Alfvén Waves Driven by Neutral Beam Ions In Reverse Magnetic Shear Plasmas on DIII–D

by

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DIII–D
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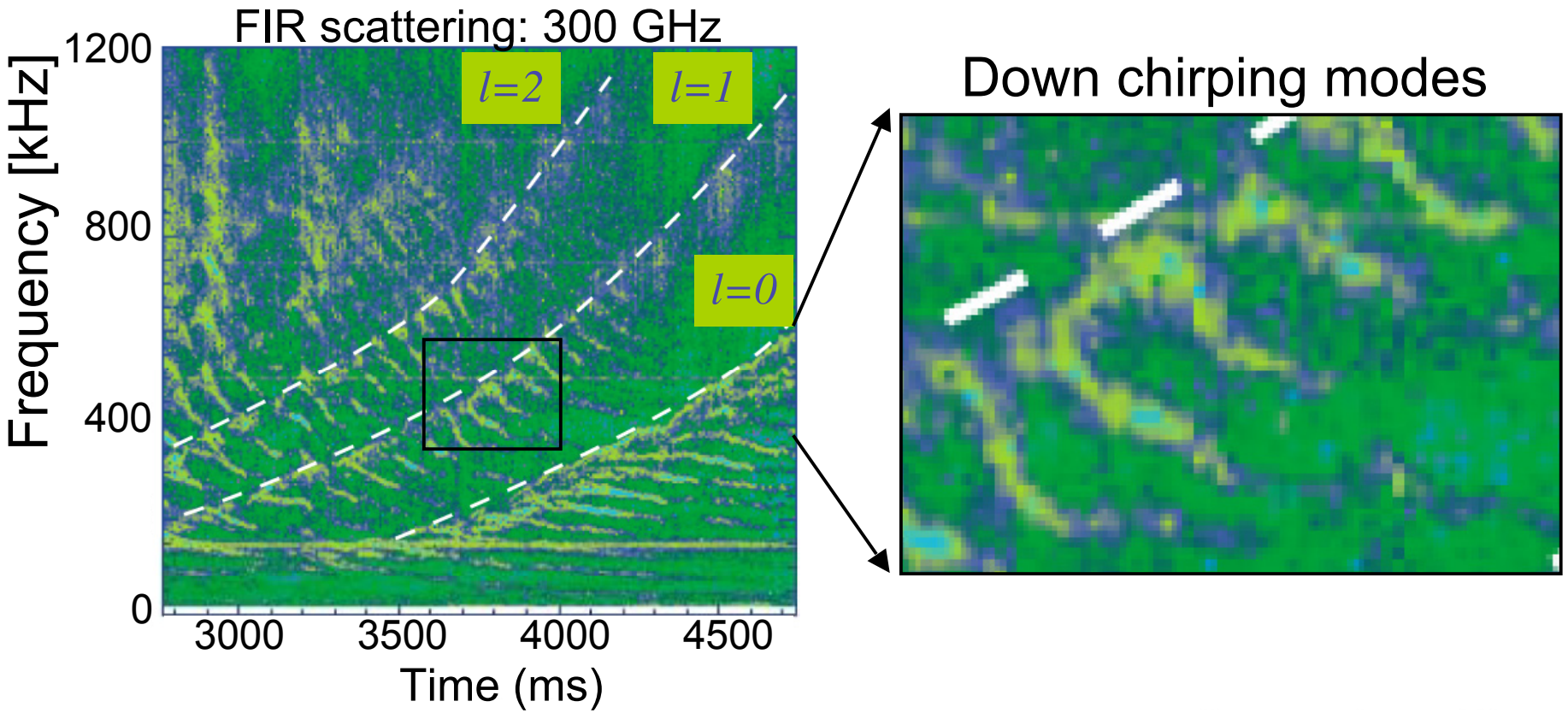
Energetic Particles can Excite Alfvén Waves in a Fusion Plasma Leading to Redistribution and Loss

- Energetic particles are generally well confined in positive shear

- Reverse magnetic shear regimes less well understood
  - *anomalies in neutron emission in TFTR and DIII-D*

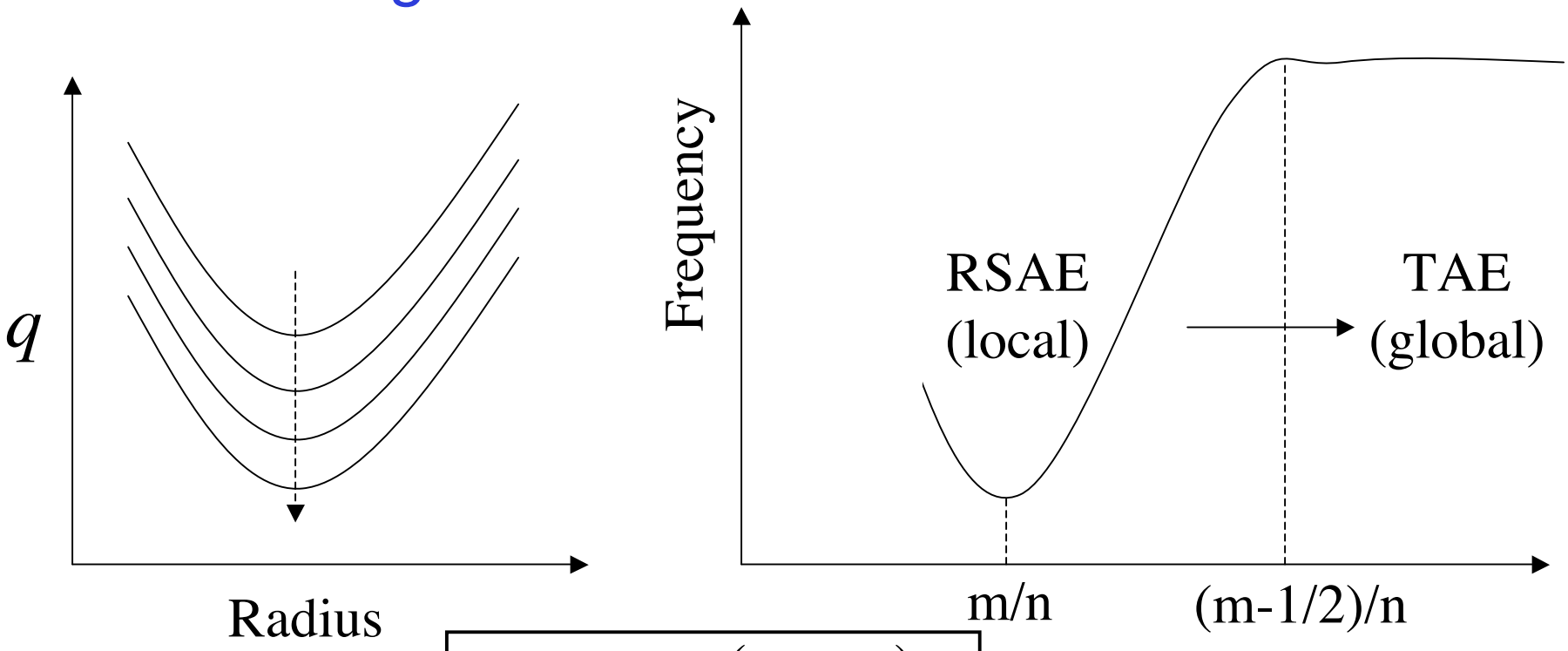
- A "Sea of Alfvén Eigenmodes" discovered in the core of DIII-D
  - *no indication on external magnetic probes*
  - *Doppler shifts indicate high toroidal mode numbers $n \approx 40$!!*
  - *implications for fast ion confinement and transport?*

Many Core Localized Modes Observed in DIII-D Quiescent H-mode Plasmas with Weak Magnetic Shear



- No magnetic signal observed on external probes
- $\Delta\omega=\omega_{rot}$ (CER), each band made up of many modes
- Neutral beam injection opposite to plasma current: $V_{||}\approx 0.3V_A$

New Theory of Alfvén Eigenmodes in Reverse Magnetic Shear Plasmas: RSAE



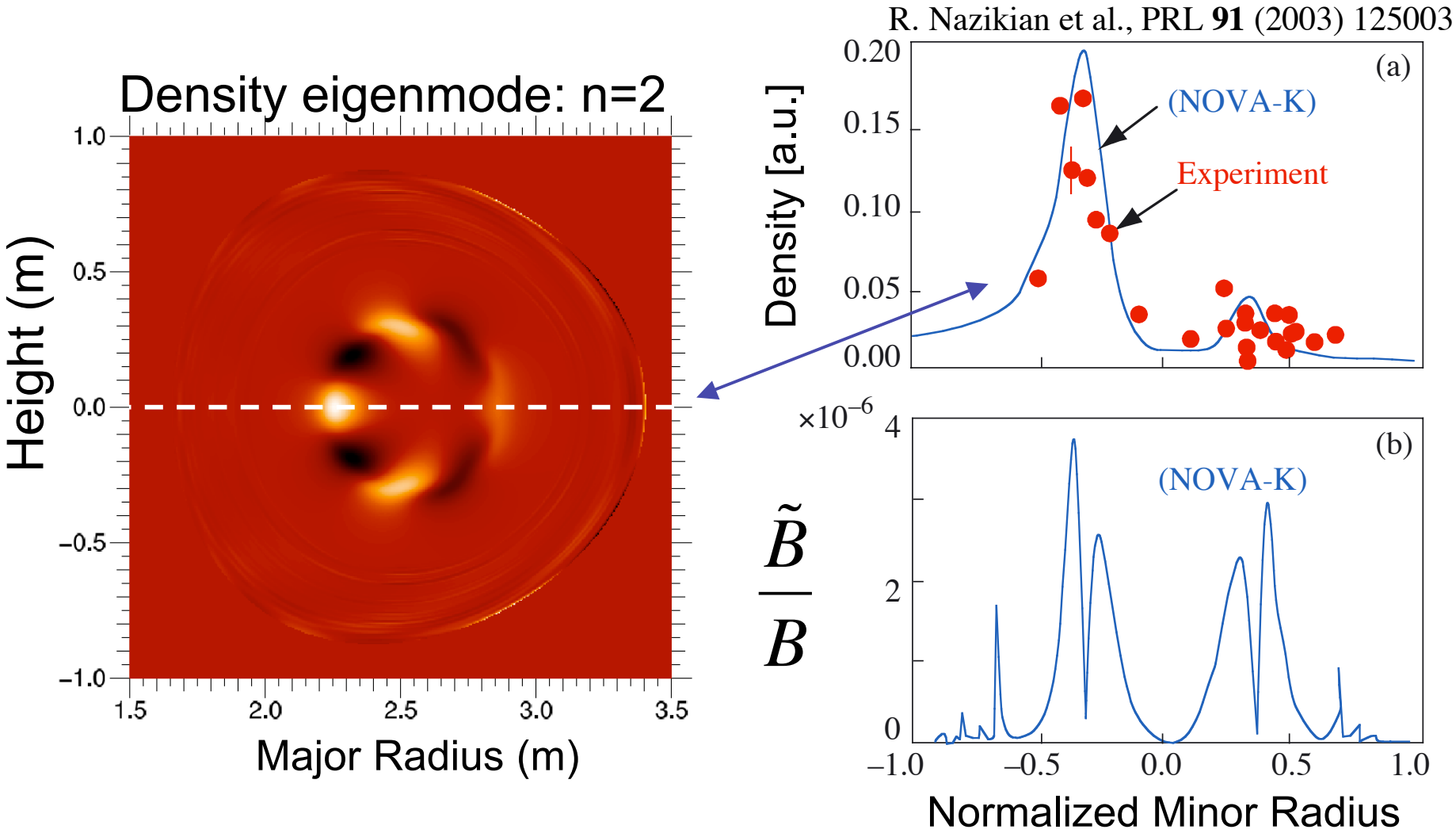
$$\omega_A = k_{\parallel} V_A = \frac{(m - nq)}{qR} V_A$$

- Prediction: Core localization, transition to global TAE
  : Frequency sweep sensitive to q-min

H.L. Berk et al., PRL **87** (2001) 185002

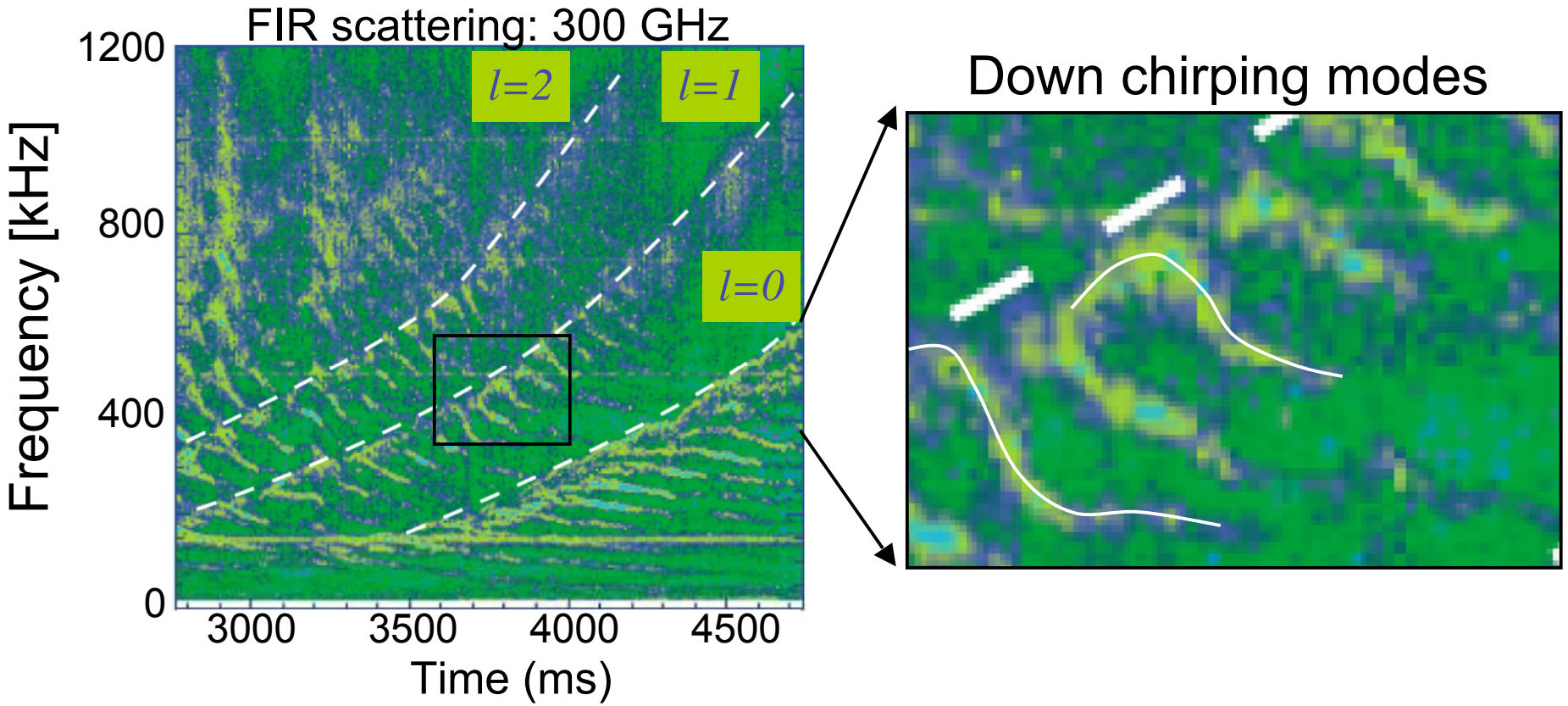
A. Fukuyama et al., IAEA 2002 TH/P3-14

Prediction Confirmed: Core Localization in TFTR DT experiments with Weak Magnetic Shear



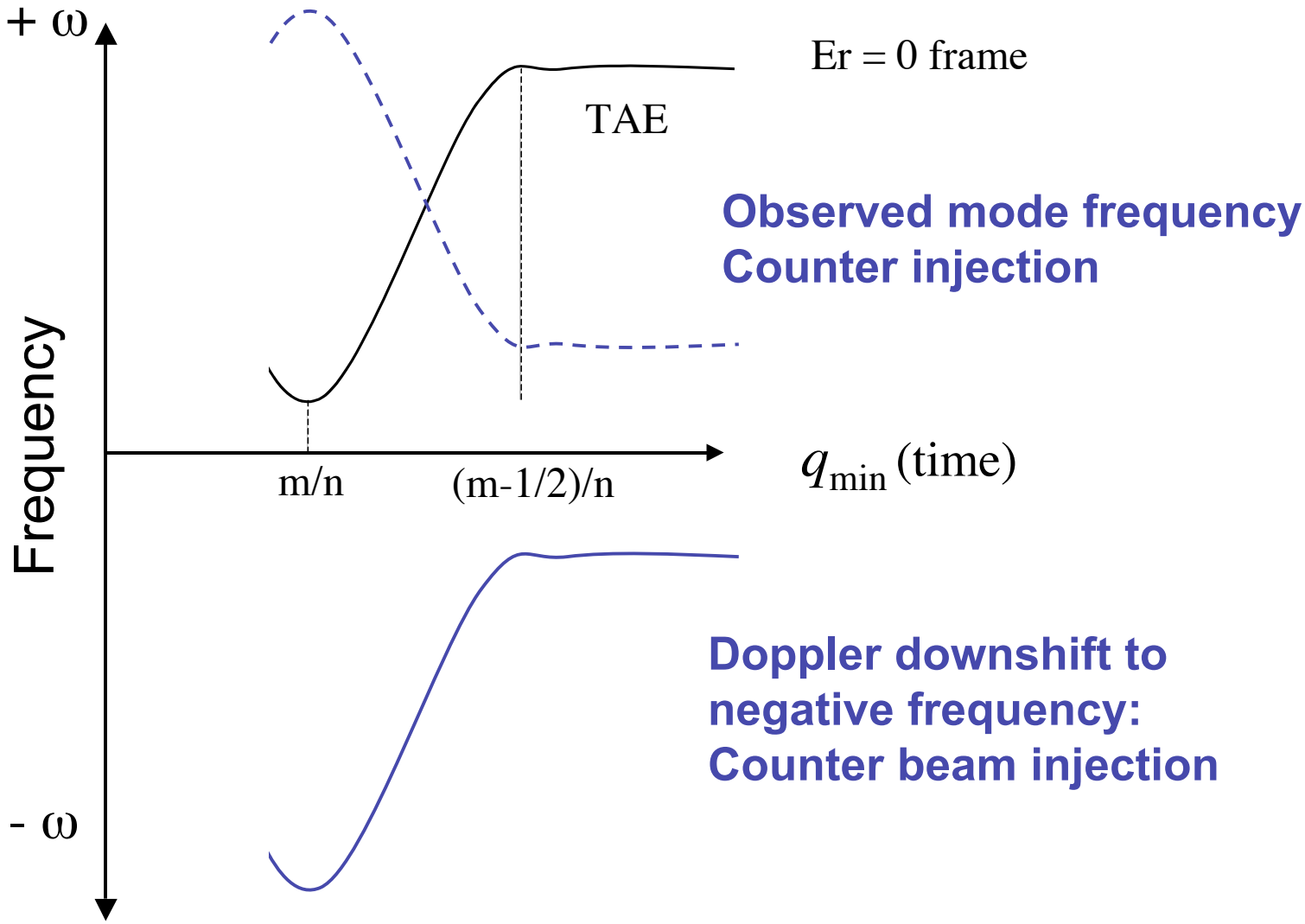
- $\tilde{B}/B \sim 2\times10^{-6}$ No alpha particle loss is observed

What are the bands of Modes on DIII-D?
Why do the individual modes sweep down in frequency?

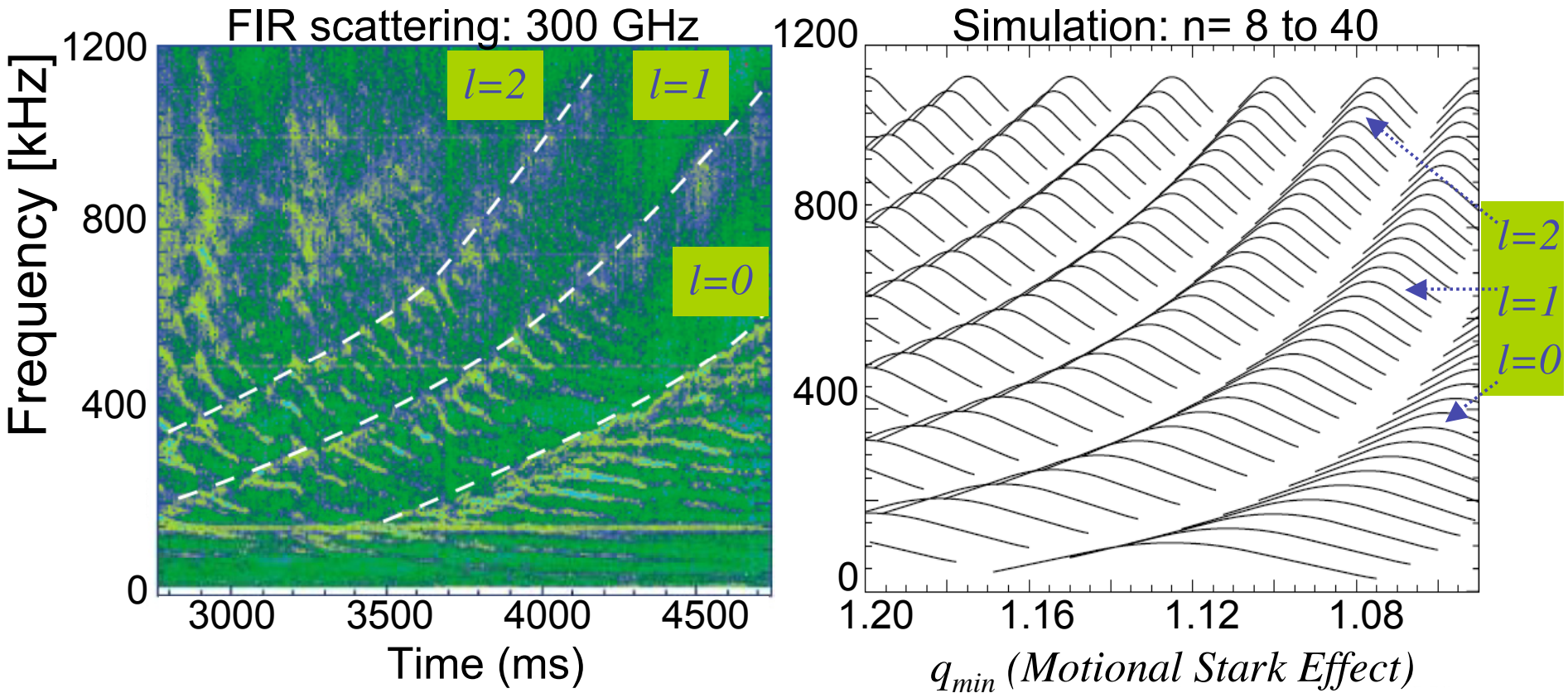


- Counter beam injection makes modes rotate opposite to direction of plasma current in lab frame

Counter beam injection causes frequency sweeping to change direction

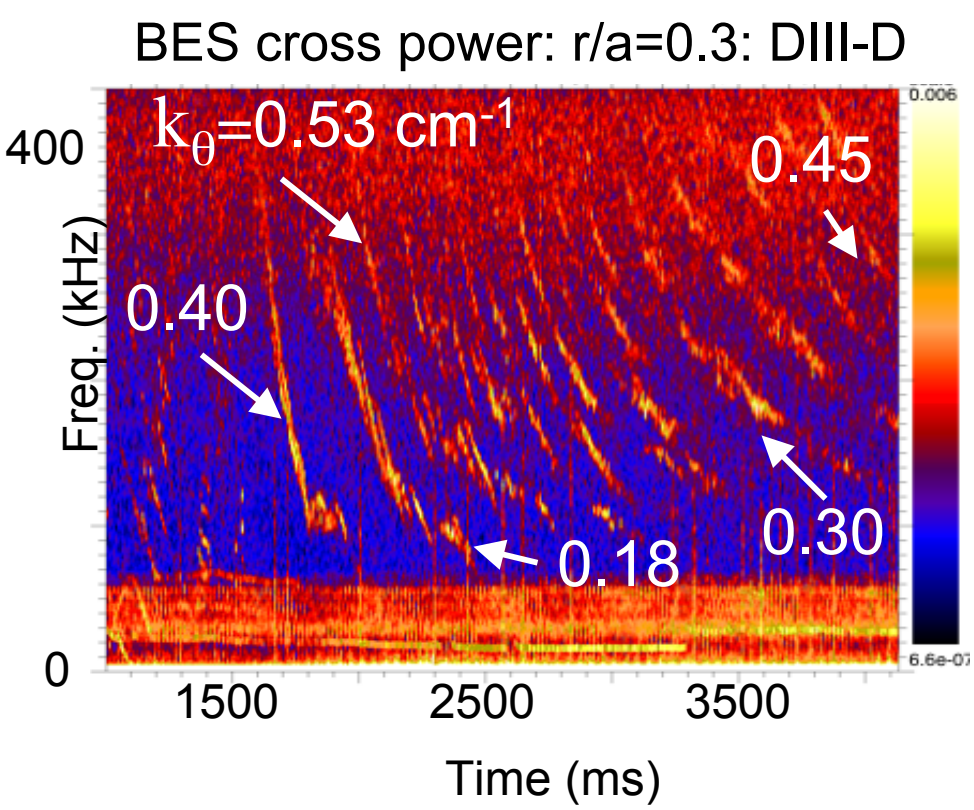


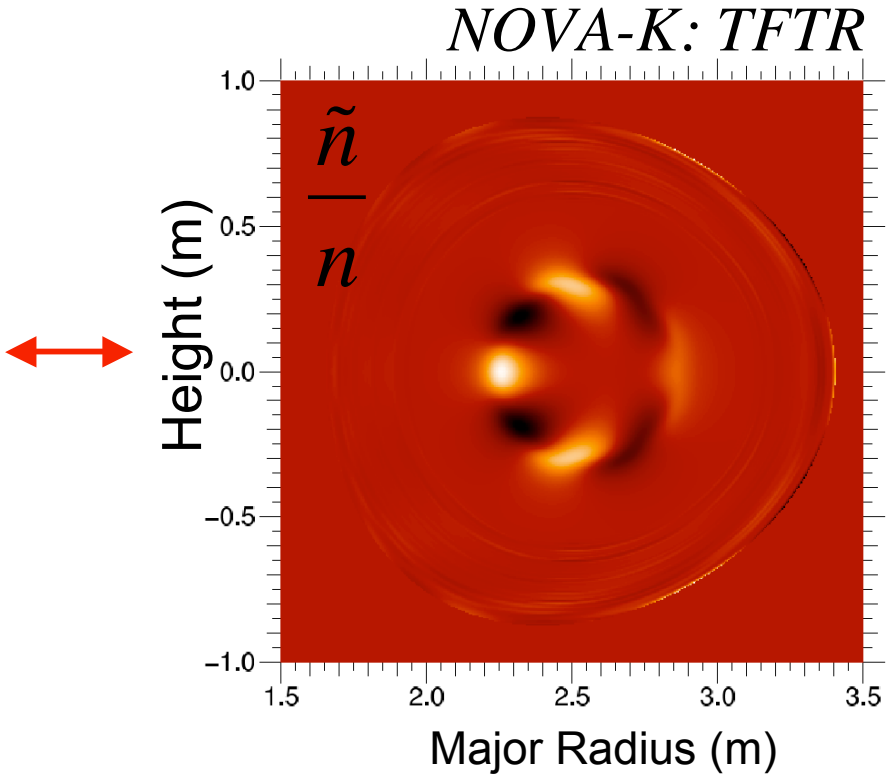
A “Sea of Core Localized Alfvén Eigenmodes” Observed in DIII-D Plasmas Driven by 80 keV Neutral Beams



- Bands of modes $m=n+l$, $l=0, 1, 2, \ldots$: $\omega_{n+1}-\omega_n \approx \omega_{rot}$ (CER)
- Neutral beam injection opposite to plasma current: $V_{||} \approx 0.3 V_A$
- $8 < n < 40$, k_θ up to 2.0 cm^{-1} (Turbulent scale length !!)

Future work: Calculate 2-D Mode Structure and Compare with Measured Poloidal/Radial Patterns





- MSE, CER, BES, FIR,…

A “Sea of Alfvén Eigenmodes” Discovered in Reverse Magnetic Shear Plasmas on DIII-D

- Such a sea of modes is relevant to burning plasma research

  - may affect fast ion confinement, distribution, loss

  - core fluctuation and confined fast ion measurements needed

Future work

- Determine poloidal mode structure
- Analyze high-n stability
- Correlate with fast ion redistribution and loss