen exceeds that of protons.

The three panels below shows maps of energetic oxygen abundance as function of geomagnetic disturbance. During periods with high geomagnetic activity, the oxygen abundance is higher. This is probably caused by enhanced outflow from the terrestrial ionosphere. [Degener, 2010]



Energetic ions upstream of the Earth's bow shock

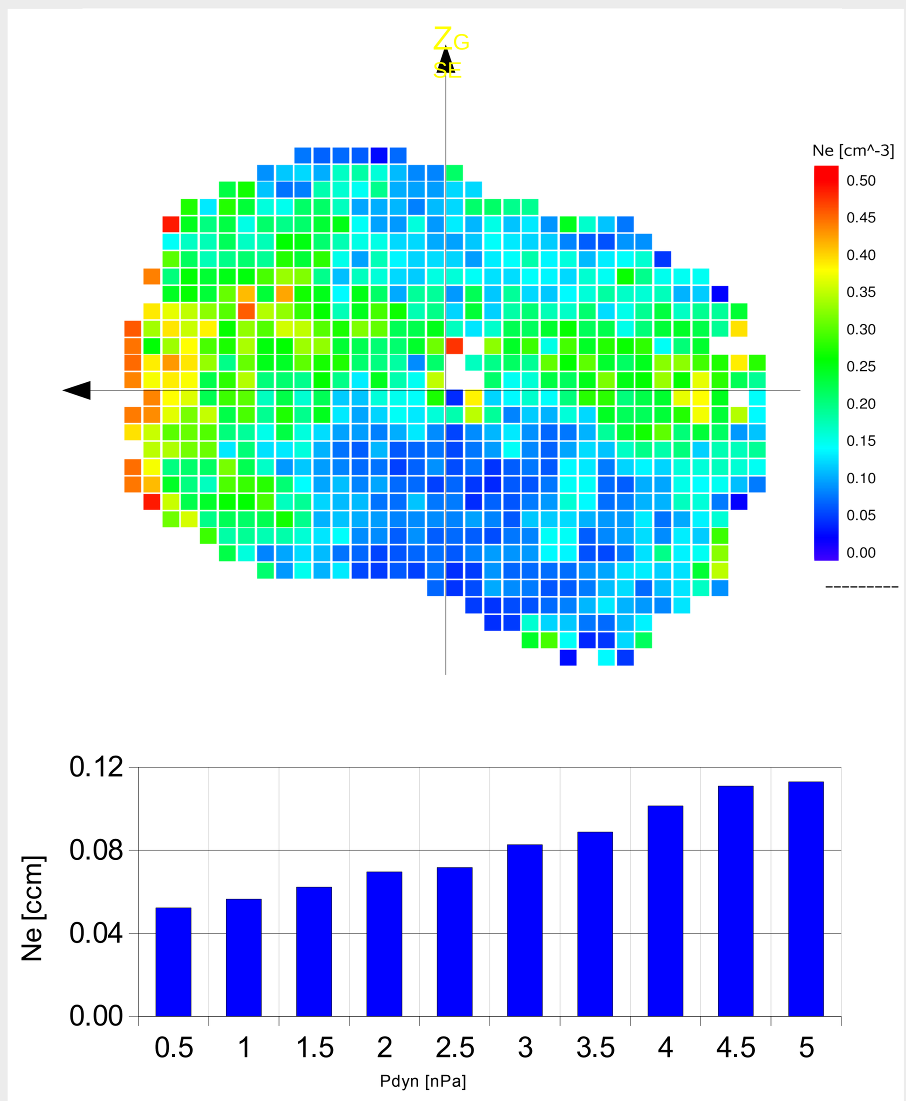


The RAPID detector has been used to determine field aligned density gradients at the terrestrial bowshock. Our results show that the diffuse ions are subject to diffusive transport and thst the ion partial densities decrease exponentially with increasing distance from the bow shock.

By complementing RAPID data with measurements from CIS (energies from 10 to 32 keV) for the same upstream ion event we find that the e-folding distance of energetic ion density increases almost linearly with energy.

The figure to the left shows e-folding distance versus energy per charge. The first four points at low energies are from Kis et al. [2004] using the CIS instrument, the higer energies are from RAPID. The straight line is a linear fit. [Kronberg et al, 2009]

Plasma density in the magnetotail lobes



The low plasma density combined with strong spacecraft charging usually makes direct measurements difficult in the magnetotail lobes. However, a new technique makes use of the spacecraft potential to derive information about electron density.

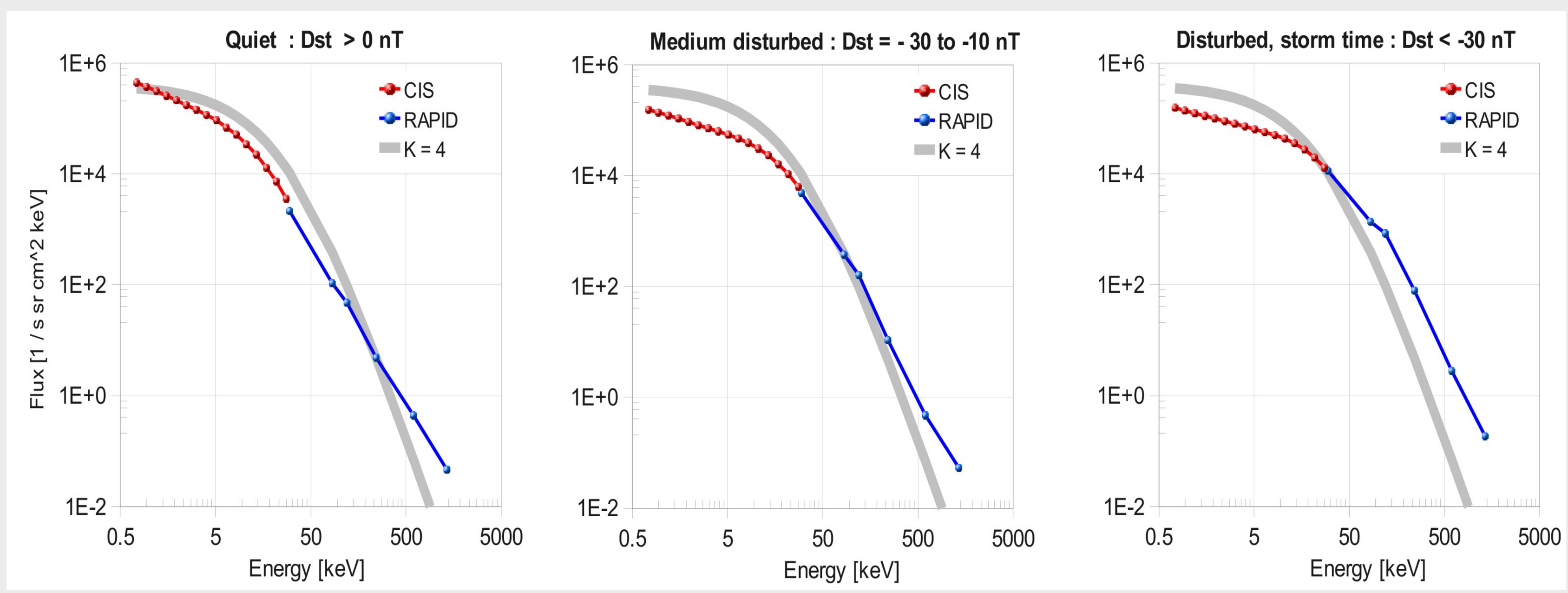
The plot to the left, shows a cross section of the geo-magnetic tail. Each colour coded square indicates an average density obtained with the spacecraft charge technique. The highest densities are found near the flanks (red colours) and near the central plasma sheet (green, yellow colours). The lobes (mostly blue colours) have densities of less than 0.1 particles/ccm. The apparent asymmetry is not physical, but due to the Cluster orbit.

The lower left plot shows how the average lobe density varies as a function of the solar wind dynamic pressure. High solar wind dynamic pressure causes a compression of the magnetosphere, and hence a higher density [Haaland 2008, 2009].

Characteristics of proton spectra in the Earths plasma sheet.

Earlier measurements of ions in the Earth's magnetic tail and plasma sheet have revealed that the energy distribution often deviates from a pure Maxwellian distribution, and often possesses a high energy tail, which can best be modelled with a power law or κ function. Such distributions are less stable than Maxwellians and can dramatically enhance the growth of plasma waves under certain conditions. The spectral slope can also provide valuable information about acceleration and diffusion processes.

Using data from the RAPID and CIS instruments, we have studied the spectral shape as function of external driver parameters and location. The most prominent driver parameters seem to be the solar wind and geomagnetic activity level. The figure below shows the spectral shape for three different ranges of geomagnetic disturbance. On average, the spectrum is harder during disturbed geomagnetic activity level.



References

Kis et al, *Multi-spacecraft observations of diffuse ions upstream of Earth's bow shock,* Geophys Res Letter, 31, 2004

Haaland et al, *Plasma convection in the magnetotail lobes: Statistical results from Cluster EDI measurements*, Ann. Geophys, August, 2008

Kronberg et al., *Comparison of periodic substorms at Jupiter and Earth*, J.Geophys. Res., 113, 2008

Haaland et al, *Mass transport in the magnetotail lobes*, Ann. Geophys. September, 2009

Kronberg et al, *Multipoint observations of energetic ions in the 30-160 keV energy range upstream of the Earth's bow shock*, J. Geophys. Res., 114, ,2009

Degener, L. *A survey of energetic oxygen in the Earth's nightside plasma sheet.*, Master Thesis project, University of Bergen/MPS, 2010.