Ambipolarity of Magnetic Fluctuation Driven Particle Transport in MST Edge

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Abstract (Revised)

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Magnetic fluctuation driven particle transport is potentially very large in MST and is expected to be ambipolar. In agreement with this expectation, magnetic fluctuation driven charge transport, $\left\langle \tilde{j}_{\|} \tilde{b}_r \right\rangle / (eB)$, has been measured in the edge of MST to be very small between sawteeth indicating that the magnetic fluctuation driven particle transport in the edge of MST is ambipolar. In contrast, it has been measured to be large during sawtooth crashes in the extreme edge. Cross-spectral analysis of $\tilde{j}_{\|}$ and $\tilde{b}_r$ as well as a form of toroidal mode analysis give insight into the physics causing magnetic fluctuation driven charge transport to be small between sawteeth.

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Why Measure Magnetic Fluctuation Driven Charge Transport?

Magnetic fluctuation driven particle transport is potentially large in MST because magnetic fluctuations are large (~ 1%).

Global magnetic fluctuations are dominated by core resonant tearing modes (m=1,n=5...9).

Tearing mode theory predicts radial magnetic field and current density fluctuations that are spatially out of phase.

It is expected that magnetic fluctuation driven particle transport, given by $\left\langle \tilde{j}_{\parallel} \tilde{b}_r \right\rangle / (eB)$, is ambipolar. **($\langle \, \rangle$ means flux surface average).**

If this is verifiable, it places a constraint on a possibly important channel for particle transport in MST as well as other channels for particle transport.

Main Results/Conclusions

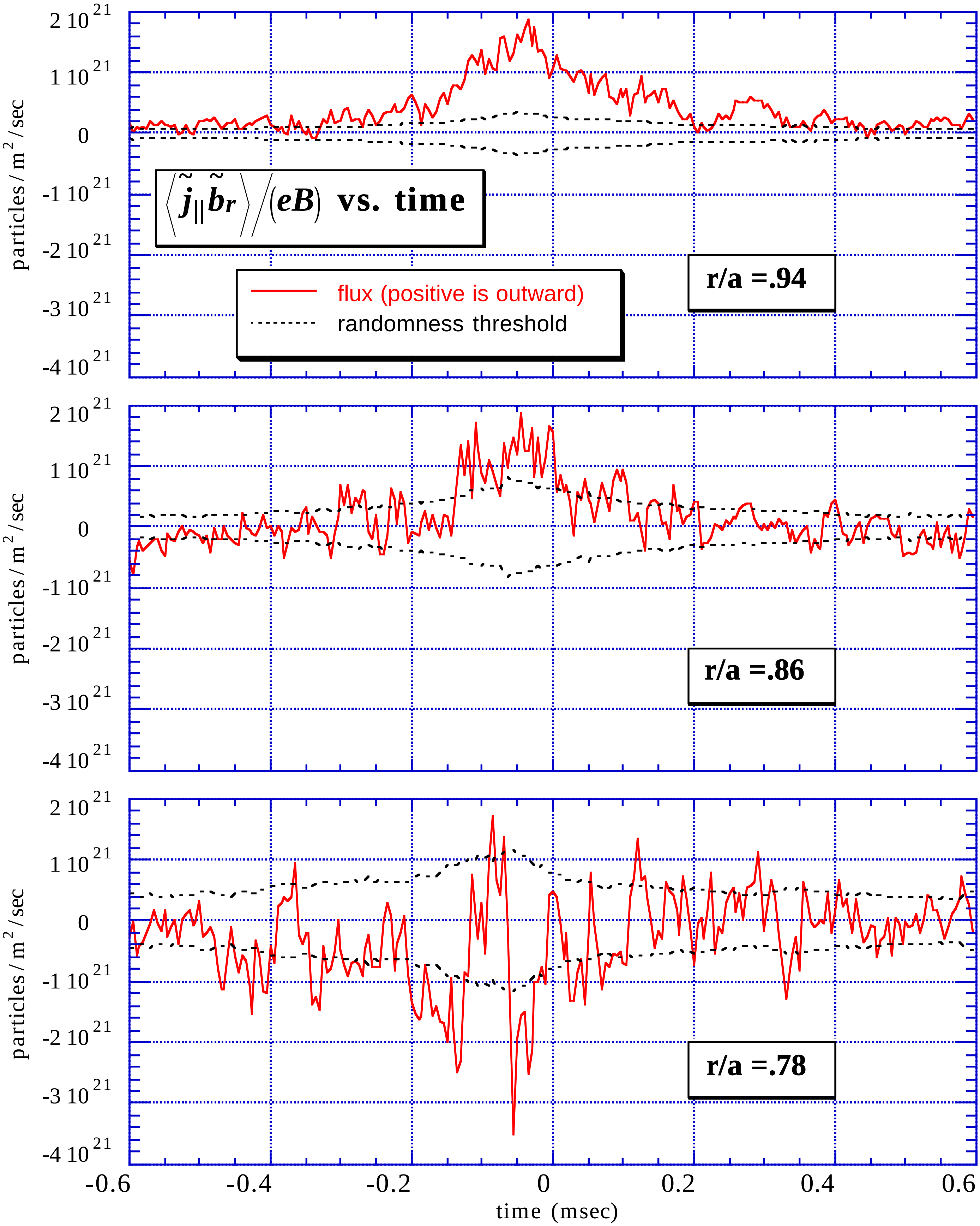
Magnetic fluctuation driven particle transport is ambipolar in MST edge between sawteeth, but not at the extreme edge during sawtooth crashes.

Physical cause of ambipolarity between sawteeth varies with r/a.

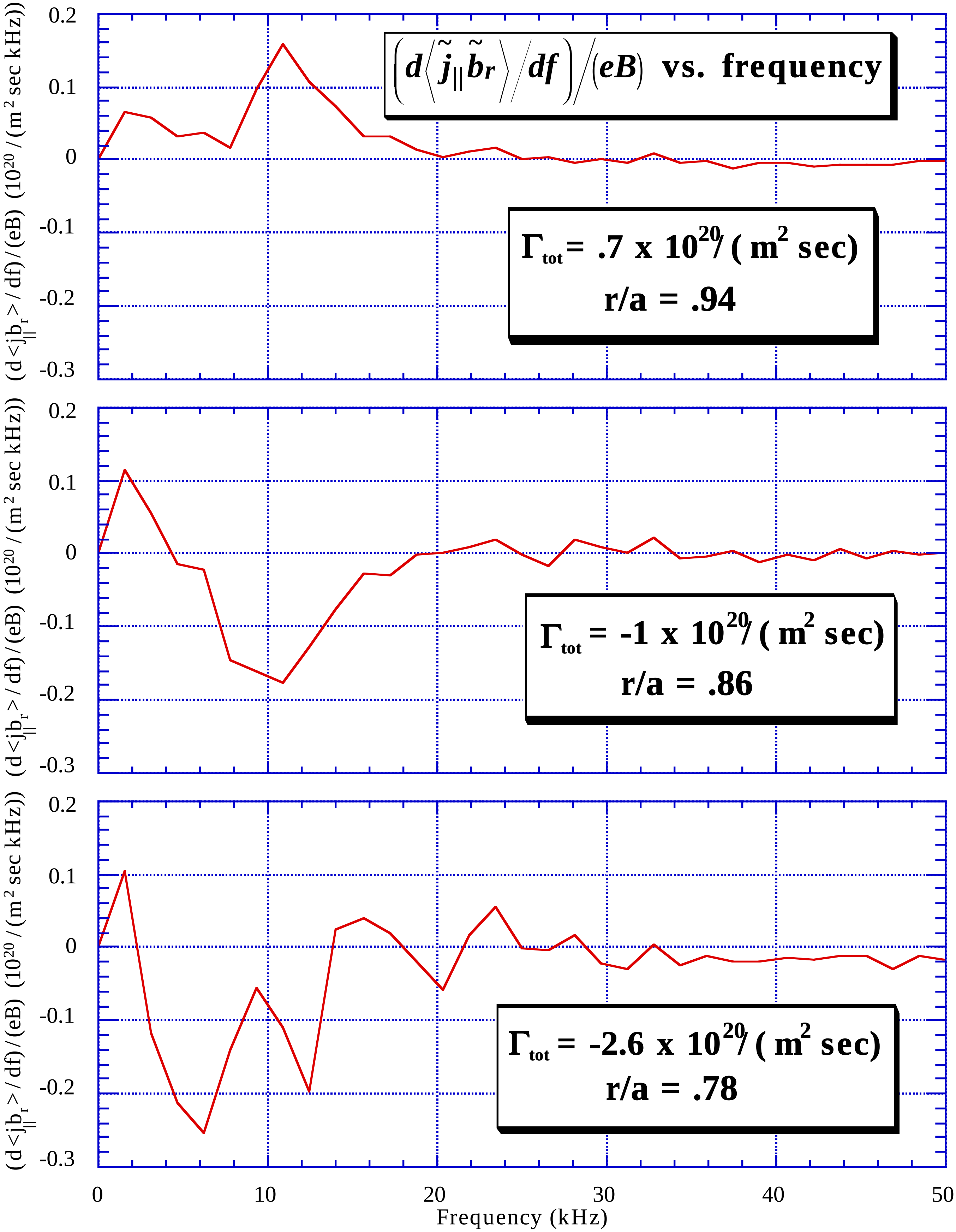
Global toroidal modes do not appear to individually contribute to charge transport between sawteeth.

$\tilde{j}_{\parallel}$ **and** $\tilde{b}_r$ **in MST edge appear to have broad n spectra, including n's due to both core resonant and edge resonant modes.**

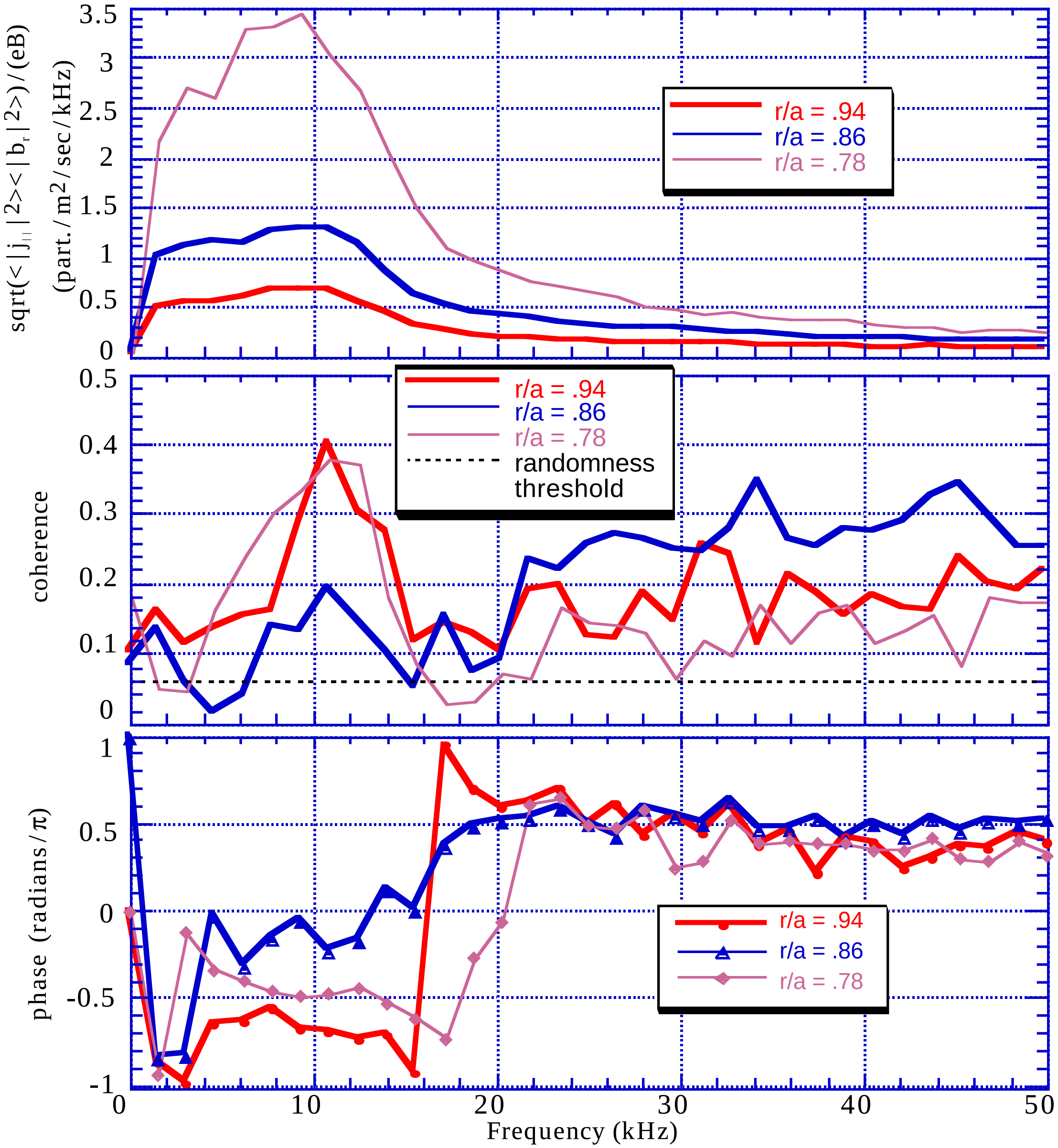
$\Gamma_i - \Gamma_e$ Due to Magnetic Fluctuations is Large During Sawtooth Crash in Extreme Edge



$\Gamma_i - \Gamma_e$ Due to Magnetic Fluctuations is Small at All Frequencies Between Sawteeth



Magnetic Fluctuation Driven Charge Transport is Small at All Frequencies in MST Edge Between Sawteeth



Cause of Small Charge Transport Varies with r/a

r/a = .94

$\tilde{j}_{\|}$ and $\tilde{b}_r$ have small combined amplitude (overcomes high coherence and being partially in phase).

r/a = .86

$\tilde{j}_{\|}$ and $\tilde{b}_r$ have low coherence and low combined amplitude (overcomes being nearly in phase)

r/a = .78

$\tilde{j}_{\|}$ and $\tilde{b}_r$ are out of phase (overcomes high combined amplitude, high coherence)

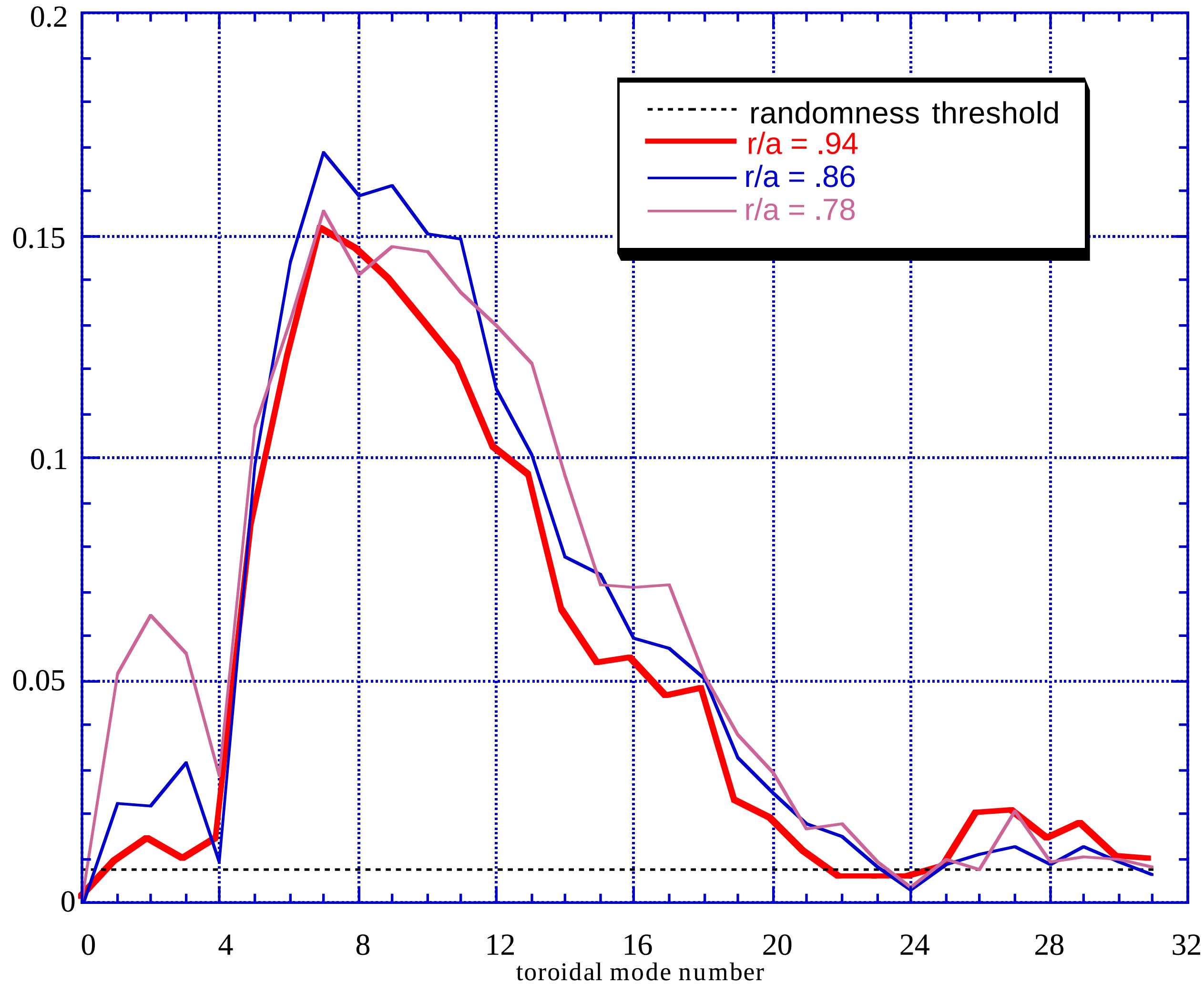
Toroidal Modes Individually Contribute Little to Magnetic Fluctuation Driven Charge Transport in MST Edge Between Sawteeth

Transport fluctuation power vs. n decreases with r/a. In other words, combined power in $\tilde{j}_{\|}$ and $\tilde{b}_r$ for each n ($\left(\left|\langle \tilde{j}_{\|}\tilde{b}_n \rangle\right|\left|\langle \tilde{b}_r\tilde{b}_n \rangle\right|\right) \Big/ \left(\left\langle \left|\tilde{b}_n\right|^2 \right\rangle eB\right)$) decreases with r/a.

"Spatial phase relationship" of $\tilde{j}_{\|}$ and $\tilde{b}_r$ vs. n, (relative phase of $\langle \tilde{b}_r\tilde{b}_n \rangle$ and $\langle \tilde{j}_{\|}\tilde{b}_n \rangle$), is close to π/2 where transport fluctuation power is highest.

$\tilde{b}_r$ has Broad "n Spectrum" Between Sawteeth

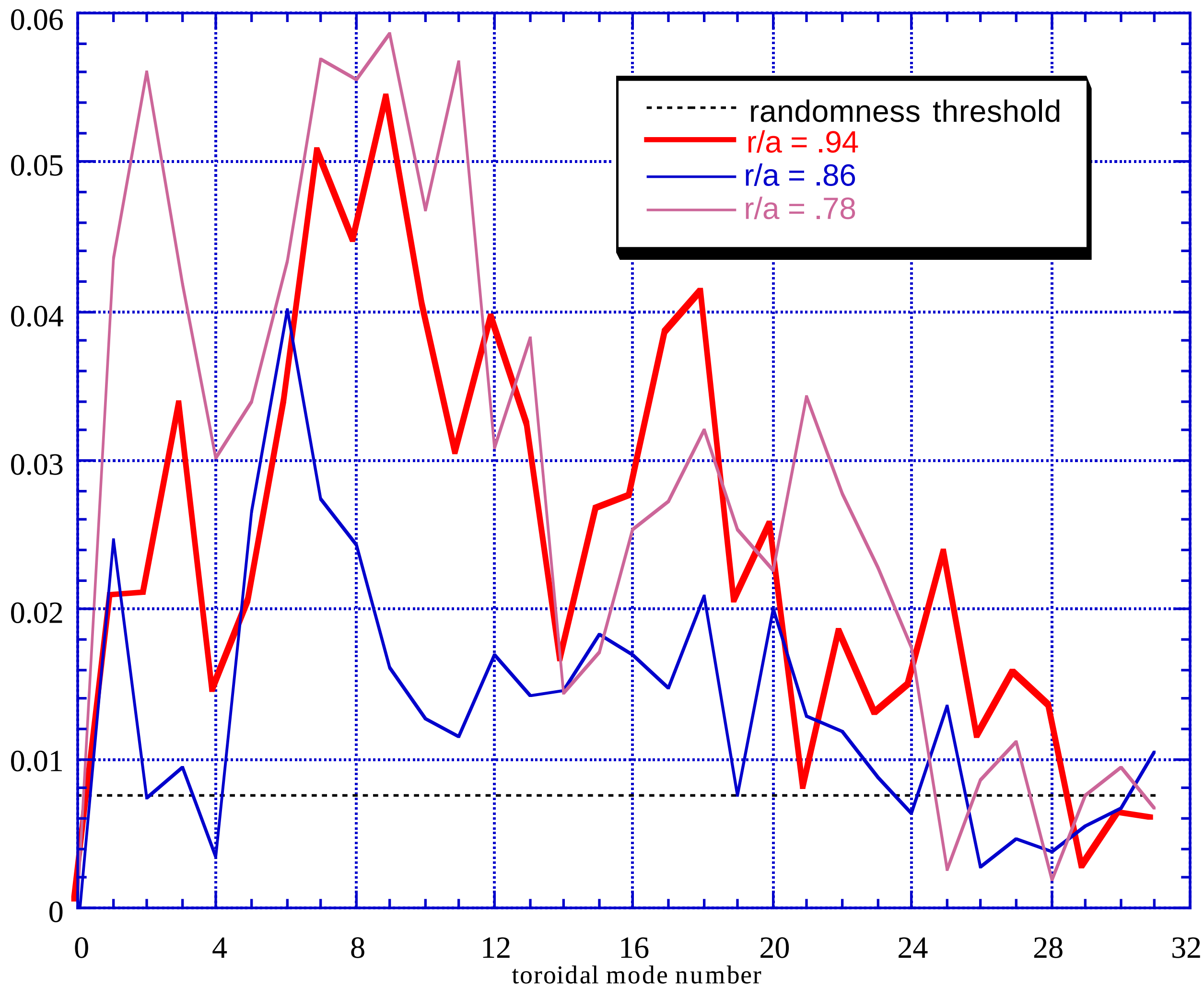
Correlation of $\tilde{b}_r$ with Toroidal Modes (i.e. $\left|\langle \tilde{b}_r \tilde{b}_n \rangle\right| \Big/ \left(\langle |\tilde{b}_r|^2 \rangle \langle |\tilde{b}_n|^2 \rangle \right)^{1/2}$)



- **$\tilde{b}_r$ shows significant correlation with modes ranging from n=5 to n≈20.**
- **n=5...20 includes core resonant and edge resonant modes**

$\tilde{j}_{\|}$ has Broad "n Spectrum" away from Reversal Surface (r/a ≈ .86) Between Sawteeth

Correlation of $\tilde{j}_{\|}$ with Toroidal Modes (i.e. $\left|\left\langle \tilde{j}_{\|} \tilde{b}_n \right\rangle\right| \Big/ \left(\left\langle \left|\tilde{j}_{\|}\right|^2 \right\rangle \left\langle \left|\tilde{b}_n\right|^2 \right\rangle \right)^{1/2}$)



- $\tilde{j}_{\|}$ **away from reversal surface shows significant correlation with modes ranging from n=5 to n≈20.**
- **n=5...20 includes core resonant and edge resonant modes**
- $\tilde{j}_{\|}$ **near the reversal surface shows poor correlation with most of these modes**

Approximate Mode Spectra of $\tilde{j}_{\|}$ and $\tilde{b}_r$ Have Been Obtained from Point Measurements of $\tilde{j}_{\|}$ and $\tilde{b}_r$ Between Sawteeth

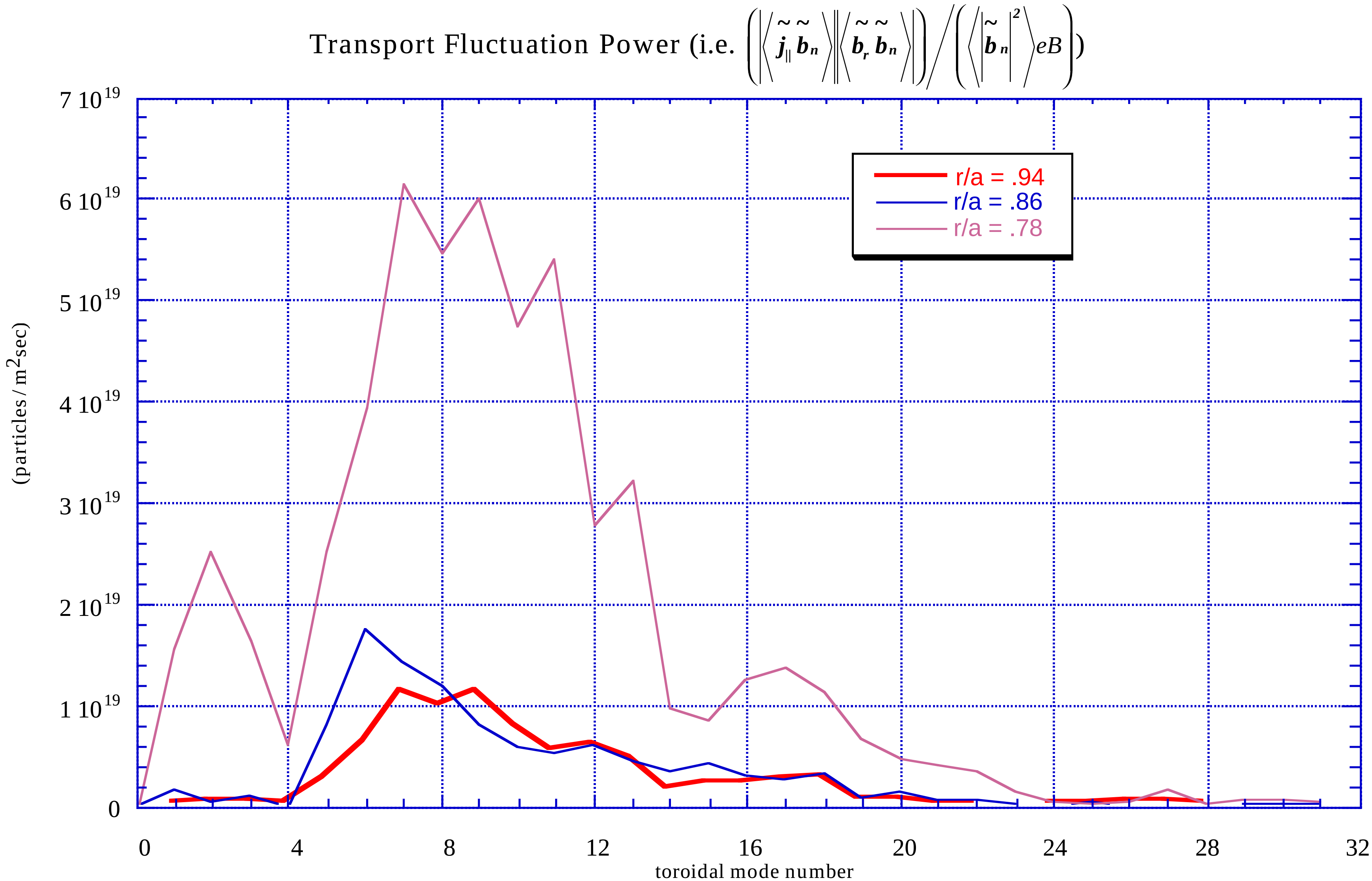
Correlation measurements have been made of point measurements of $\tilde{j}_{\|}$ and $\tilde{b}_r$ inside plasma with toroidal magnetic mode amplitudes measured at plasma surface (i.e. $\left|\left\langle \tilde{j}_{\|} \tilde{b}_n \right\rangle\right| \Big/ \left(\left\langle \left|\tilde{j}_{\|}\right|^2 \right\rangle \left\langle \left|\tilde{b}_n\right|^2 \right\rangle \right)^{1/2}$ and $\left|\left\langle \tilde{b}_r \tilde{b}_n \right\rangle\right| \Big/ \left(\left\langle \left|\tilde{b}_r\right|^2 \right\rangle \left\langle \left|\tilde{b}_n\right|^2 \right\rangle \right)^{1/2}$).

$\tilde{b}_r$ shows significant correlation with modes ranging from n=5 to n≈20 throughout plasma edge. This range includes core resonant modes as well as edge resonant modes.

$\tilde{j}_{\|}$ away from reversal surface (r/a≈.86) shows significant correlation with modes ranging from n=5 to n≈20. Near the reversal surface, it shows poor correlation with most of these modes.

Degree of correlation of $\tilde{j}_{\|}$ and $\tilde{b}_r$ with toroidal modes suggests that a significant part of their power is accounted for by global toroidal modes.

Transport Fluctuation Power vs. n ("$\left(b_{r,n} * j_{\|,n}\right) / (eB)$") Decreases with r/a at All n Between Sawteeth



Relative Spatial Phase of $\tilde{j}_{||}$ and $\tilde{b}_r$ vs. n is close to π/2 where Transport Fluctuation Power is High Between Sawteeth