

# EXPERIMENTAL EVIDENCE OF RESONANT CAVITIES IN THE HIGH-LATITUDE IONOSPHERE ABOVE SVALBARD



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## Abstract

Many studies of ultra low frequency waves in the 0.1–5 Hz range, both observational and theoretical, make reference to the role of three specific resonant cavities in supporting wave growth or propagation in the ionosphere. These three cavities are the ionospheric waveguide, the ionospheric Alfvén resonator (IAR) and the resonator associated with the auroral acceleration region (RAAR). The first is centered on the  $F_2$  region density peak, the second is bounded below by the conducting  $E$  region and above by sharp gradients in the Alfvén speed at a few thousand kilometers and the third, which shares a lower boundary with the IAR, is bounded above by a potential drop due to auroral precipitation.

This study presents observations of resonance structures appearing in induction coil magnetometer data from three stations in Svalbard, Norway: Hornsund (CGM Lat. = 74.23°, MLT Midnight = 21:01), Longyearbyen (CGM Lat. = 75.29°, MLT Midnight = 20:50) and Ny Ålesund (CGM Lat. = 76.30° MLAT, MLT Midnight = 20:56). We visually inspect Fourier spectra to determine locations of spectral enhancements between 0.1–1 Hz and use a characteristic spectrum to determine the resonator quality factor,  $Q$ , which is a measure of the wave power amplification within the resonator. Equivalently, this is a measure of the coupling efficiency of the resonator to some input perturbation. This study will provide support for the upcoming Magnetosphere–Ionosphere Coupling in the Alfvén Resonator (MICA) sounding rocket mission.

## Background

The graphic shown in Figure 1 is a cartoon of three resonant structures described in the literature.

- A waveguide for compressional fast-mode emissions propagating perpendicular to the background magnetic field (see, for example, *Manchester 1966*, and *Greifinger & Greifinger 1968*)
- Two Alfvén resonators
  - The Ionospheric Alfvén Resonator (IAR), bounded below by the highly-conducting  $E$  region and above by a sharp peak in the Alfvén velocity (see, for example, *Lysak 1999*, and *Chaston, et al. 2002*)
  - A resonator associated with the auroral acceleration region (RAAR), bounded below by the highly-conducting  $E$  region and above by a field-aligned potential drop characteristic of the auroral acceleration region (see *Pilipenko 2002*).

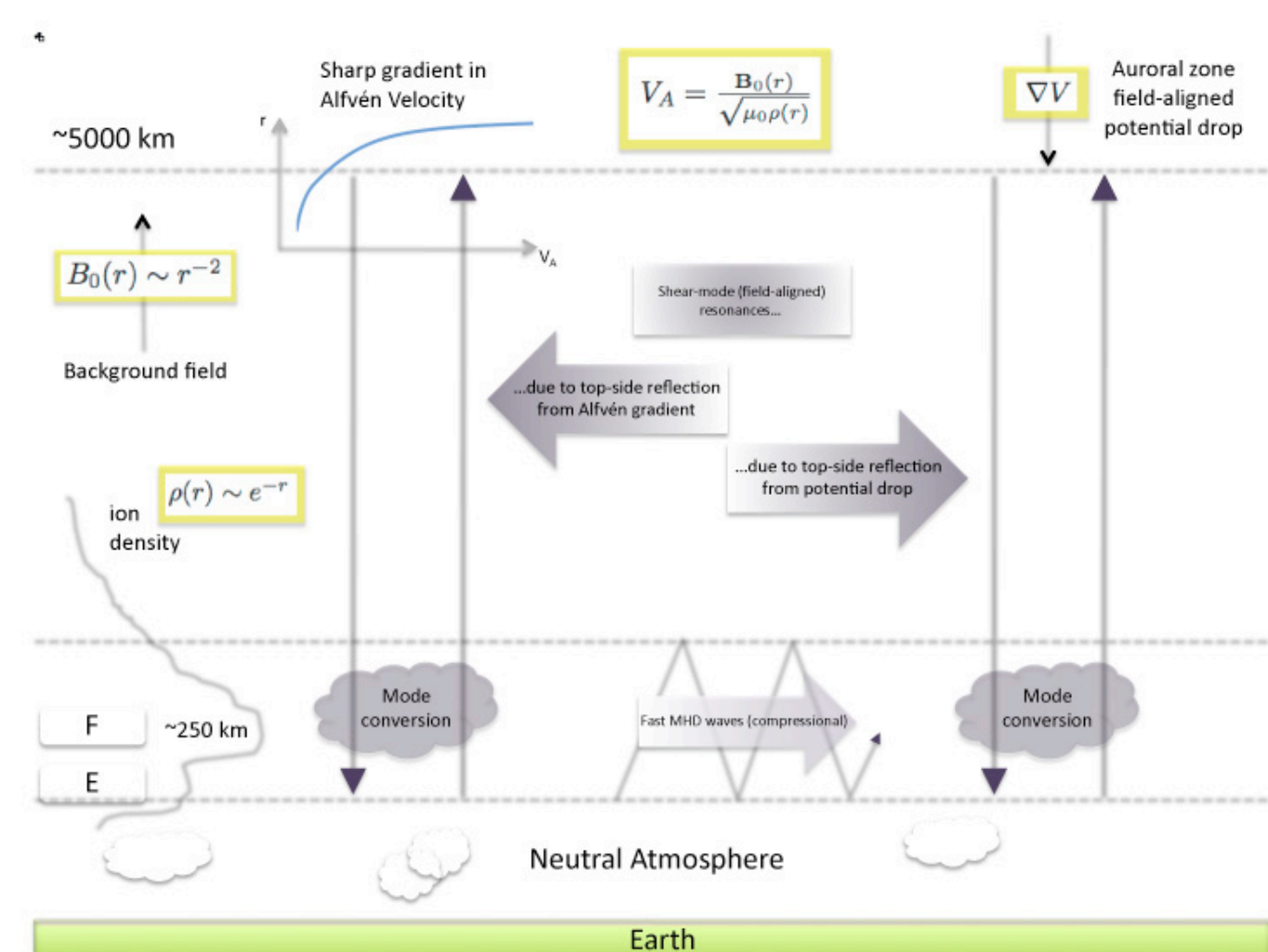


Figure 1: Models of ionospheric resonant structures

## Estimating the Quality Factor

1. Visually inspect dynamic spectrograms for spectral enhancements associated with bursty wave power.
2. Compute time-averaged power:  $\bar{P}(f) = \frac{1}{\Delta t} \int_{t_0}^{t_1} P(f, t) dt$ , where  $\Delta t = t_1 - t_0$  is long enough to characterize the enhancement but small enough to avoid nearby high-power broadband events (usually  $\sim 5$  minutes)
3. De-trend the averaged power by subtracting a “quiet time” Pi1B (i.e. an average of Pi1B events without spectral enhancements, shown in red below).
4. Locate central frequency,  $f_0$  (frequency of maximum averaged power), and bandwidth,  $\Delta f$  (full width at half max).
5. Compute quality factor:  $Q = \frac{f_0}{\Delta f}$

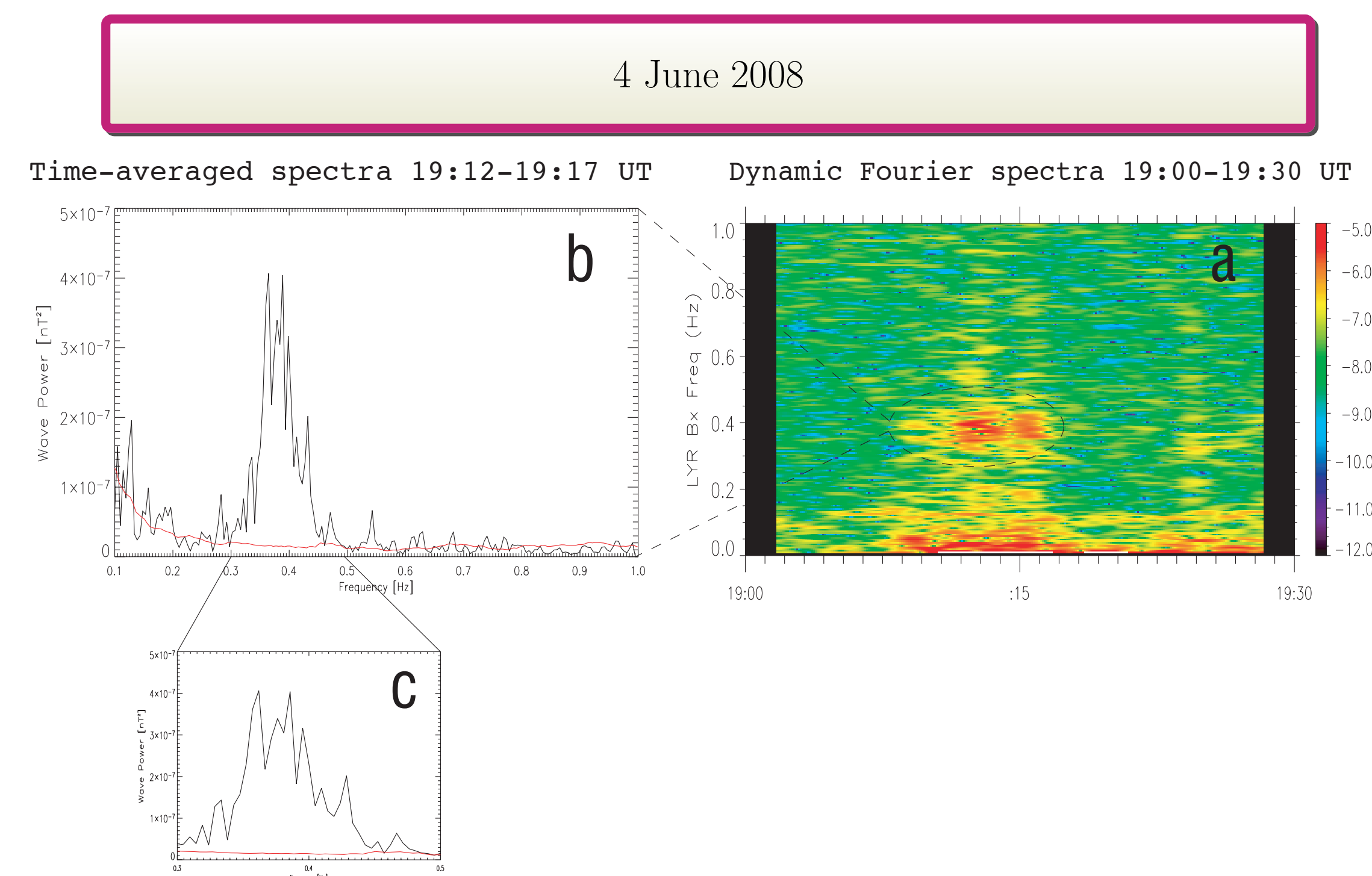


Figure 2: (a) Fourier-transformed induction-coil magnetometer data from 19:00–19:30 UT on 4 June 2008, (b) time-averaged spectra taken from the interval 19:12–19:17 UT, (c) close-up of the frequency interval 0.3–0.5 Hz containing the spectral enhancement.

$$Q = \frac{0.373 \text{ Hz}}{0.400 \text{ Hz} - 0.350 \text{ Hz}} = 7.46$$

## 12 February 2008

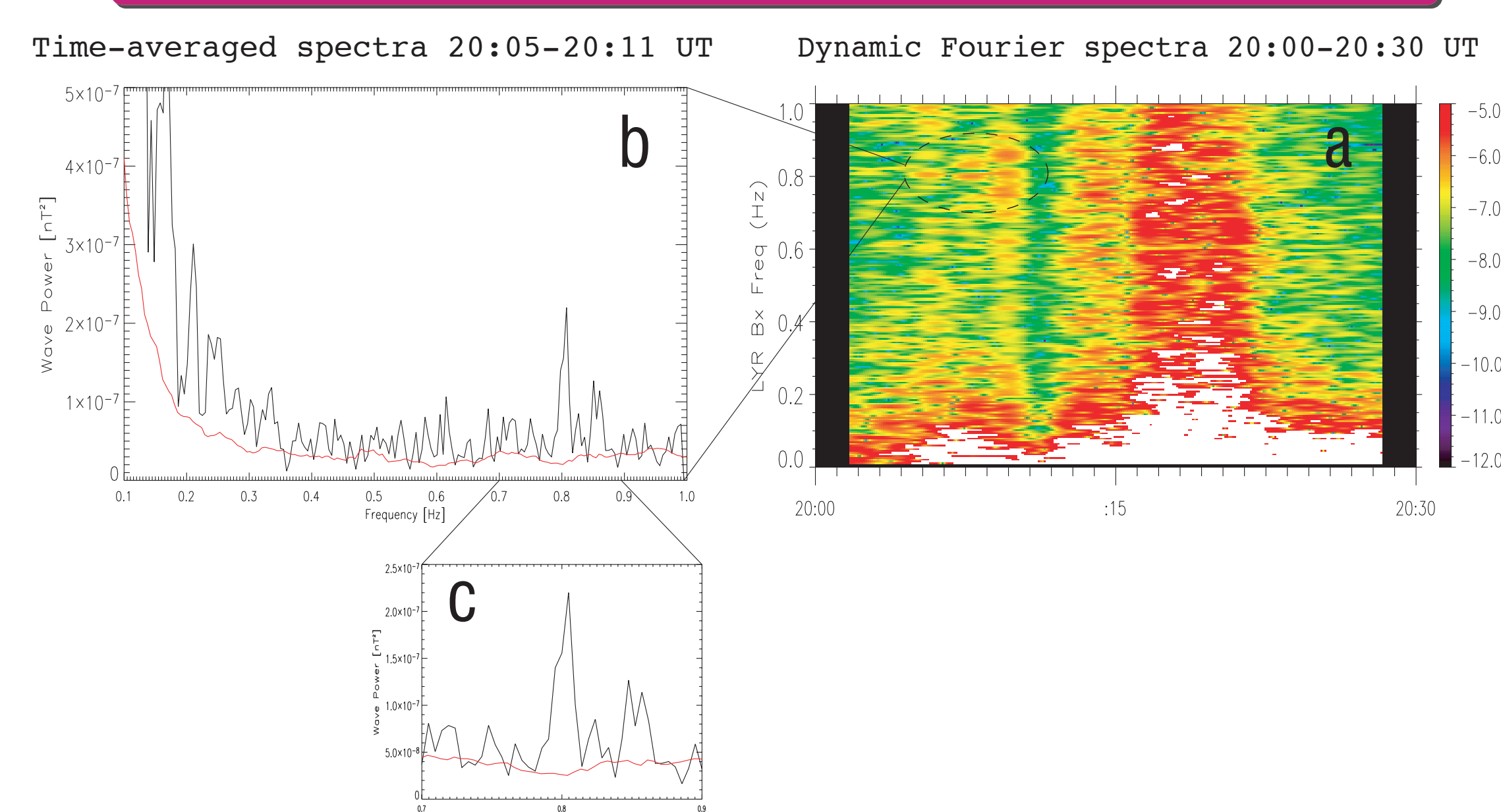


Figure 3: (a) Fourier-transformed induction-coil magnetometer data from 20:00–20:30 UT on 12 February 2008, (b) time-averaged spectra taken from the interval 20:05–20:11 UT, (c) close-up of the frequency interval 0.7–0.9 Hz containing the spectral enhancement.

$$Q = \frac{0.805 \text{ Hz}}{0.809 \text{ Hz} - 0.794 \text{ Hz}} = 53.7$$

## Enhancements observed during SPEAR heating

Spectral enhancements have been observed above Svalbard during operation of the Space Plasma Exploration by Active Radar (SPEAR) experiment. Figure 4 shows a (faint) excitation observed in induction-coil magnetometer data during SPEAR heating. The energy in the resonator can be modeled by the equation  $U = \frac{QK}{\omega_0} (1 - e^{-\omega_0 t/Q})$

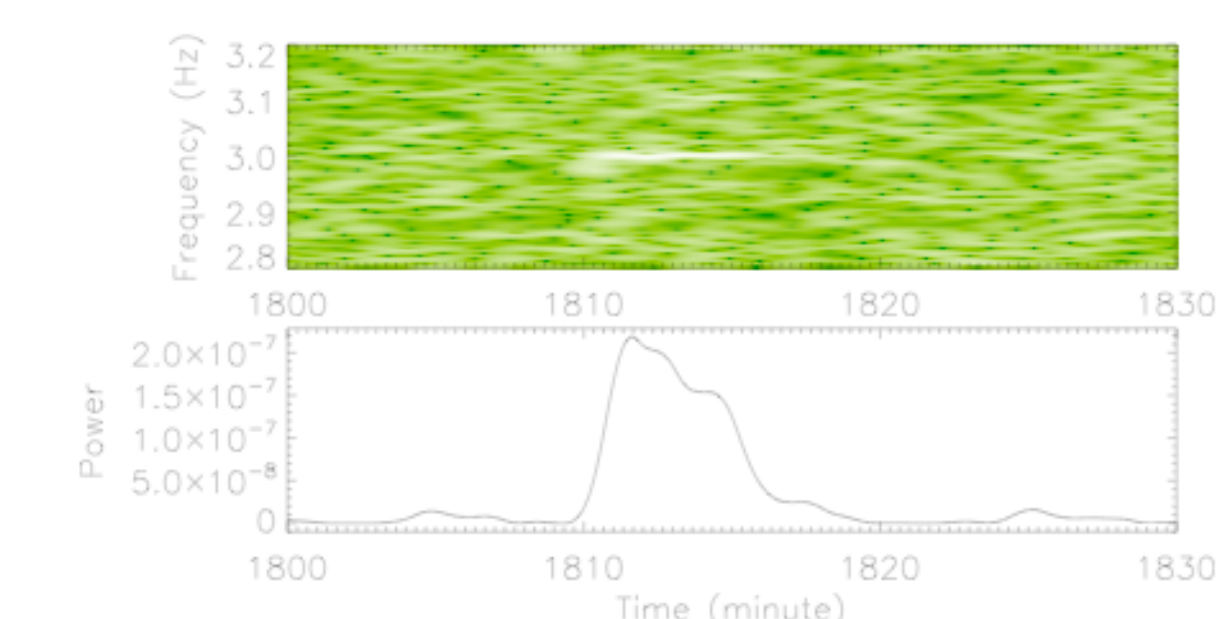


Figure 4: Spectral enhancement observed during ionospheric heating by SPEAR.

Further exploration using the SPEAR experiment will provide a helpful check of the type of analysis exhibited in Figures 2 and 3.

## The MICA Mission

The MICA mission, scheduled to launch from the Poker Flat Research Range in February 2012, will investigate the ionospheric response to the Ionospheric Alfvén Resonator near an auroral arc in an attempt to answer the question, “does the ionosphere play an active or passive role in controlling auroral arcs?” Analysis of data from ground-based induction-coil magnetometers situated underneath the rocket trajectory will support observations made by instruments on the rocket payload.

## Observations and Conclusions

- Quasi-narrowband spectral enhancements can be seen in data from high-latitude induction-coil magnetometers.
- Enhancements appear co-temporally with bursty ULF signals during both sunlit and dark ionospheric conditions at 100 km, but...
- ...they exhibit greater time-averaged wave power and wider spectral width during sunlit periods, thus making them much more visible in Fourier transformed data during periods of sunlight. This effect can give the impression that spectral enhancement occurrence peaks at high-latitudes in the summer and falls to zero during the winter.
- Estimation of resonator quality factor,  $Q$ , based on a small number of events, shows values ranging from  $\sim 8$  to  $\sim 50$ .

## Acknowledgements

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