# Direct Comparison of GPI and BES measurements of Edge Fluctuations in NSTX

Y. Sechrest[1], D. Smith[2], T. Munsat[1], S. J. Zweben[3] ([1] CU-Boulder, [2] UW-Madison, [3] PPPL)

## Abstract

The Gas Puff Imaging (GPI) diagnostic has been used in numerous studies of turbulent fluctuations in the edge region of NSTX since its installation in 2001. Before the recent 2010 run campaign a Beam Emission Spectroscopy (BES) diagnostic was added on NSTX to study density fluctuations in the scrape-off layer (SOL), edge, and pedestal regions. Both diagnostics operate using similar principles to view visible light fluctuations from collisional excitation of neutral atoms, and the diagnostic views share coverage at some R and Z positions just above the outboard midplane. Making use of these commonalities, we conduct a cross-diagnostic comparison of fluctuation measurements of edge turbulence in NSTX including: poloidal correlation lengths, decorrelation times, probability density functions and their moments, and dominant poloidal wavenumber estimates. In addition, we explore cross-correlation and cross-spectral analyses between diagnostics. By characterizing the amount of shared information, it may be possible to use the two diagnostics collaboratively to effectively extend the diagnostic coverage.

## Why are Edge Fluctuations Interesting?

- Steep gradients in edge drive various instabilities
- Transport at edge leads to loss of particles and heat to open flux regions
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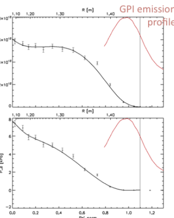
- This Study: Compare fluctuations measured by GPI and BES in MHD-quiescent, ELM-Free, H-mode plasmas




## Gas Puff Imaging

- Discharges neutral deuterium into edge
- Images visible light from collisional excitation ($D_\alpha$ 656 nm)
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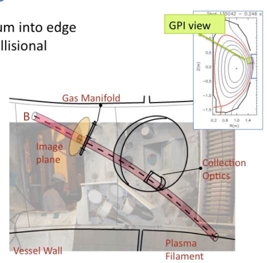


## Beam Emission Spectroscopy

- Measures $D_\alpha$ emission from collisional excitation of heating beam neutrals
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- Figure at right illustrates BES channel positioning relative to GPI view
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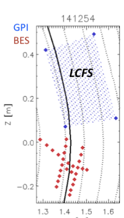
- $\delta I/I \approx C\ \delta n/n$




*BES channels and GPI points mapped along field lines to same constant toroidal angle cross-section

## Cross-diagnostic correlation and coherence are strong

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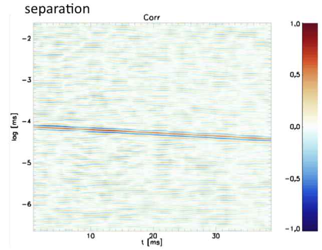
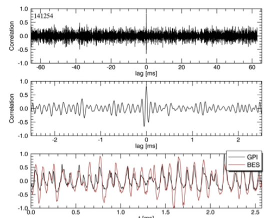
- Correct BES timebase using linear fit to persistent correlation feature
- Unable unravel time offset due to physical separation



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- Strong Correlations, R>0.7
- Raw traces exhibit clear correlation

**Cross-phase and Coherence:**
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- Steady cross-phase
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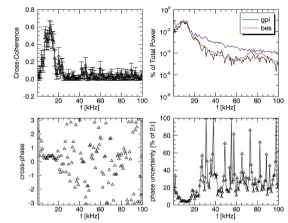

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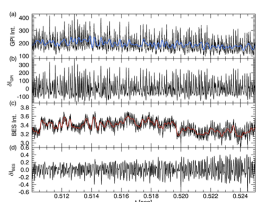
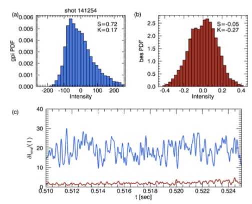
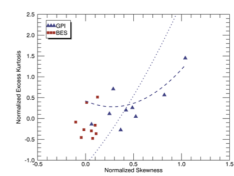
**Fluctuation traces:**
- Frequencies <4 kHz sensitive to beam oscillations
- $\bar{I}$ low pass filtered at 4 kHz
- $\delta I = I - \bar{I}$





**Fluctuation PDFs:**
- Distinctly different distributions
- GPI positively skewed, non-zero excess kurtosis
- BES near Gaussian
- GPI relative fluctuations much larger

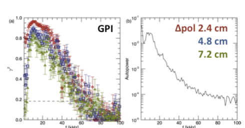
**Skewness and Kurtosis:**
- GPI moments
  - Exhibit positive skew
  - Trend most consistent with previous observations of L-mode plasma (dashed)*
- BES moments
  - Group around zero skew
  - Kurtosis marginally differs from Gaussian

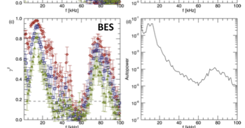


*Sattin, et al. PPCF 2009

## Measured characteristic scales for fluctuations show partial agreement

**Coherence and Autopower:**
- Similar features below 50 kHz
- 80 kHz feature seen in some shots, not present in GPI
- Focus on < 40 kHz

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- BP filtered fluctuations, 7-30 kHz
- Envelope calculated with Hilbert Transform
- Envelope decay at zero time lag yields $L_{POL}$
- Decay of Envelope peak vs. time of peak yields $\tau_C$

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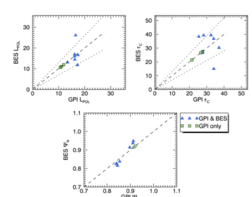
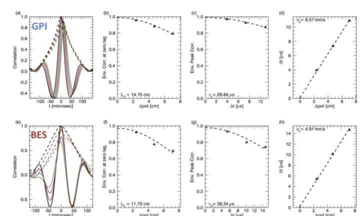
- Poloidal corr. Length estimates agree within +/- 30%
- Decorrelation times agree within +/- 40%
- Typical L-mode values: 4 cm, 6 microsec





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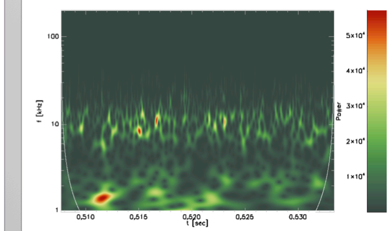

**Time and Frequency Behavior:**
- Time localized, Intermittent pulses of activity
- Activity concentrated in f=4-30 kHz band

**Summary description of fluctuations:**
- Localized, traveling pulses
  - GPI observations, correlation functions, and CWT describe spatially localized, traveling, pulses/wavepackets
- Intermittent events in 4-30 kHz band
  - CWT describes intermittent, time localized events distributed around 4-30 kHz band
- Coherent for "long" times/distances
  - Cross-diagnostic comparison shows that pulses travel coherently between diagnostic views (~40 cm)
  - Characteristic decorrelation times ~30 microsec

**2D correlation maps:**
- Correlate all pixels with reference pixel
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- Green line traces field through gas cloud
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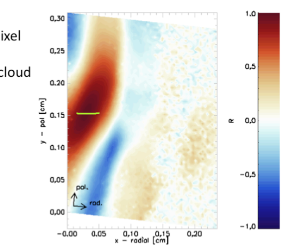
- Further analysis needed



**Outstanding Questions:**
- Large difference in dI/I
- Cross-correlations do not peak on shared flux surfaces
- Can Atomic Physics explain these?

## Summary

- Edge fluctuations in MHD-quiescent, ELM-free, H-mode plasmas compared
- Strong cross-diagnostic correlation and coherence are observed at separations of ~36 cm
- Fluctuation statistics differ between the diagnostics
- Measured poloidal corr. lengths and decorrelation time show agreement at +/- 40%
- Dominant fluctuation band of 4-30 kHz exhibits short-lived, intermittent time -frequency behavior.
- Large dI/I differences and peak locations of cross-correlation still unexplained

## Acknowledgements

We would like to acknowledge the entire NSTX team whose combined efforts made this work possible. This work was supported by DOE Grants DE-SC0001966 and DE-FG02-08ER54995

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*and the NSTX Research Team*


**Division of Plasma Physics**
**Denver**
**Nov 2013**

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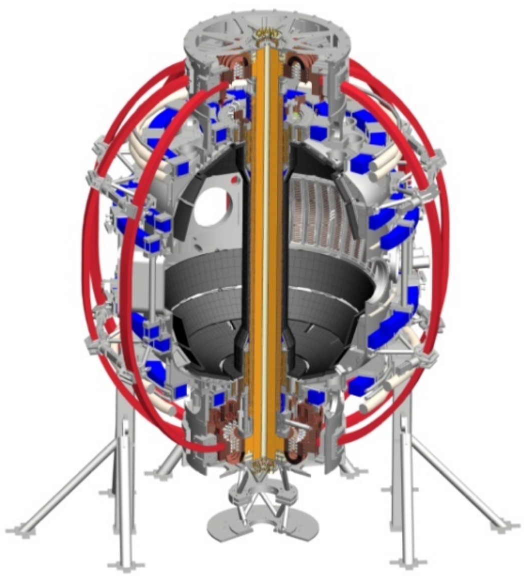

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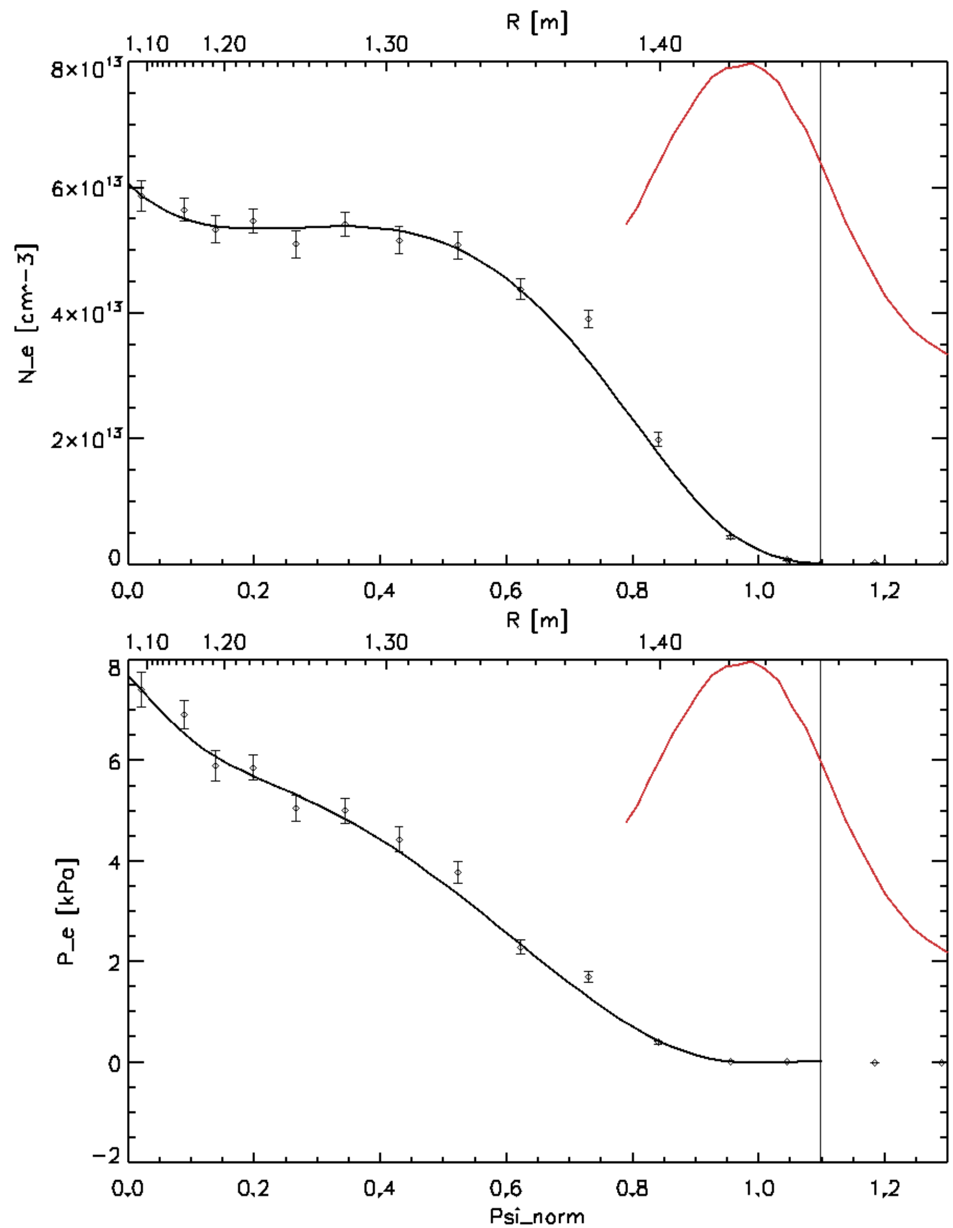

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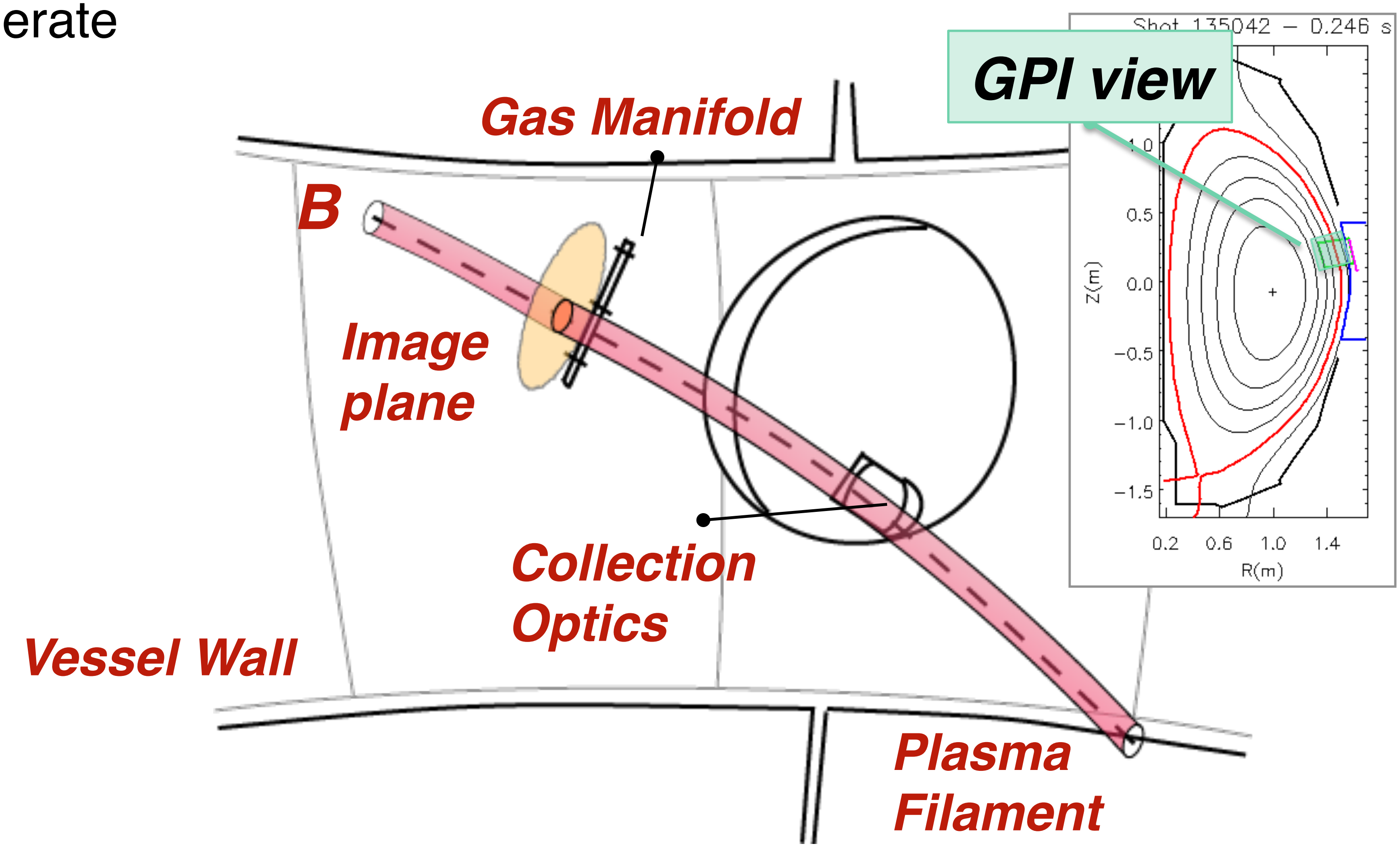

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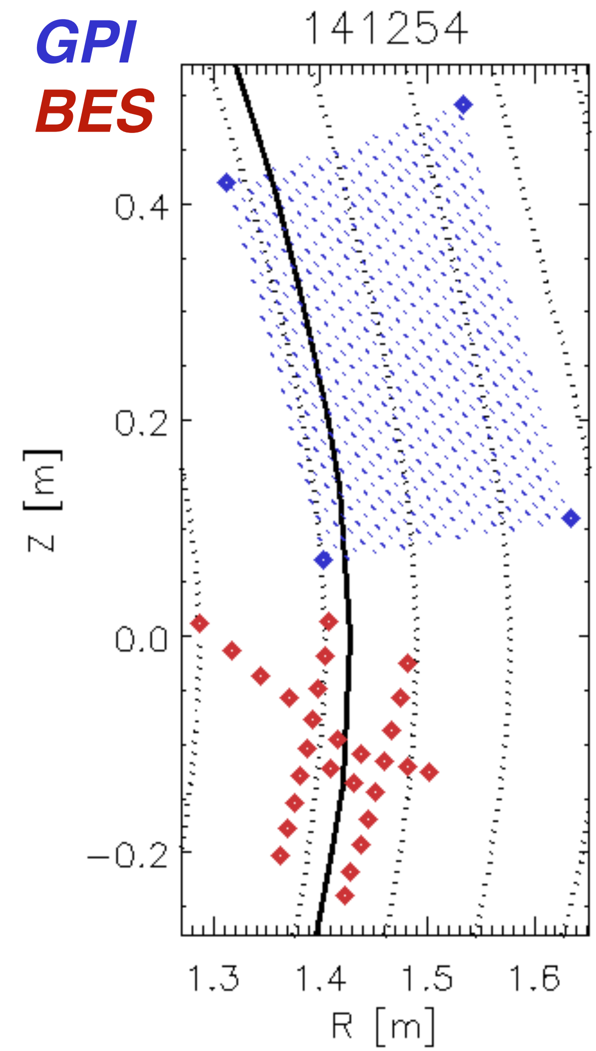


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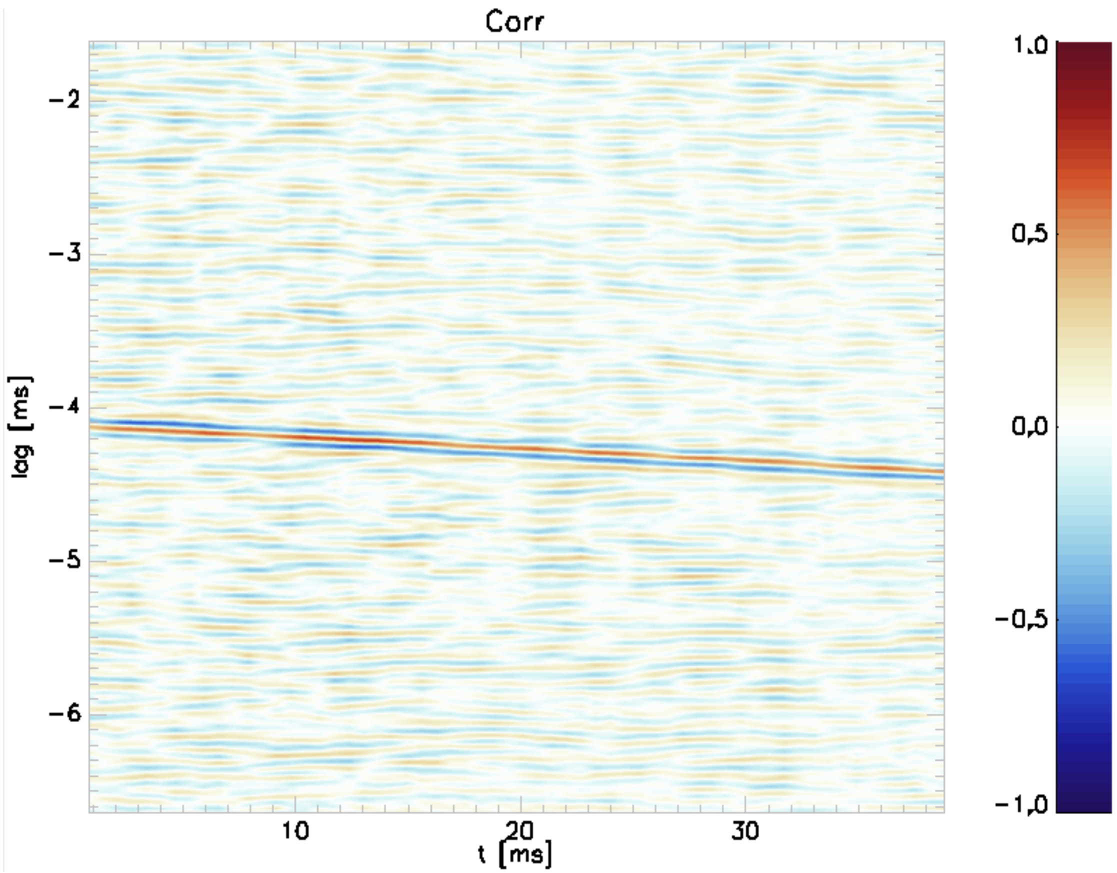

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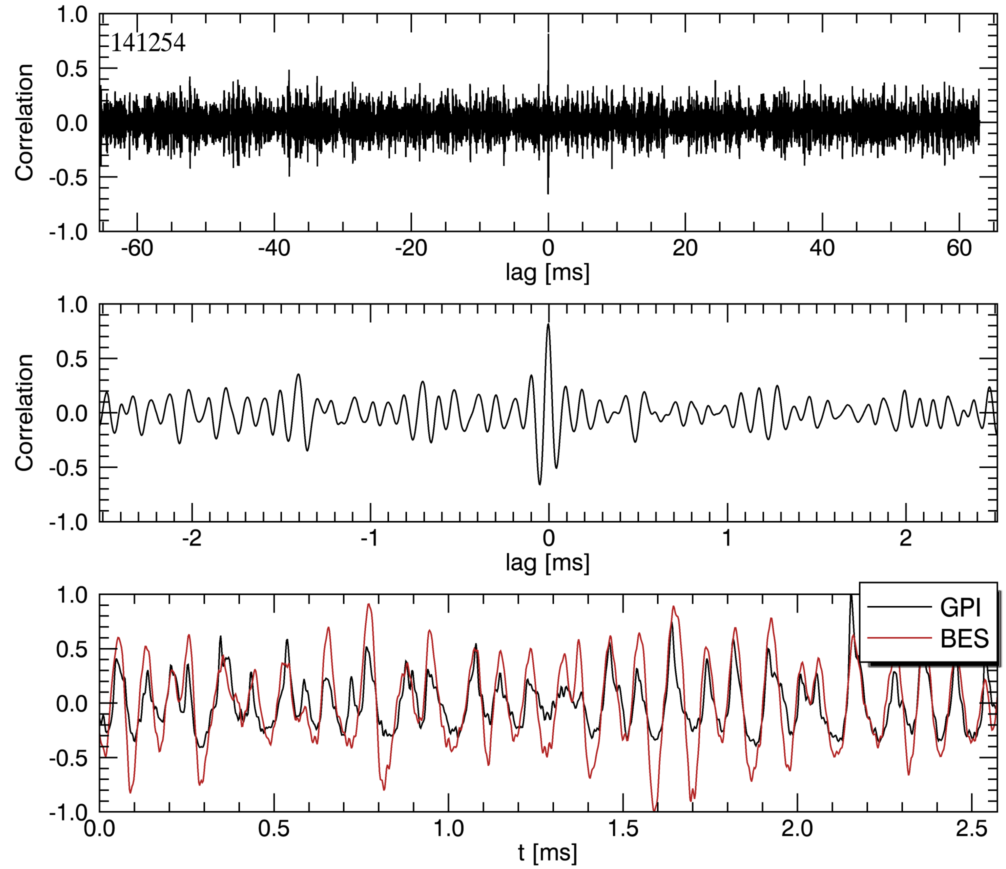

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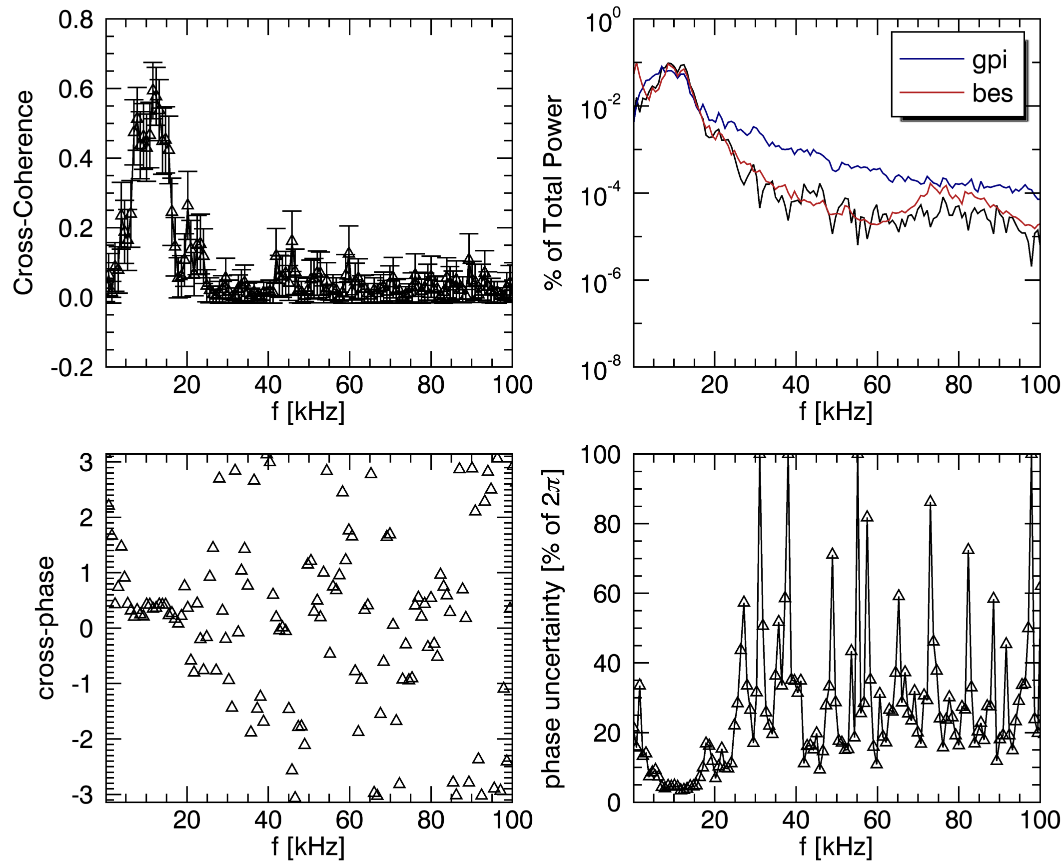

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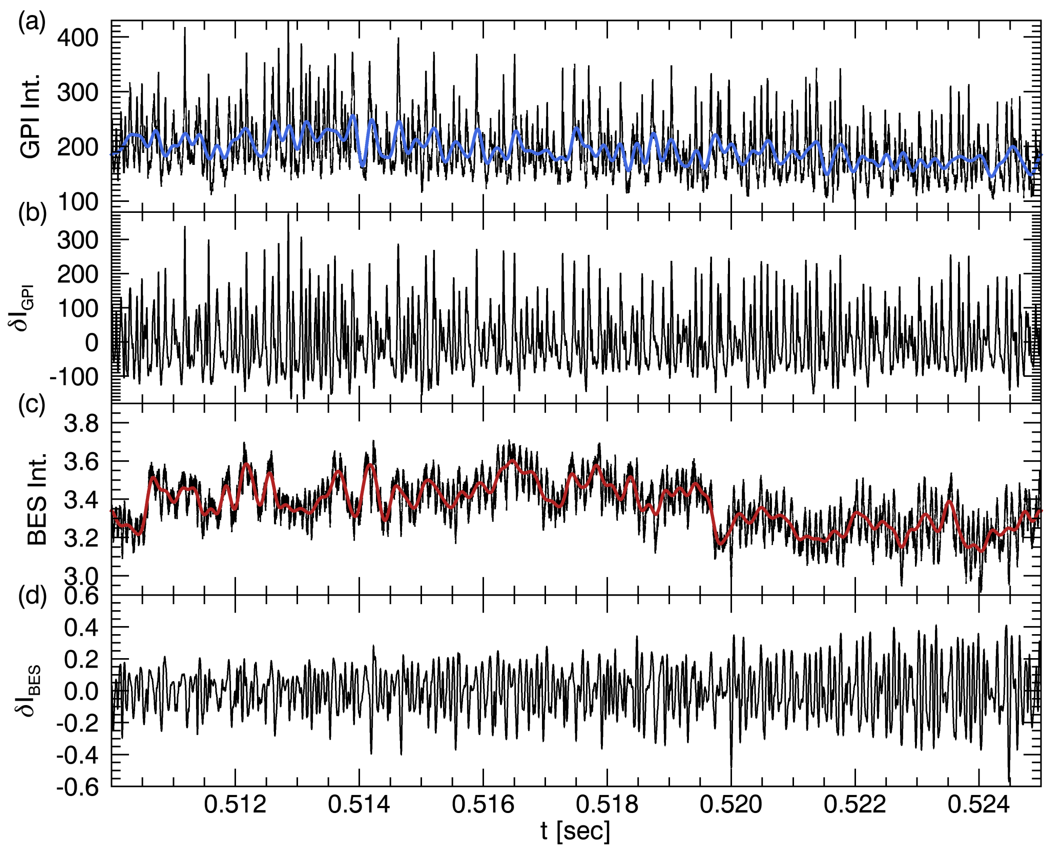

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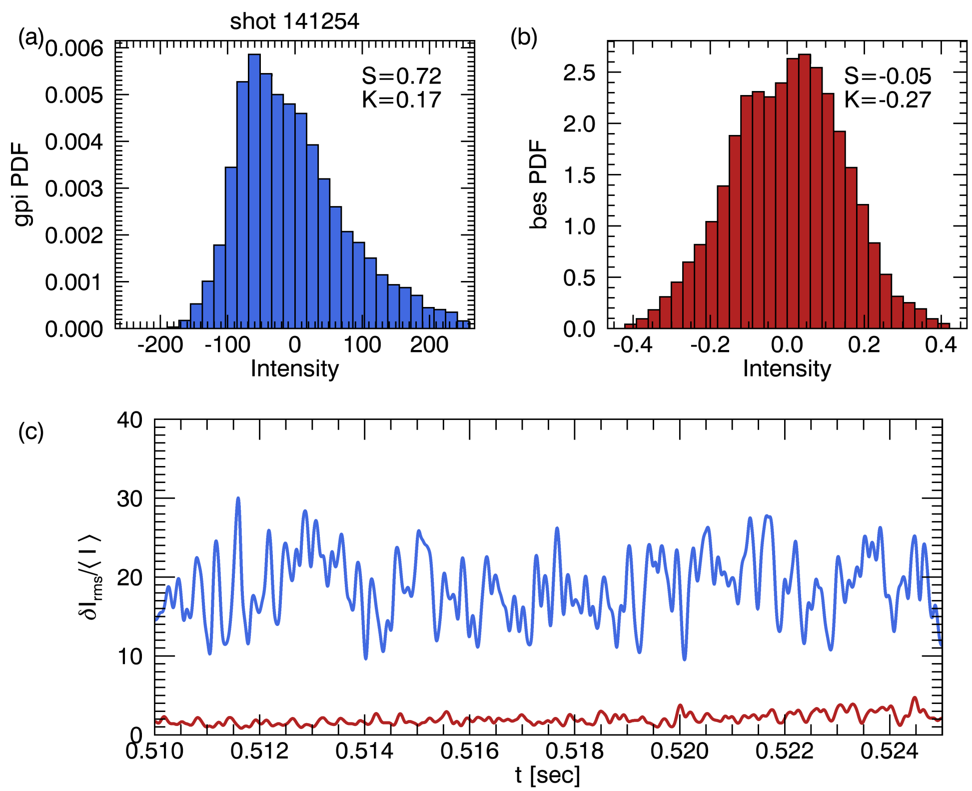
- Large difference in relative fluctuation levels



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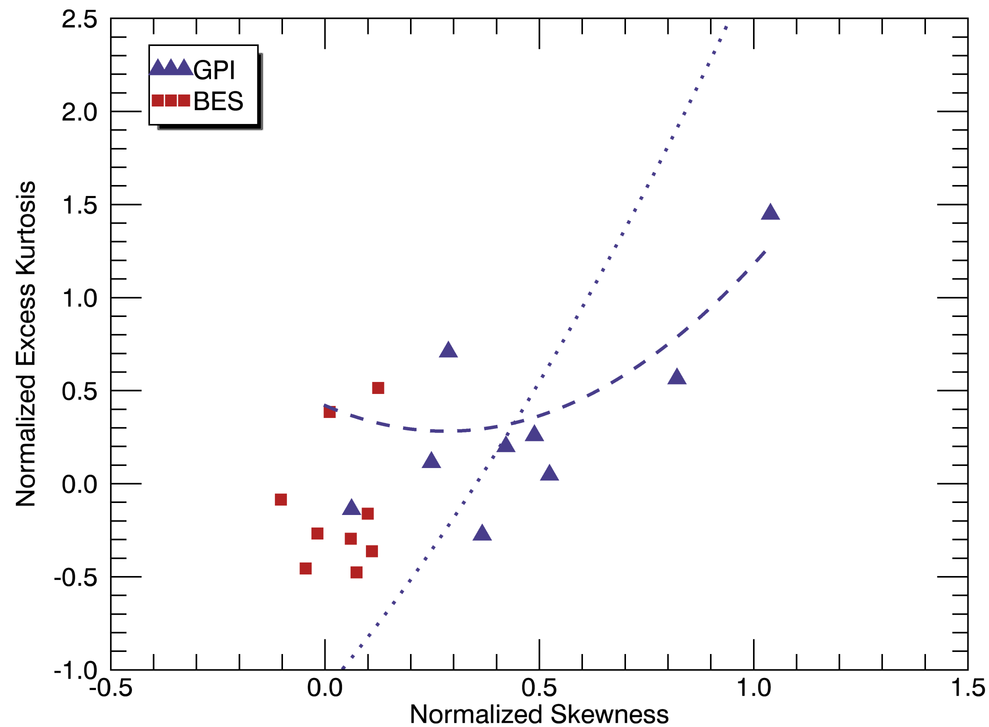
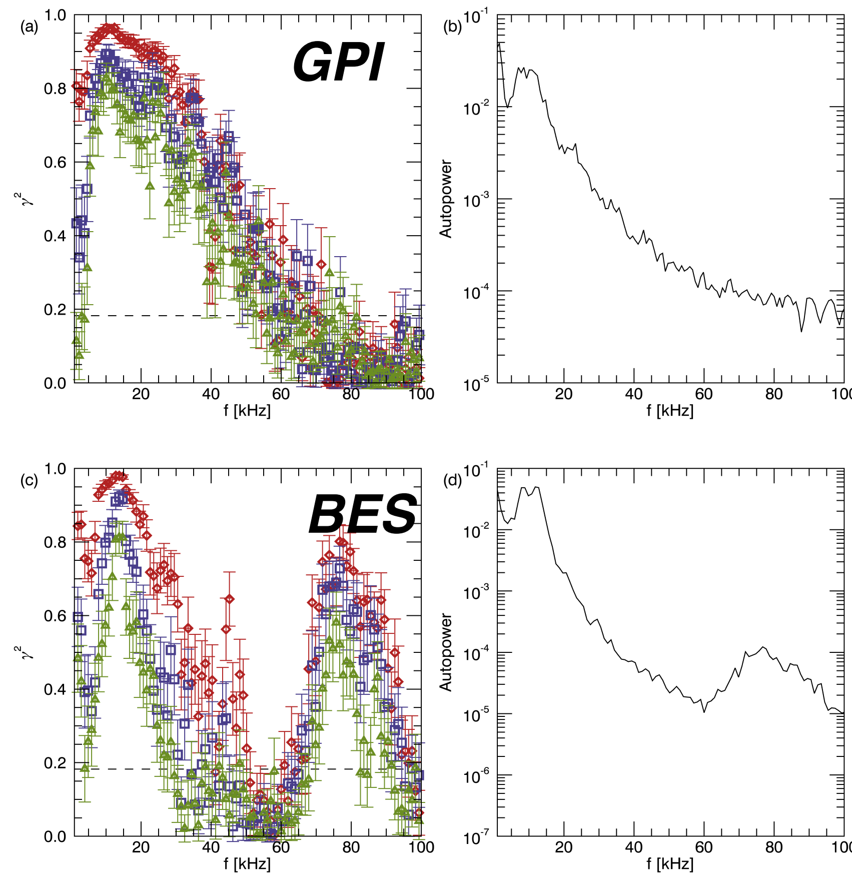


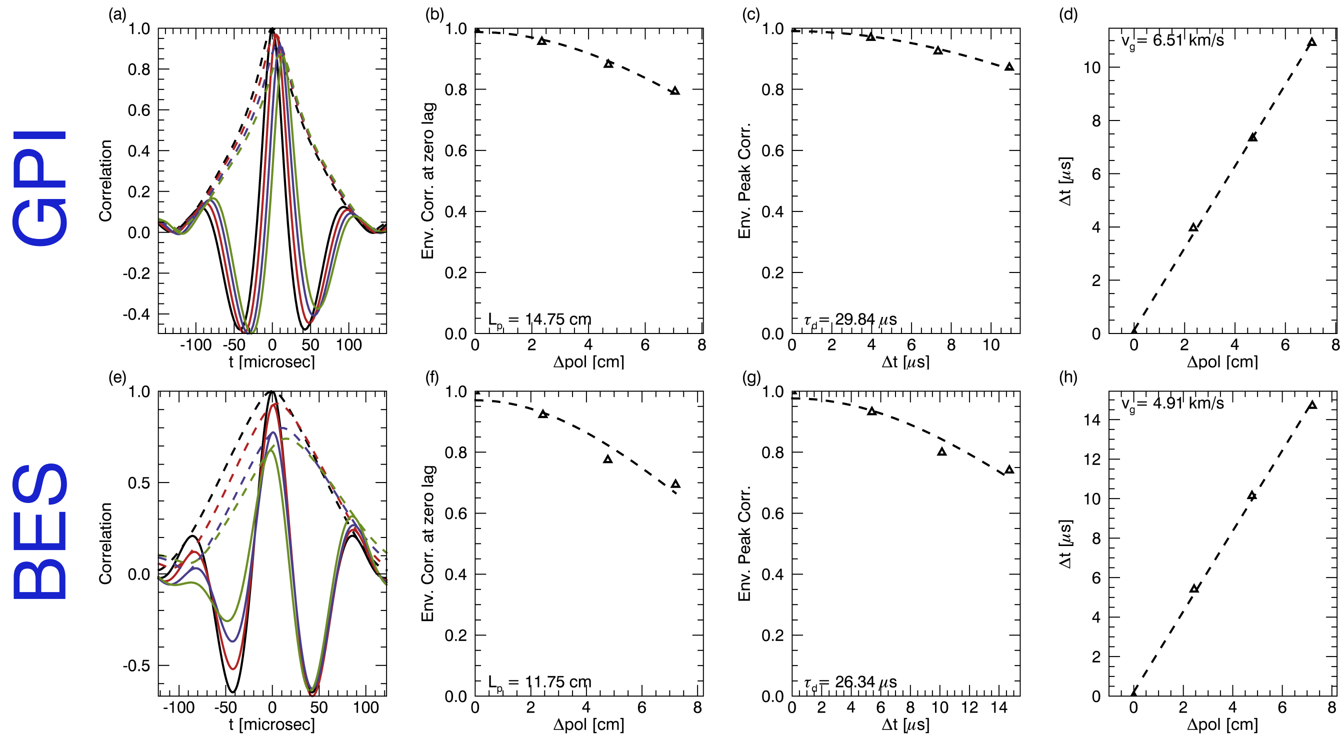
# Measured characteristic scales show moderate agreement

## Coherence and Autopower:

- Low frequencies exhibit similar features
- Some High frequency content not present in GPI
- Focus on 7-30 kHz band




*ΔPOL: 2.4 cm, 4.8 cm, 7.2 cm*

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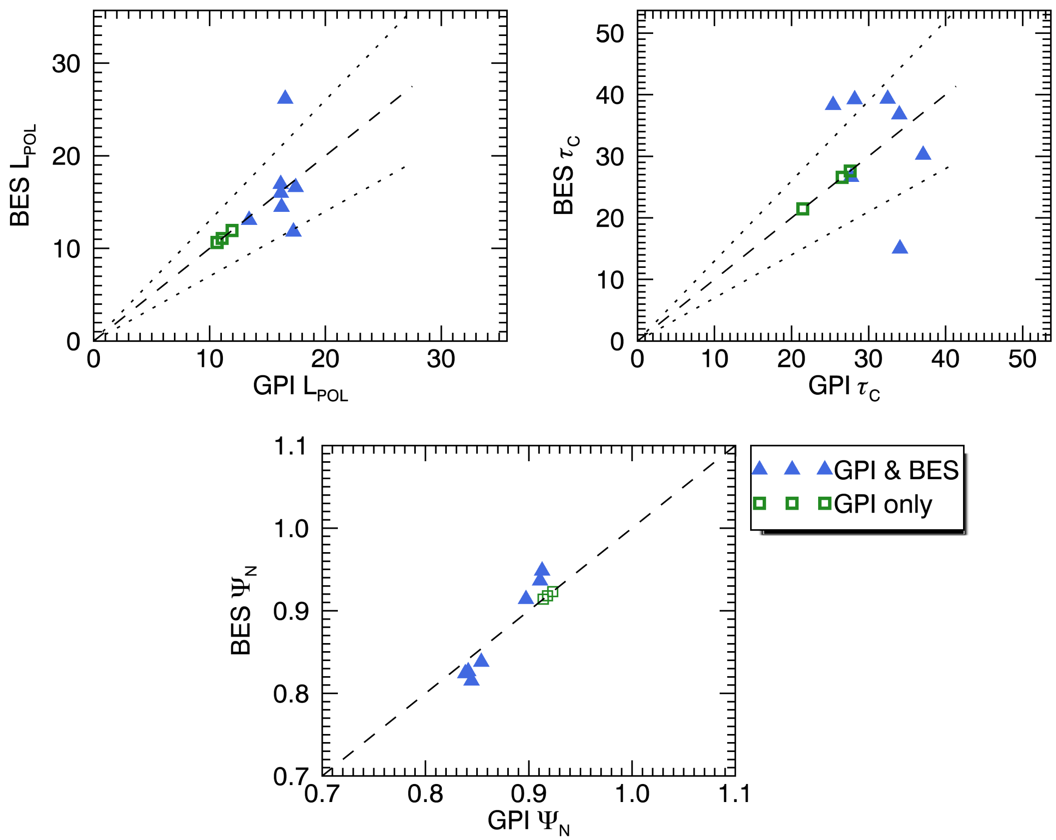

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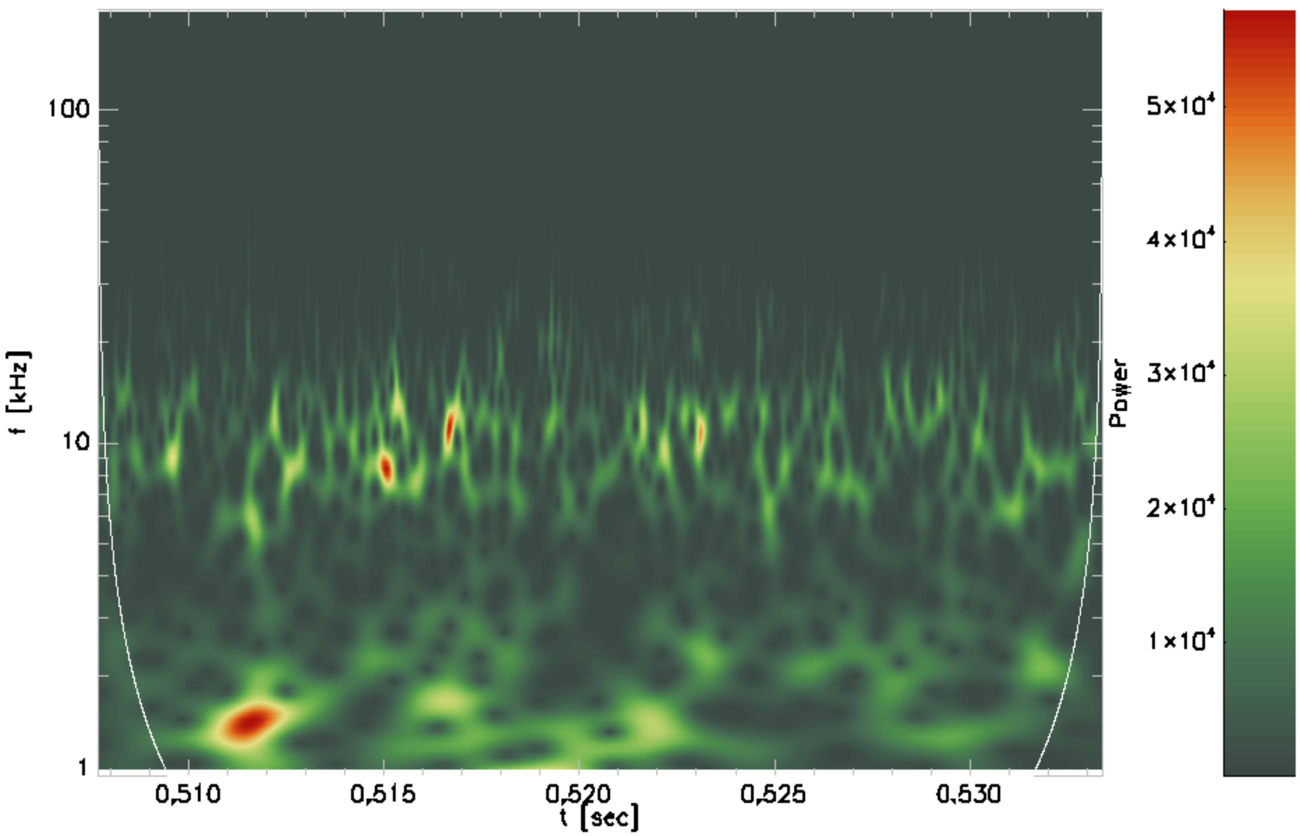


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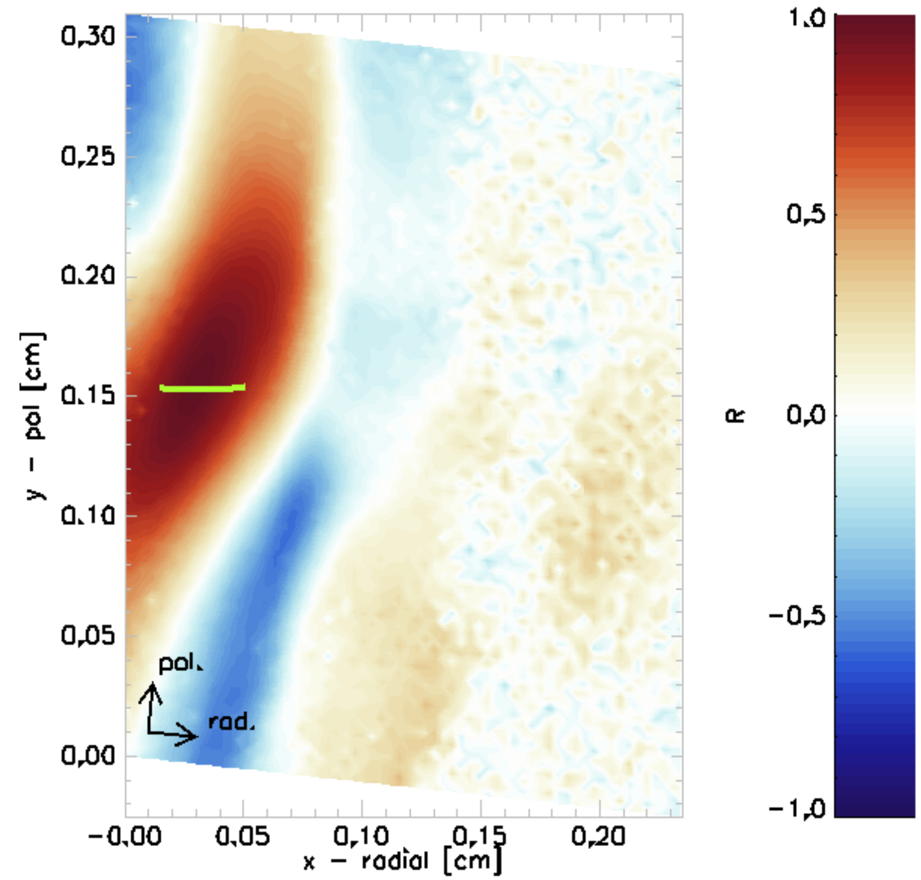

## Outstanding Questions:

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- Tilted/Sheared correlation structures

# Summary

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- Fluctuation statistics differ between the diagnostics
- Measured poloidal corr. lengths and decorrelation time show reasonable agreement
- Strong cross-diagnostic correlation and coherence are observed at separations of ~36 cm
- Dominant fluctuation band of 4-30 kHz exhibits short-lived, intermittent time-frequency behavior.

# Acknowledgements

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