Plasma turbulence, intermittency and wave-coupling in the polar cap based on the ICI-2 sounding rocket experiment

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The ICI-2 sounding rocket

The Investigation of Cusp Irregularities 2 (ICI-2) sounding rocket

- Launched from Ny-Ålesund, Svalbard, Norway (78.9° N, 11.9° E) at 1035 UT on the 5th of December 2008.

- **Objectives**: Resolve irregularity structures at meter-scales and quantify the gradient drift instability process.

- **Instruments**: m-NLP, AC/DC Electric field experiment, low-energy electron spectrometer (LEP), solid-state spectrometer...

Lorentzen et al., JGR, [2010], Oksavik et al., JGR, [2012],
Space conditions

Figure: SuperDARN velocity maps over Svalbard superimposed on 6300 Å all-sky Imager (ASI) data from Longyearbyen. The two top panels and the two bottom panels show the plasma velocities before and during the ICI-2 launch, respectively. The flow close to Svalbard was mostly directed north-west, in the range $v \in [750, 1250]$ m/s.
The ICI-2 Flight

Figure: Top) Electron density. Middle) Spectrogram of $\Delta Ne/Ne$. Bottom) Slopes of the power spectra.
Examples of power spectra

Figure: left) PSD between 271.5 s and 273.5 s. right) PSD between 265 s and 267 s. Spicher et al., GRL, [2014]
Spectral indices

Spicher et al., GRL, [2014]
Random vs Coherent structures

Case A

Case B

Moen et al., GRL, [2012]
Random vs Coherent structures: Spectra

Case A

\[ p_1 = -1.6 \]
\[ p_2 = -4.7 \]

Case B

\[ p_1 = -1.9 \]
\[ p_2 = -4.7 \]
Bispectral Analysis: Example

\[ f(t) = \cos(f_1 t + \phi_1) + \cos(f_2 t + \phi_2) + \cos(f_3 t + \phi_3) + \text{rand} \]  

(1)
Higher Order Statistics

**The Structure function**

The $m$-th order structure functions is defined as

$$S(m, \tau) = \langle |y(t + \tau) - y(t)|^m \rangle,$$  \hfill (2)

**Intermittency**

For a *scale invariant* system, the structure function obeys a universal scaling law

$$S(m, \tau) \propto \tau^{g(m)},$$  \hfill (3)

where $g(m)$ is the scaling exponent. In the case of the K41 turbulence theory, the velocity fluctuations and their $m$-th moments would follow a power law with exponent $g(m) = m/3$. Deviations from a linear dependence of $g(m)$ are attributed to spatial inhomogeneous redistribution of the energy: *Intermittency*
Figure: a) Structure functions of order $m = 1, 2, 3, 4$ for Case A (red) and Case B (blue). b) Slopes $g(m)$ of the structure functions in the inertial ranges. c) Empirical Flatness.
## Summary

### Spectral Analysis

- The power spectra of the strong electron density fluctuations exhibit a dual-slope characteristic, with $p_1 \approx -1.8$ below $f \approx 40\,\text{Hz}$ and $p_2 \approx -4$ above $f \approx 40\,\text{Hz}$.
- **Bispectrum** and **Intermittency**: possibly two different mechanisms but similar power spectra. Difference due to direct particle precipitation?

### Outlook

- ICI-3, ICI-4, MICA ...
- Simulations
- Multi-instruments
Thank you for your attention!