Search for Edge Zonal Flows in Alcator C-Mod

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• Motivation
• Methods
• Results
Significance of Zonal Flows

- Zonal flows are m=0 fluid flows, generally with small radial correlation length and low frequency (f < drift waves)

- Zonal flows can reduce energy in drift wave turbulence, and so reduce turbulent radial transport (in theory)

Free Energy Source, \(\text{grad } T, \text{grad } n\)

- Drift Waves
- Wave Dissipation
- Zonal Flows
- Flow Energy Dissipation (i.e., Collisional Friction)

Theory review - Diamond et al, PPCF ’05
Experimental review – Fujisawa NF ’09
Drift wave review - Tynan et al PPCF ‘09
Edge Turbulence Imaging in Alcator C-Mod

- Gas puff imaging diagnostic using $D_2$ puff in field of view
- Viewing area along $B \sim 6$ cm radially x 6 cm poloidally
- Camera imaging 64x64 pixels at 400,000 frames/sec
Method to Evaluate Turbulence Velocity

- Use 2-D cross-correlation to find $V_{\text{pol}}$ of turbulence in $\sim 25 \mu s$
- Average $V_{\text{pol}}$ over poloidal field of view ($\sim 5$ correlation lengths)
- Assume $V_{\text{pol}}$ of turbulence is the same as poloidal ExB flow velocity (as in BES in DIII-D, Doppler reflectometry in AUG)
Poloidal Velocity Frequency Spectra

- For some ICRF cases see coherent mode at ~6-7 kHz
- More often broadband, intermittent spectra ~1-20 kHz
Radial Profile of Poloidal Velocity Spectra

• Spectra of coherent mode extends over $-1.5 \, \text{cm} < \rho \leq 1.0 \, \text{cm}$
• Spectrum of broadband features within $\pm 1 \, \text{cm}$ of separatrix

coherent mode with ICRF

broadband intermittent flow
Correlation with Magnetic Fluctuations

- Coherent $V_{pol}$ mode is correlated with B-dot from coils
- This magnetic mode seems to have $n=0$ like zonal flow
Poloidal Velocity Fluctuations vs. Density

- Magnitude of poloidal velocity fluctuations does not vary in a simple way with line-averaged density, $B$, or power

- But radial correlation width of $V_{pol}$ decreases with density
Poloidal Velocity at L-H Transition

- Coherent mode in $V_{pol}$ disappears at L-H transition at all radii, at least in the one shot obtained so far.

![Graph showing spectrum of $V_{pol}$ just inside separatrix just before L-H transition.](image)
Theoretical GAM Frequency for C-Mod

- From a fit to GAM eigenfrequency for various plasma shapes
  \[ f = G \frac{c_s}{\pi R} \] with \( R = R_o + r \), and \( c_s = \left[ \frac{\gamma(T_i+T_e)}{m_i} \right]^{1/2} \)
  where \( G \sim (2^{-1/2}) \frac{2}{(1+\kappa)} \) \( (1+1/(2A^{2/3}) (1+1/(4q^2)) \)

- For C-Mod \( A=3, \kappa=1.6, q=3, T_e=T_i=50 \text{ eV}, \gamma=4/3 \) and \( m_i=2 \)
  \[ \Rightarrow \quad f_{\text{GAM}} \sim 20 \text{ kHz} \]

- But radial profile of observed oscillation does not follow the radial profile of \( T_e^{1/2} \) within \( \rho = \pm 0.5 \text{ cm} \) \( (T_e \sim 35-350 \text{ eV}) \)
Summary of C-Mod Results

- Coherent zonal-like flows or GAMs at ~6-7 kHz seen in edge of some ICRF shots, with correlated magnetic fluctuations
- More commonly, see broadband, intermittent poloidal velocity fluctuations with radial correlation decreasing with density
- Coherent velocity fluctuations disappear at the L-H transition

Experiments next year will investigate whether the coherent mode is related to ICRF-driven “E-GAMs”