KTH ROYAL INSTITUTE OF TECHNOLOGY

Investigating waves and instabilities in the auroral E region via multi-point in-situ measurements from the SPIDER sounding rocket

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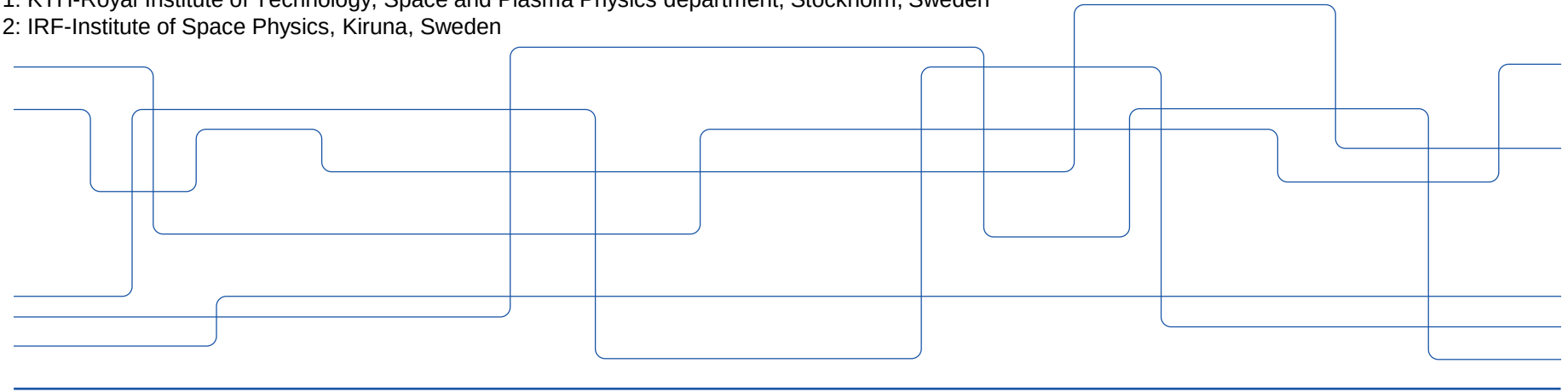


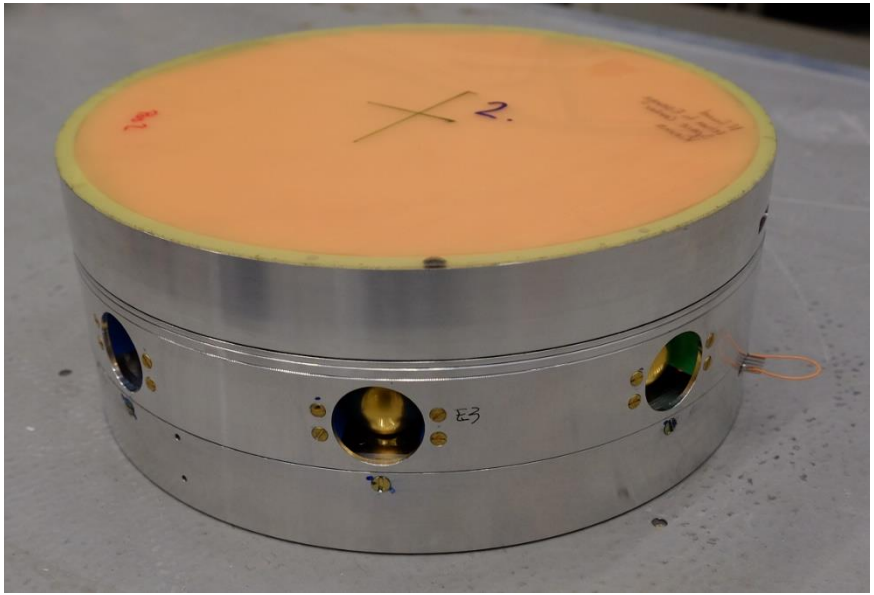
The SPIDER sounding rocket

SPIDER: Small Payloads for Investigation of Disturbances in Electrojet by Rockets

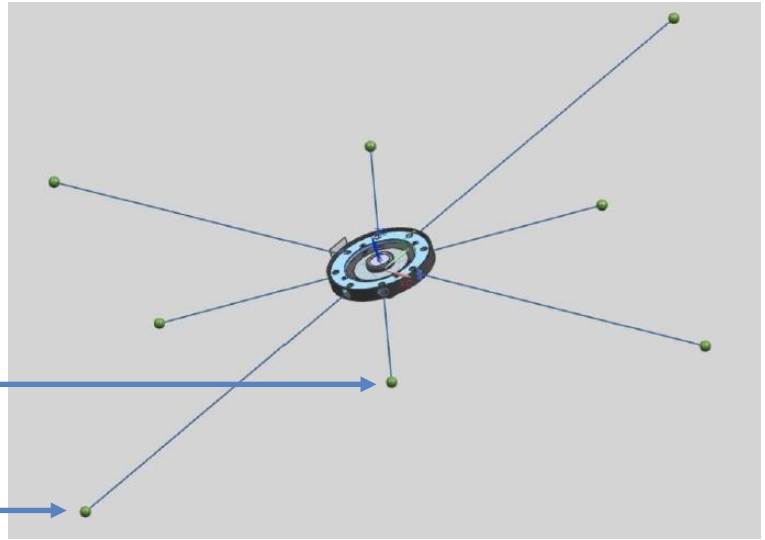
Launched on February 2nd 2016 from Esrange in northern Sweden.

10 Free Falling Units (FFUs) released inside a westward travelling auroral electrojet.

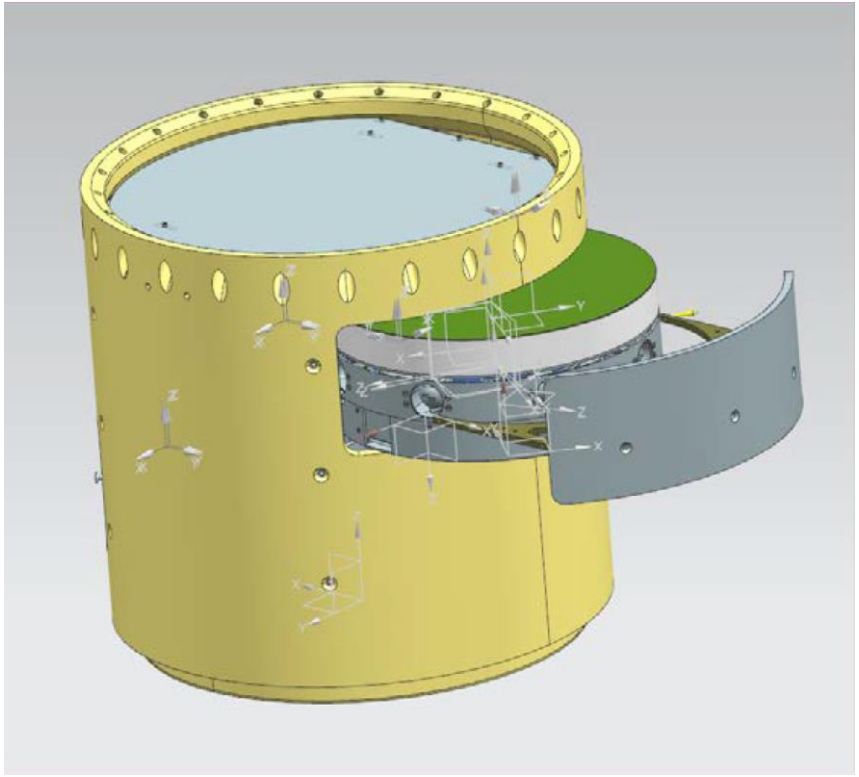
Free Falling Units (FFUs)



- Four spherical Langmuir probes.
- Four spherical Electric field probes.
- One 3-axis magnetometer.
- GPS recorder.
- Gyroscopes/accelerometers.



Rocket Mounted Units (RMU)



FFUs recovery

Data was stored onboard the FFUs, which were recovered the next morning by helicopter. Six FFUs out of ten were found but only three with usable data (FFU02, FFU03, FFU06).

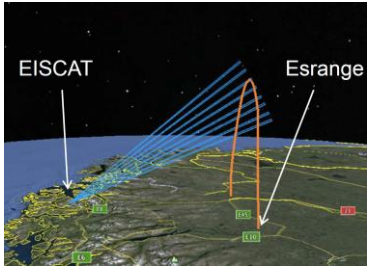
Despite some technical issues with the FFUs, this presentation will give an overview of the results from the flight with the aim to demonstrate the capabilities of multi-point measurements for auroral studies. The following will be discussed:

i) In-situ mapping of the plasma properties of the aurora.
ii) Investigating turbulences through density and magnetic field measurements.
iii) Investigating instabilities via electric field measurement
iv) Studying wave propagations via electric field measurement.
v) Understanding the auroral dynamic by comparing with ground-based optical observations.

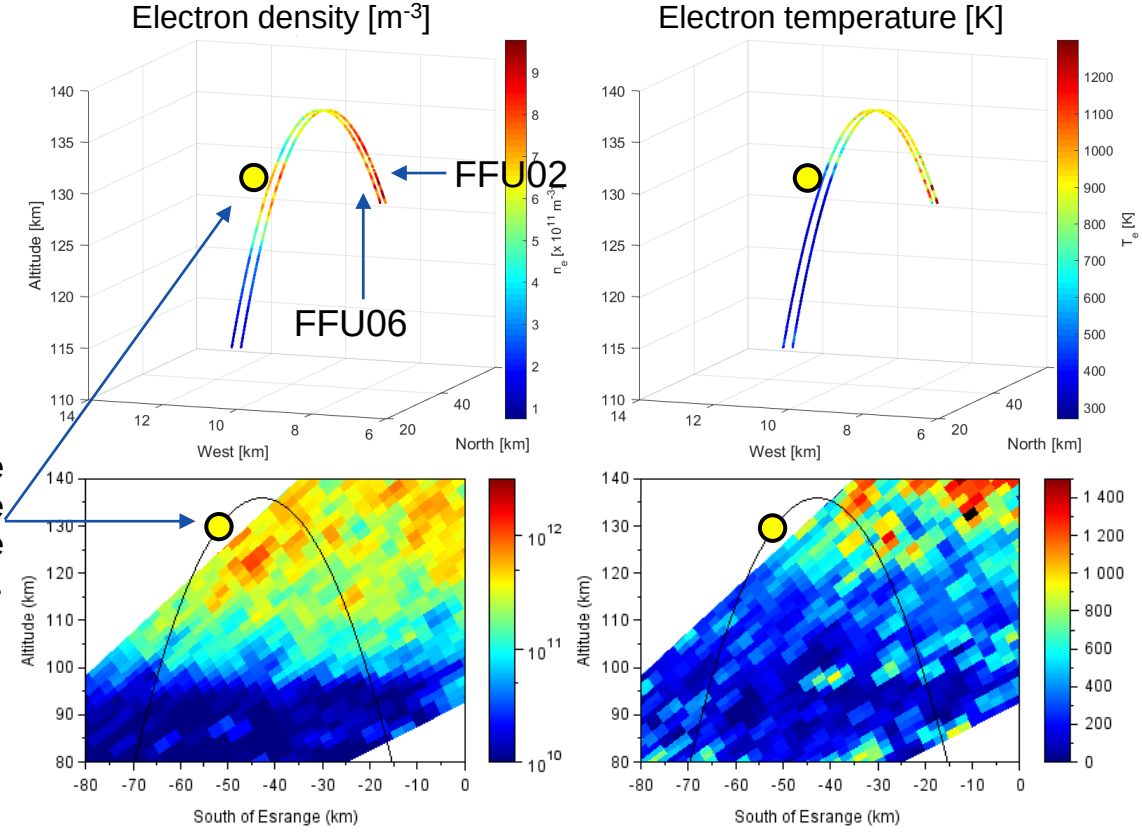
i) In-situ mapping of plasma properties

The electron density and temperature were obtained from the Langmuir probe measurements for two FFUs (top panels).

The EISCAT UHF radar in Tromsø also measured the electron density and temperature during the flight (bottom panels).



Position of the rocket at the time of the measurement.



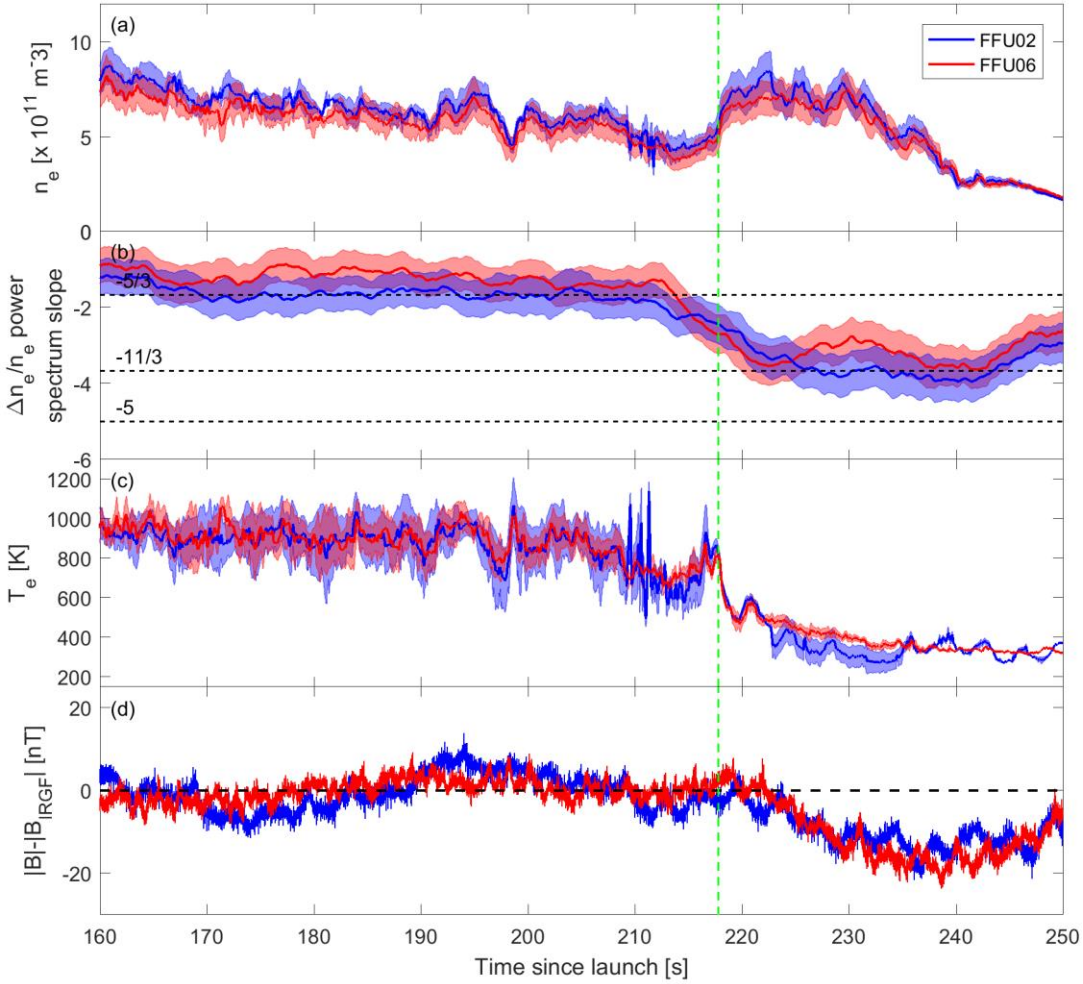
Very good agreement between remote and in-situ measurements.

The FFUs are providing a much higher temporal and spatial resolution.

ii) Density and magnetic field perturbation

(a) Electron density
(b) Slope of density power spectra: energy cascade indicator.
(c) Electron temperature
(d) Magnetic field residual

The FFUs entered an over-dense plasma region at 218s, with a sudden drop in the temperature. The slope of the density power spectra changes from the typical Kolmogorov regime (-5/3) to -11/3, which might indicate a drift waves instability [1].
Around the same time, the magnetic field is reduced locally, indicating Hall current in the region.



[1] Kintner, P.M. & Seyler, C.E. Space SciRev (1985)

iii) Search for Farley-Buneman instability

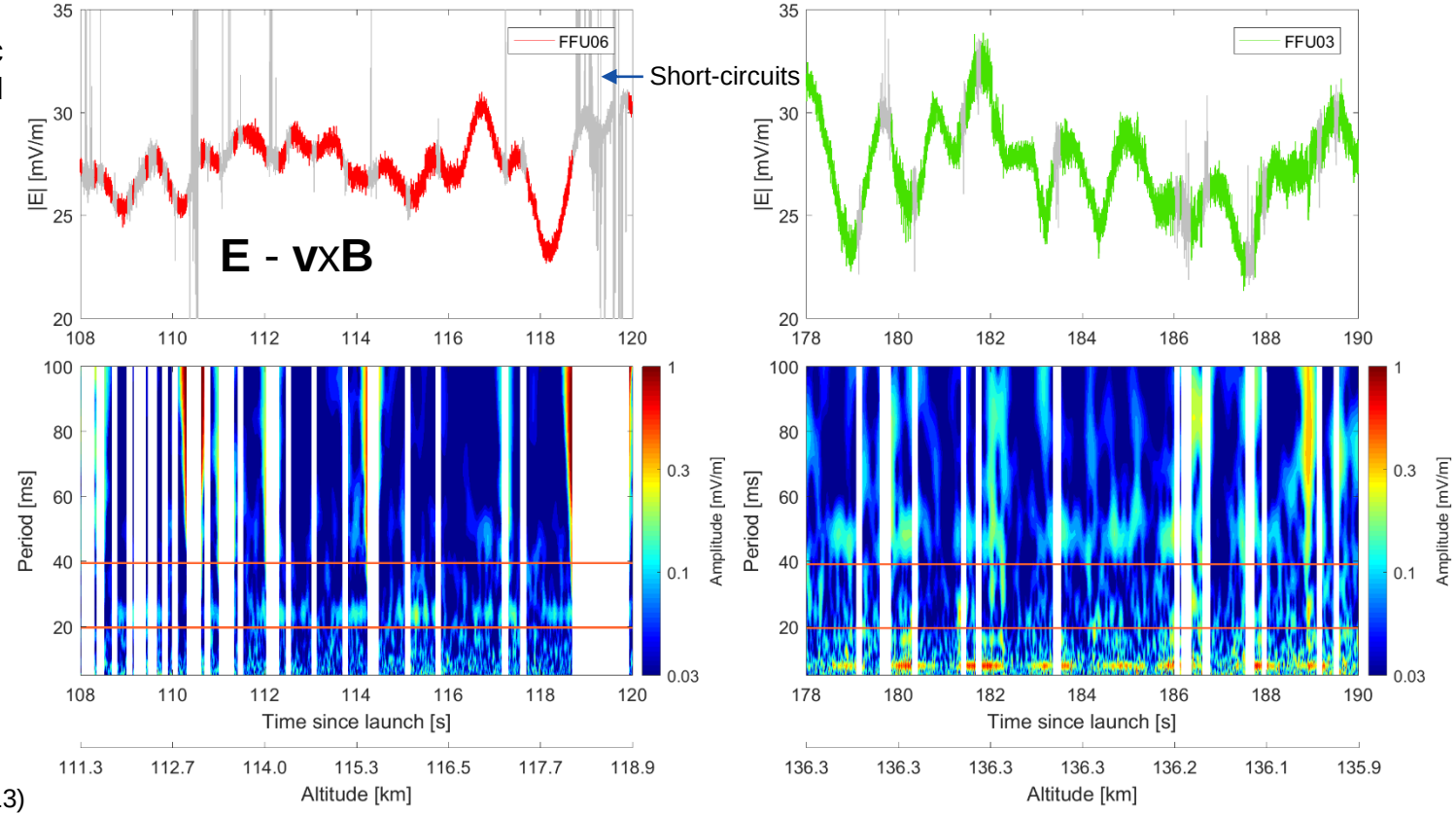
Two examples of electric field time series (top) and wavelet analysis (bottom)

Expected spatial scale of the instability [2]:

- 10 m: 40 ms
- 5 m: 20 ms

Weak power with harmonics of 48 ms are seen, likely due to internal frequency (i.e. LP sweep frequency).

No Farley-Buneman instability seen.



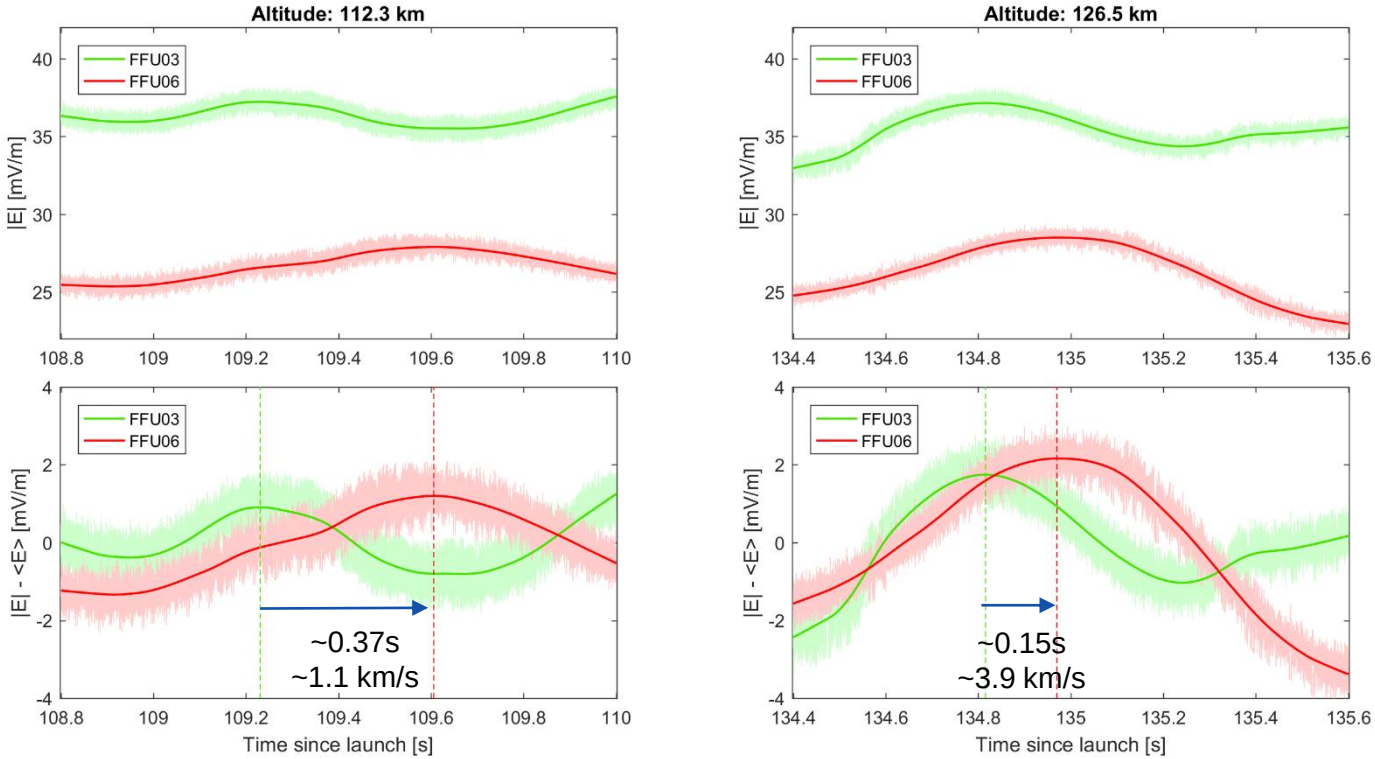
[2] Oppenheim and Dimant (2013)

iv) Propagation of electric field perturbation

Two examples:

E - vxB

Mean removed

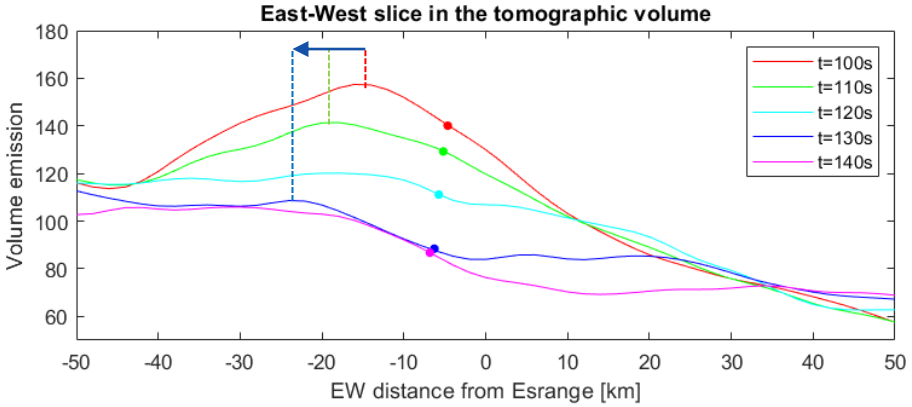


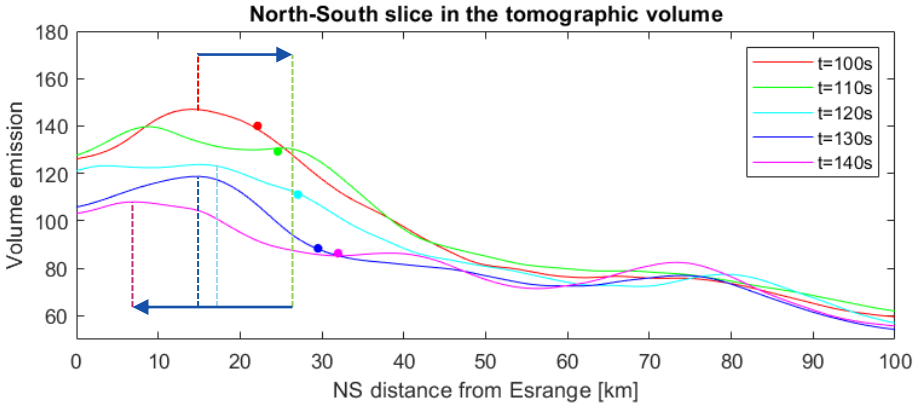
These perturbations can also be studied in density, but FFU03 LP data was unusable. Comparison of perturbations seen in density between FFU02 and FFU06 was done but the temporal resolution (0.05s for LP sweep) was not high enough for estimating the velocity.

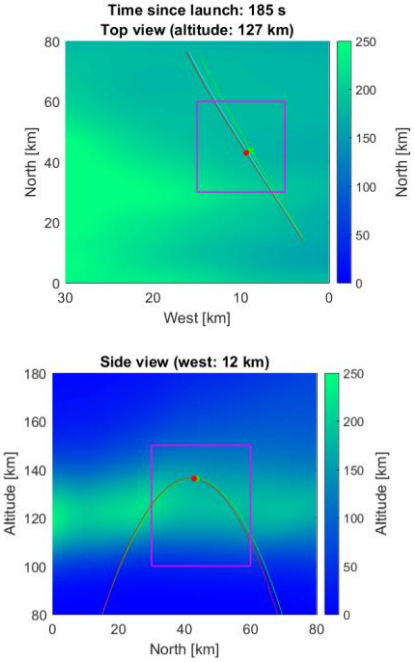
v) Auroral motion on larger scales

The aurora was moving westward with oscillating north-south movement (northward between 100-110s and then southward).
The aurora intensity was also decreasing with time.

The overall EW velocity of the aurora was in the 100 to 500 m/s range, whereas the NS displacement appeared to be faster (~1 km/s). Hence, the propagating perturbation seen in the previous slide at 110s is likely due to the aurora moving towards the north. Higher resolution images would be needed to see the second perturbation at 135s (moving much faster) as it is not seen in the tomographic reconstruction.



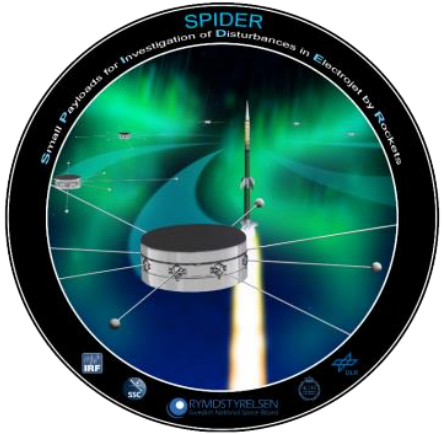




Top: example of tomographic reconstruction of the aurora from the ALIS optical system (green line emission)

Left: EW and NS slices in the tomographic volume at various time. Dots shows the position of the FFUs at each time.

Conclusion



- **SPIDER demonstrated that multi-point *in-situ* measurements inside an aurora is feasible.**
- Hints of turbulence seen in the electron density but no clear detection of Farley-Buneman instability in the electric field (weak field + parasitic internal periodicities).
- **Multi-point measurements** can allow to study **wave propagation**, as well as producing details **3D map of the plasma parameters**.
- Comparison with ground-based radar and optical observation can provide confidence in the *in-situ* observations and distinguish between temporal and spatial variations.

In February 2020 SPIDER flew again inside a pulsating aurora with **8 FFUs** with **improved recovery system**, **active wobble control system** and **adaptive sweeps.**
Five FFUs were recovered and a lot of data need to be analysed!