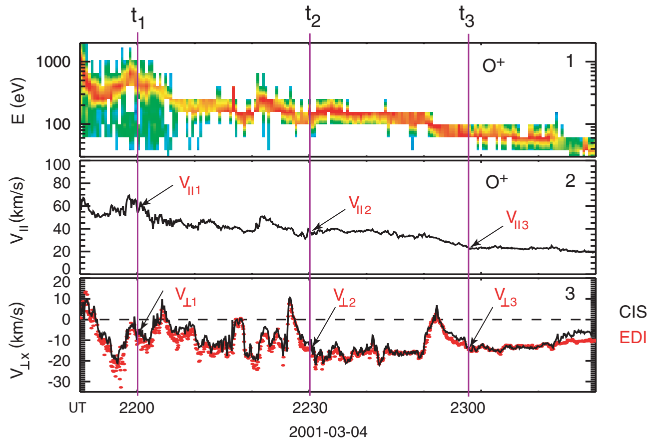
Oxygen Beams in the Cusp and Polar Cap

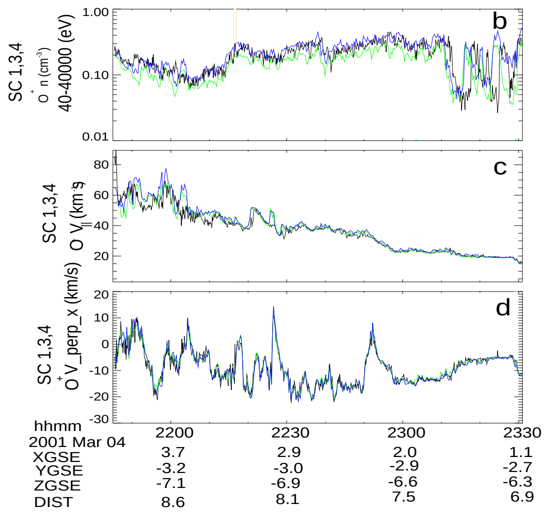
Data from the CODIF (Composition and Distribution Function Analyzer) sensor of the Cluster Ion Spectrometry Experiment (CIS) show the frequent presence of singly ionized oxygen ions of ionospheric origin with a narrow energy distribution on polar cap magnetic field lines. Figure 1 (top panel) shows an energy-time spectrogram of O^+ ions as observed on 4 March 2001. The feature to note is the narrow band of intense fluxes that proceeds to lower and lower energies while the spececraft moves from the cusp over the polar cap towards the magnetotail. The center panel on the left shows that the parallel speeds computed from the O^+ velocity distributions range from $\sim$ 60 to 20 km/s. At those speeds it will take the ions between 1000 and 3000 seconds to reach Cluster altitudes. During this time the field lines will have moved tailward by a distance determined by their convection velocity, shown in the bottom panel. The black line is derived from the O^+ distributions, while the red symbols are from the measurements of the drift of artificially injected electrons by EDI. Noting the entirely different nature of the measurements, the agreement is simply remarkable.

Similar dispersion features at low energies have first been observed with the spacecraft DE1 (Lockwood et al., 1985) and can be interpreted as a velocity dispersion effect: ions injected with a broad energy spectrum from a narrow source in latitude at low altitudes on the dayside, all will move up the magnetic field lines, but end up at different locations, determined by the ratio of the speed at which they move along the magnetic field and the speed with which those field lines move over the polar cap. The measurements confirm the generally anti-sunward convection ($V_x < 0$), consistent with the southward directed IMF reported at this time from solar wind monitors onboard the Advancend Composition Explorer (ACE). Taking 15 km/s as the average convection velocity, one obtains between 2.5 and 7.5 R_E as the distance the field lines (and the O^+ ions) have moved tailward in the time it took the ions to move up the field lines to Cluster altitudes.

Figure 2 shows the density, parallel velocity, and perpendicular velocity, V_x, derived from the O^+ velocity distribution measured onboard S/C-1, S/C-3 and S/C-4. The velocity time dispersion seen in the parallel velocity can be used to infer information on the energy and pitchangle distribution of ion injection (e.g. Bouhram et al., 2002). Note the large sudden variations of the perpendicular velocity. The striking result is that the perpendicular velocities are essentially identical, with zero time shift. The cross-correlation of different pairs of S/C using 1 sec resolution EDI data shows that the time shift is less than 1 sec. This means that the observed variations in V_x, in particular the short bursts of sunward convection, are not the result of the spacecraft moving relative to the polar cap convection cells, but that these changes are temporal in nature, probably caused by substorm related dipolarizations of the tail magnetic field.



Measurement of an O^+ beam on 4 March, 2001 with CODIF on CLUSTER S/C-3 in the cusp and polar cap region. Energy – time spectrogram (top panel), parallel velocity (middle panel), and perpendicular velocity V_x as determined with CODIF (black) and directly measured with EDI (red).



Measurement of the oxygen density (top panel), parallel velocity (middle panel), and x–component of the perpendicular velocity, V_x (bottom panel) on spacecraft 1 (black), 3 (green), and 4 (blue). The striking feature is the essentially identical perpendicular velocity on all spacecraft, with zero timelag.

References

Lockwood, et al., JGR, 90, 4099, 1985.

Bouhram, M., et al., JGR, 107, 2002.

B. Klecker, Y. V. Bogdanova, G. Paschmann, P. Puhl-Quinn, H. Vaith, T. Phan