Plasma spectrometers with beam tracking strategies for space weather science applications

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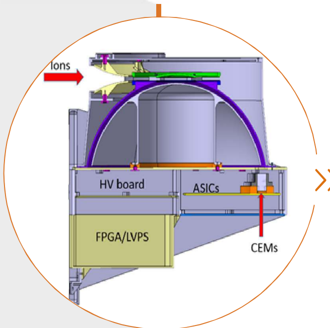
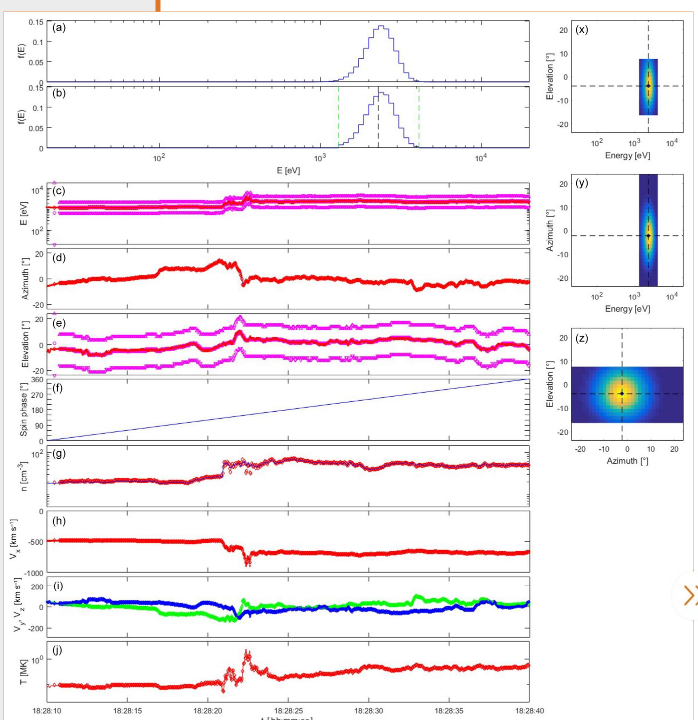


What is beam tracking?

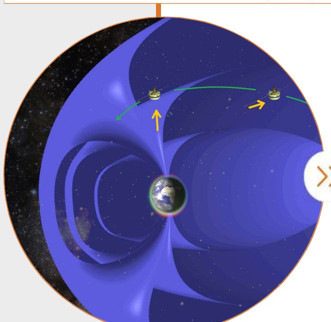
“Beam tracking” is a strategy for measuring particle velocity distribution functions (VDFs) in which one covers only that part of the energy spectrum and those directions that are expected to be populated. Classical plasma spectrometers typically do not do this as they often rely on spacecraft spin to collect 3D VDFs. The use of electrostatic deflectors in front of the energy analyser section can overcome the time resolution limit that originates from the spacecraft spin.



Application to the solar wind

Beam tracking is perfect for measuring the solar wind: the thermal solar wind covers only part of the sky and has a limited energy range, although the mean beam energy and direction can change significantly. From a Sun-pointing platform a spectrometer can view the solar wind continuously and acquire VDFs at a rate limited only by technology. Simulations for the THOR CSW instrument have validated the approach. Beam tracking allows rapid acquisition (< 100 ms) of high angular (1.5°) and energy resolution (<7%) VDFs, while being robust against beam loss.

Plasma spectrometer measurements of a constant Maxwellian solar wind beam on a rapidly spinning spacecraft using internal energy and elevation beam tracking: (a) energy spectrum of the Maxwellian solar wind; (b) energy spectrum as acquired by the plasma spectrometer at the end, with the vertical dashed lines indicating the center and the bounds of the sampled energy range; (c) energy as a function of time, where the horizontal blue line represents the true solar wind value, the small red dots are the Faraday cup measurements every 30 ms (not used with internal beam tracking), the magenta circles and triangles indicate the center and the bounds of the sampled energy range, and the red diamonds give the mean energy as determined by the spectrometer; (d) azimuth; (e) elevation; (f) spin phase; (g) density; (h, i) velocity in the spacecraft frame of reference (x axis pointing to the Sun, spacecraft spinning in the y-z plane), and (j) temperature; (x) energy–elevation, (y) energy–azimuth, and (z) azimuth–elevation projections of the VDF at the end of the simulation.



Application to auroral beams

Another space weather relevant application would be to apply beam tracking to focus on precipitating electron/upwelling ion beams below/above the auroral acceleration region: these are typically confined to a narrow cone around the magnetic field, and are nearly mono-energetic with an energy from tens of eV up to 10 keV, at least for electrostatic aurora. As seen from a spin-stabilized spacecraft, the beam direction can change dramatically – beyond what can be dealt with by the deflectors. Therefore, beam tracking works only in a sub-region unless multiple detector heads are used.

Conclusion

The advantages of beam tracking are a faster VDF acquisition for a given angular/energy resolution or a higher angular/energy resolution for a given acquisition rate. Beam tracking can be very effective and can be implemented fairly easily with present-day technology. Limitations of electrostatic deflectors restrict their applicability. Beam tracking can optimally use resources to the benefit of space weather monitoring.

Reference

J. De Keyser et al. Beam tracking strategies for fast acquisition of solar wind velocity distribution functions with high energy and angular resolutions. *Ann. Geophys.*, 36, 1285–1302, 2018. https://doi.org/10.5194/angeo-36-1285-2018

More info ?

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