Bispectral Analysis of the L-H transition as seen in the NSTX GPI data

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Outline

- Introduction
- Background and motivation
- Application of bispectral analysis to NSTX GPI data
- Summary/Conclusions
- Future Work

Bispectral Analysis

Bispectrum

$$B(f_1, f_2) = < \Phi(f_1)\Phi(f_2)\Phi^*(f_3) > \qquad f_1 + f_2 = f_3$$

Squared Bicoherence

$$b^2(f_1, f_2) = \frac{|B(f_1, f_2)|^2}{< |\Phi(f_1)\Phi(f_2)|^2 >< |\Phi(f_3)|^2 >} \qquad 0 \leq b^2(f_1, f_2) \leq 1$$

The bicoherence is a measure of phase coherence between three Fourier modes in the system

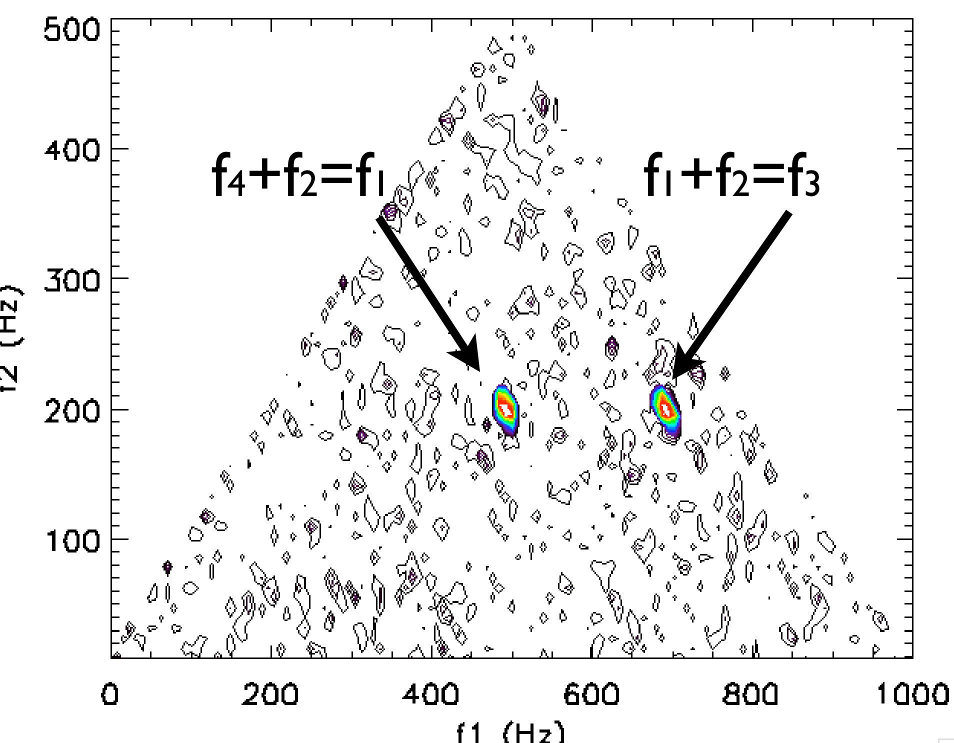
Interpretation of bicoherence figures

$$g(t) = sin(f_1 + \phi_1) + sin(f_2 + \phi_2) + sin(f_3 + \phi_3) + sin(f_4 + \phi_4)$$

$$f_1 + f_2 = f_3 \qquad f_1 - f_2 = f_4 \qquad \phi_{1,2} = random[-\pi, \pi]$$

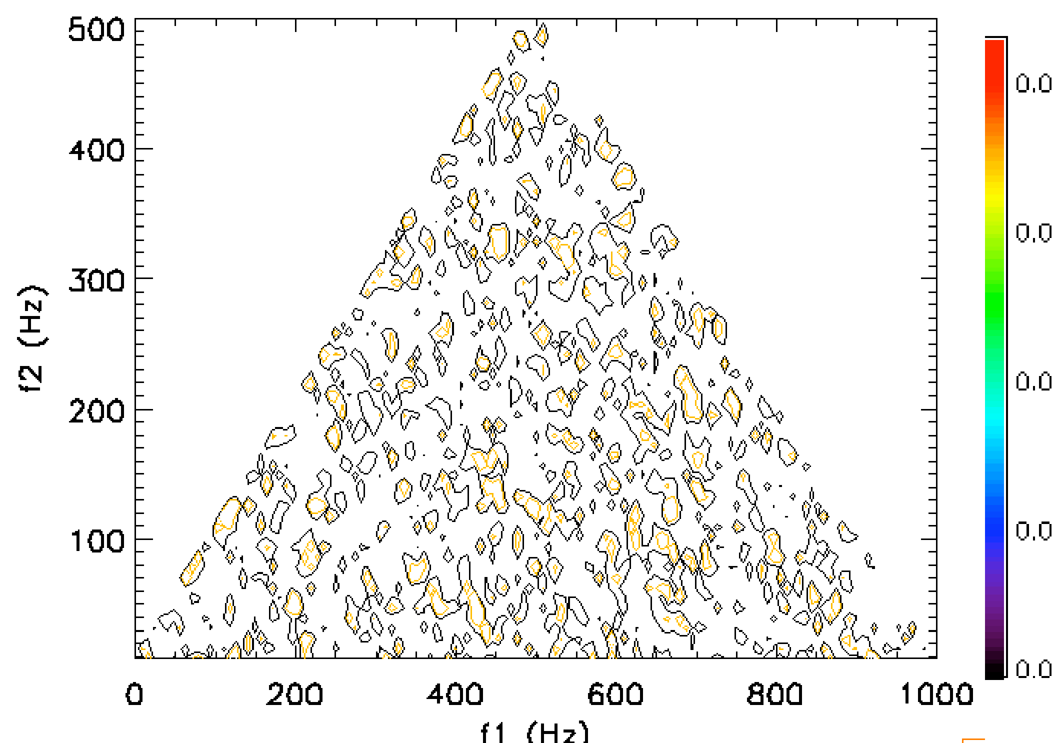
Coupled

$$\phi_1 + \phi_2 = \phi_3$$
$$\phi_1 - \phi_2 = \phi_4$$



Uncoupled

$$\phi_3 = random[-\pi, \pi]$$
$$\phi_4 = random[-\pi, \pi]$$



Interpretation of bicoherence figures

Summed bicoherence gives a measure of the strength of the coupling at the sum frequency f_3 with respect to all other frequencies

$$b^2(f_3) = \sum_{f_1+f_2=f_3} b^2_{f_3}(f_1, f_2)$$

Total bicoherence gives a measure of the relative strength of coupling summed over all frequencies

$$b^2 = \sum_{f_1} \sum_{f_2} b^2_{f_3}(f_1, f_2)$$

Definitions given by Van Milligan (1995) and Tynan (2001)

Background and Motivation

It was reported in 2001 that the nonlinear coupling between small scale high-frequency turbulence and larger scale low-frequency fluctuations increases prior to an L-H transition in DIII-D .

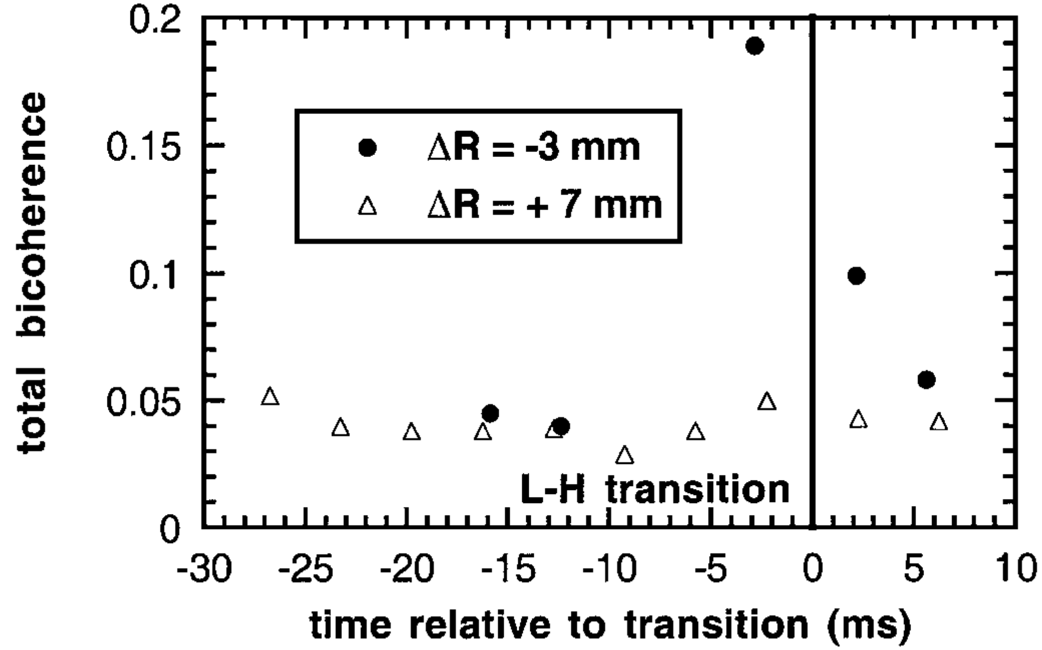
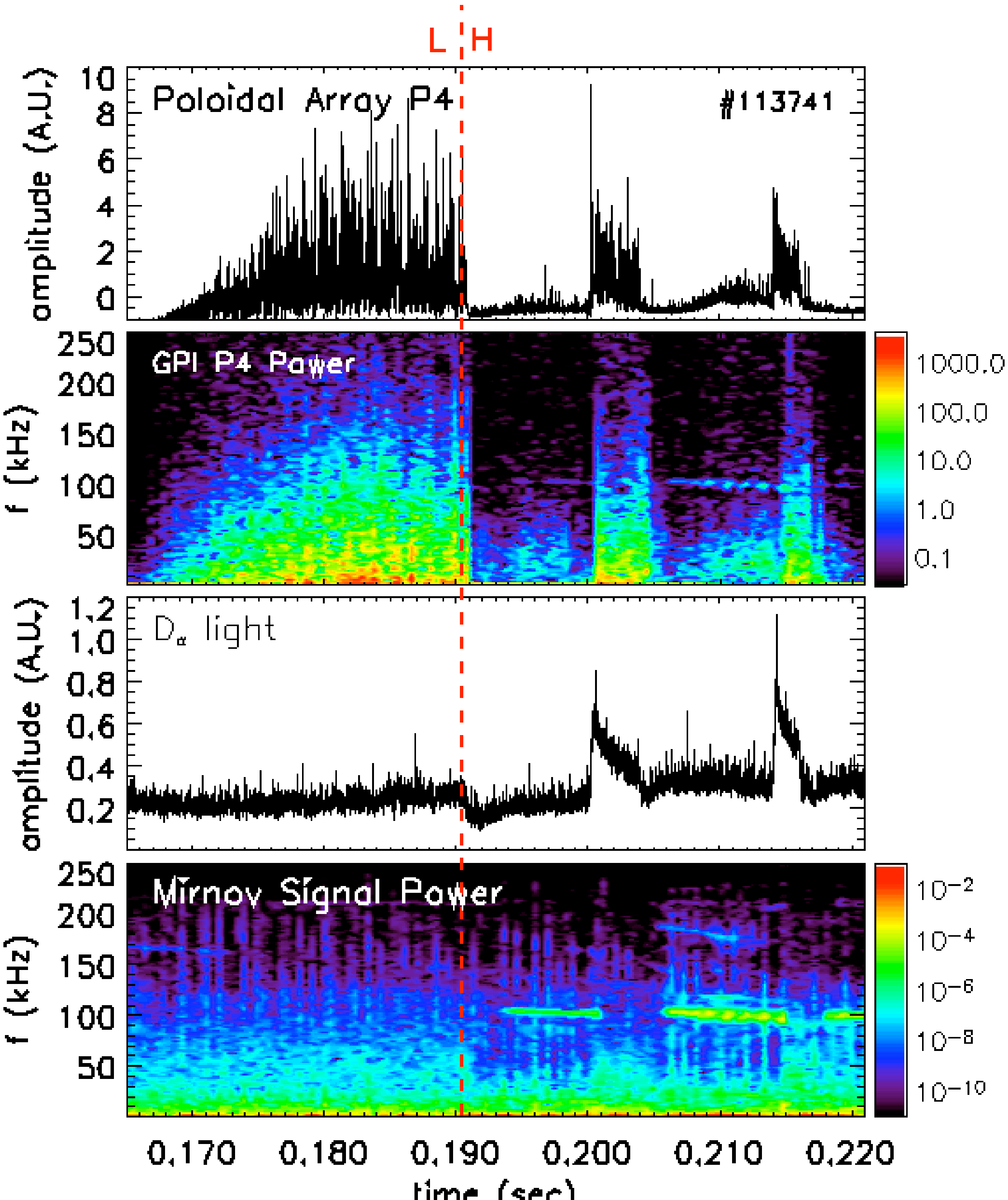


FIG. 4. Evolution of the total bicoherence of I_{sat} 3 mm inside (•) and 7 mm outside (△) the separatrix.

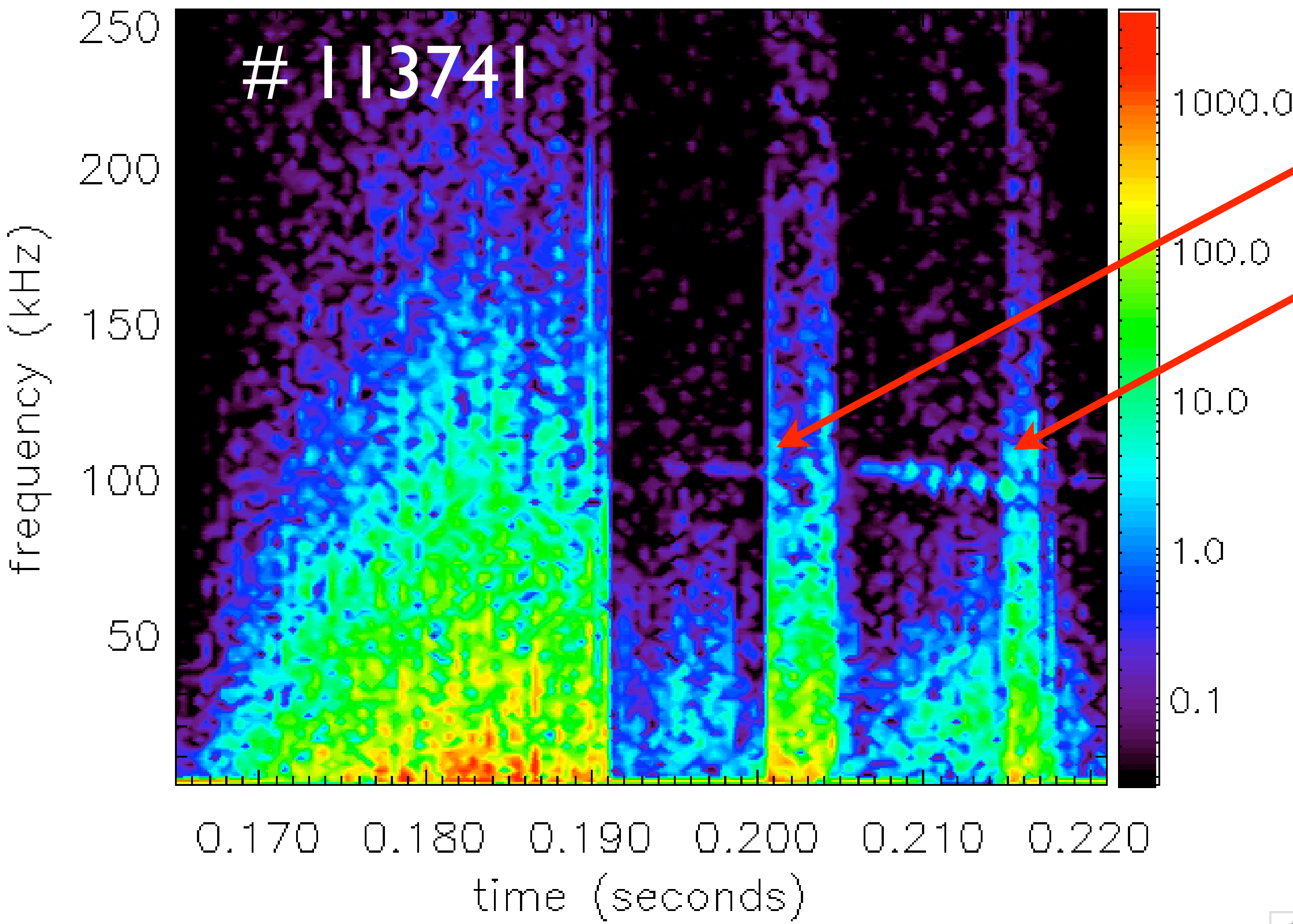
Figure and caption taken from:
Increased Nonlinear Coupling between Turbulence and Low-Frequency Fluctuations at the L-H Transition
R. A. Moyer, G. R. Tynan, C. Holland, and M. J. Burin
Phys. Rev. Lett. 87, 135001 (2001)

GPI Chord Data



Light amplitude signals from the GPI 1-D chords show decreased fluctuation amplitude after the L-H transition

Power Spectrum from GPI chord signal



A mode at ~100 kHz appears during the H-mode

There are no long-lived modes during the L-mode or during Ohmic shots

Viewing region of GPI chord data with respect to the separatrix may affect bicoherence results

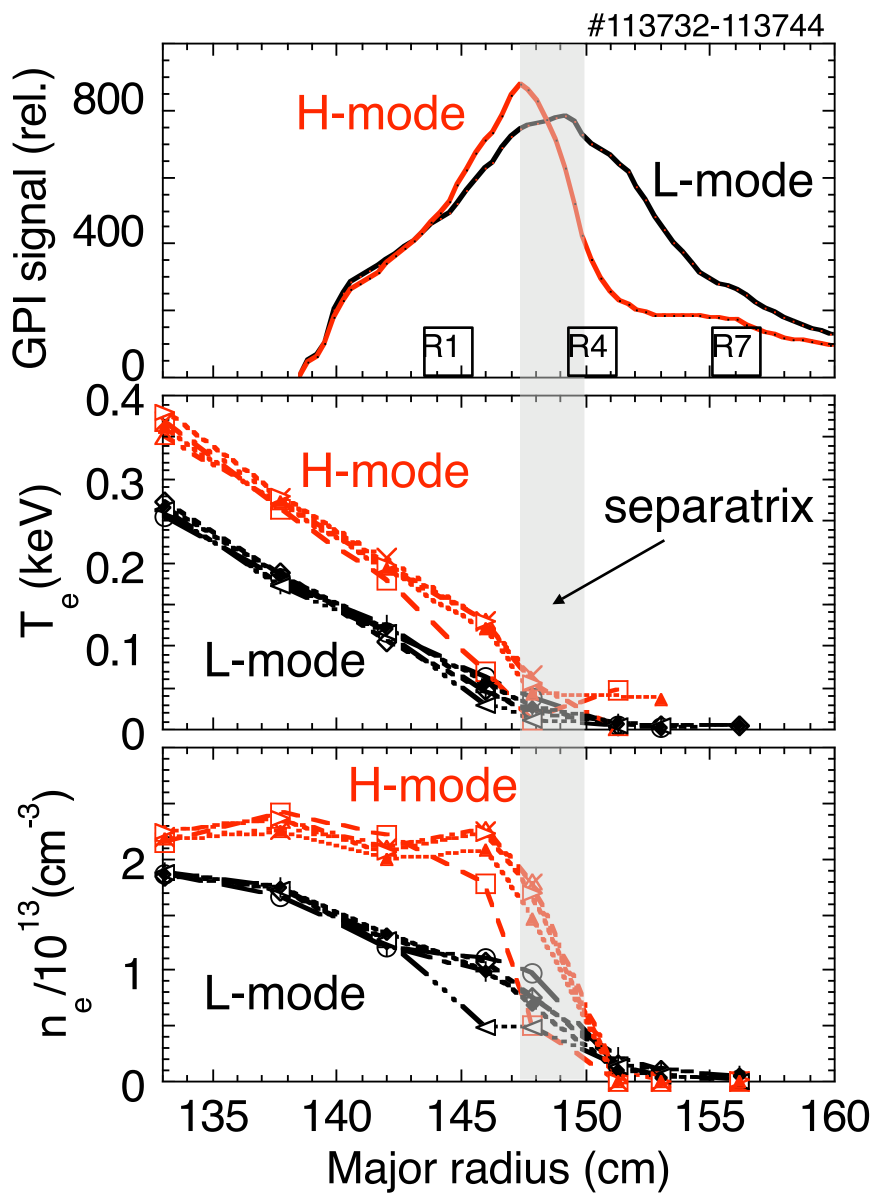
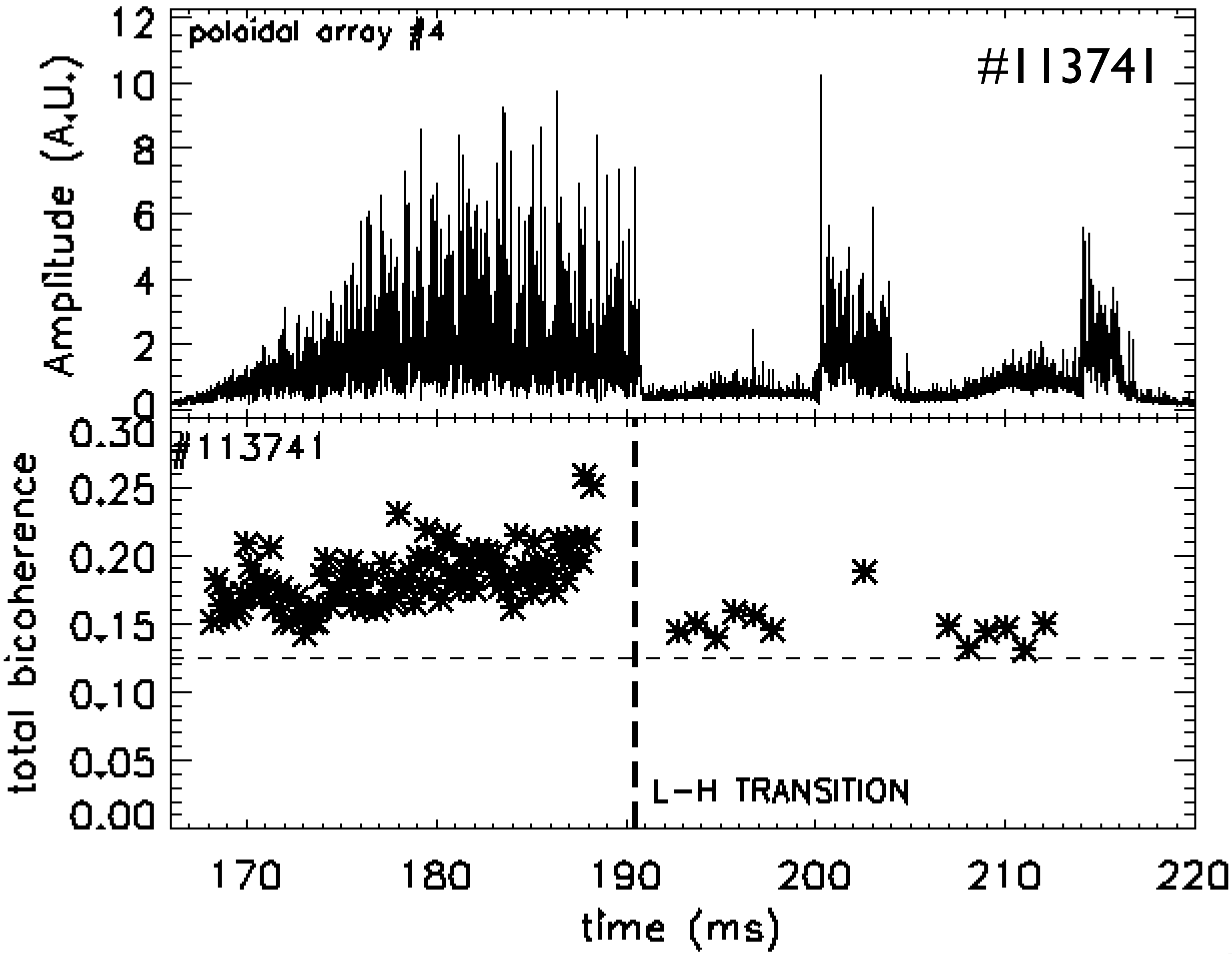


Figure: S.Zweben TTF 2005

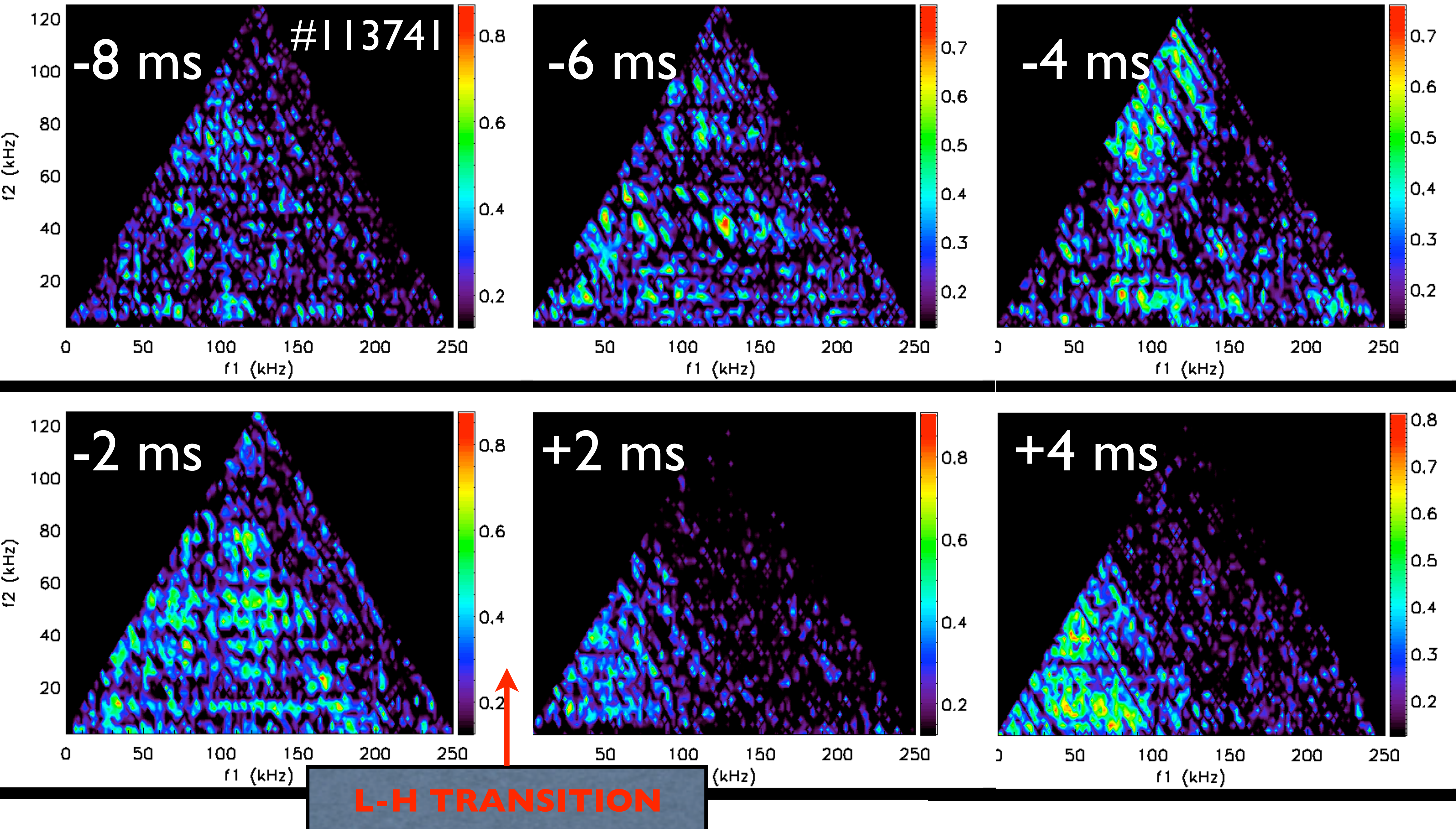
The GPI poloidal detector array on NSTX was located near the separatrix for the shots analysed

The DIIID study saw an increase in bicoherence just inside the separatrix

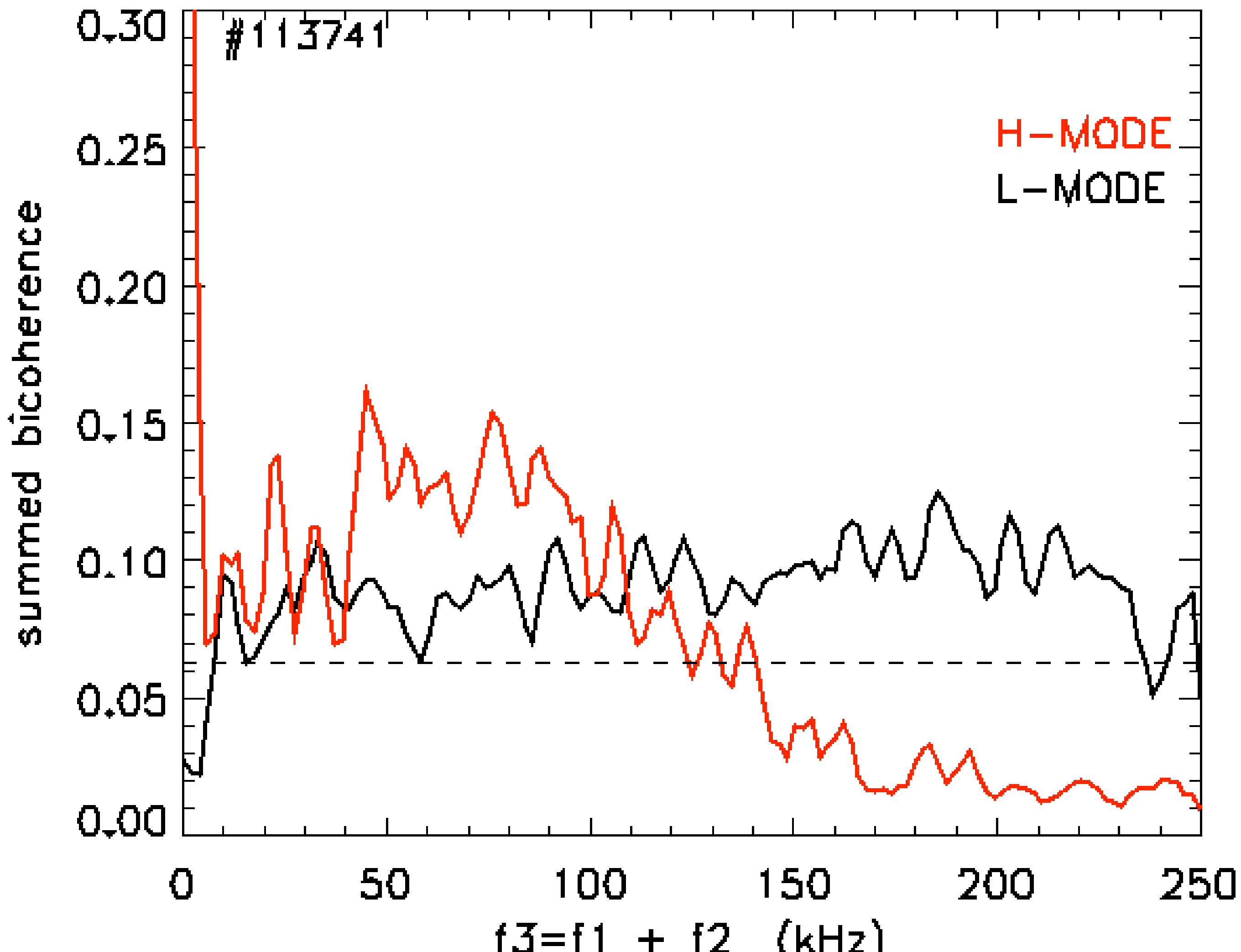
Total bicoherence of the GPI signal tends to decrease following the L-H transition

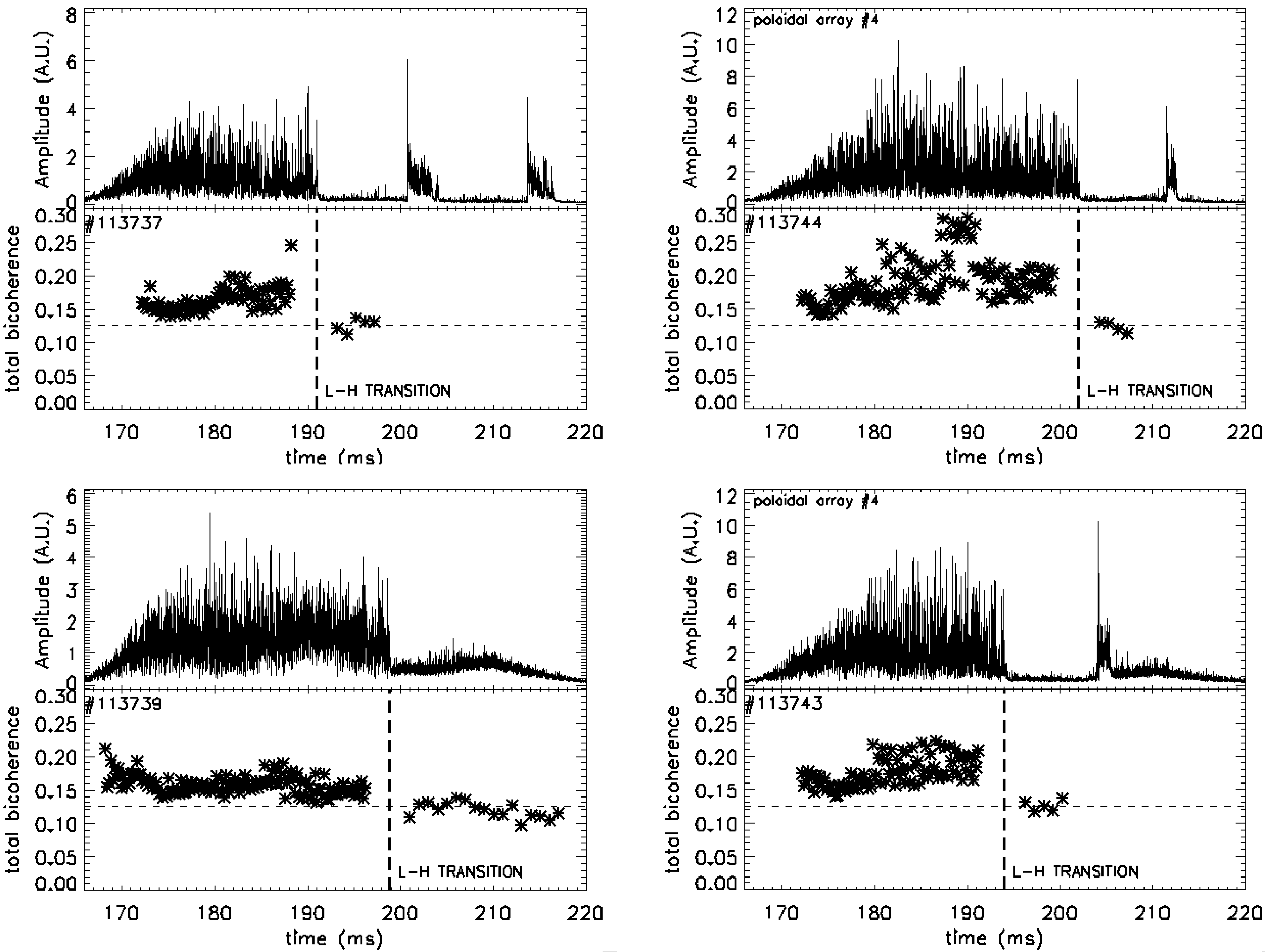


Total bicoherence decreases following the L-H transition and the coupling is localized to low sum frequencies



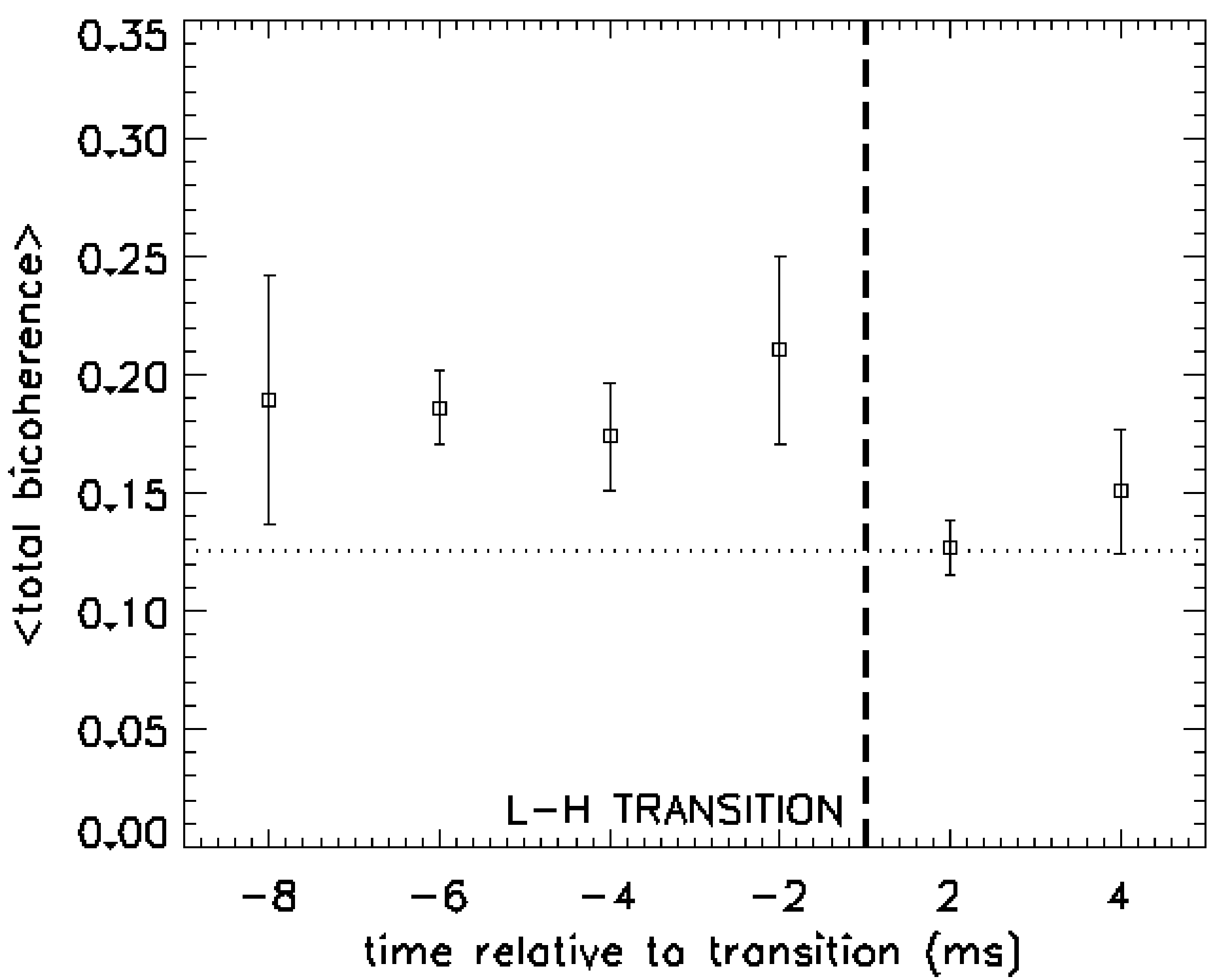
The summed auto-bicoherence indicates that coupling shifts to low sum frequencies following the L-H transition





Amplitude (A.U.)
total bicoherence
time (ms)
#113737
L-H TRANSITION
poloidal array #4
#113744
L-H TRANSITION
#113739
L-H TRANSITION
poloidal array #4
#113743
L-H TRANSITION

The total bicoherence averaged over 5 shots with an L-H transition shows a typical trend found in NSTX data



113737
113739
113741
113743
113744

Summary of NSTX results and Conclusions

- The total bicoherence decreases going from L-mode to H-mode
- During H-mode, coupling occurs mostly at low sum frequencies (f_3 < 100 kHz), implying either sum coupling of large scales with other larger scales or difference coupling between small and large scales
- All L-H transition NSTX shots indicate there is no significant increase in the amount of coupling prior to the L-H transition

Future Work

- Calculate radial profile of the bicoherence
- Increase the digitization rate of the GPI 1-D detector data
- Compare bicoherence evolution with 2-D camera images.
- Apply wavelet analysis to compute the bicoherence of GPI data and compare to FFT method