Similarity of Edge Turbulence in Various Configurations of HSX

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Overview

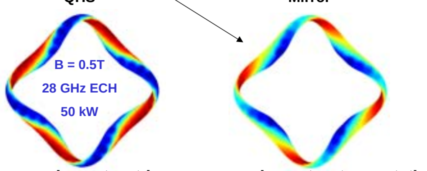
- Turbulence measurements at the edge are very similar between the quasi-symmetric and non-symmetric configurations, including:
  - Fluctuation levels and spectra
  - Correlation lengths and times
  - Growth rates inferred from bispectral analysis
- Many of the turbulence features are consistent with electron drift waves, including:
  - Mode velocities
  - Correlation time scales on order of linear growth rates
  - n-φ cross-phases
- Inward turbulent transport is measured at low density where E×B shear rates are larger than at high density

Experimental Details

•HSX has a helical axis of symmetry in |B| and a resulting predicted very low level of neoclassical transport

•For experimental flexibility, the quasi-helical symmetry can be broken by adding a mirror field

QHS | Mirror

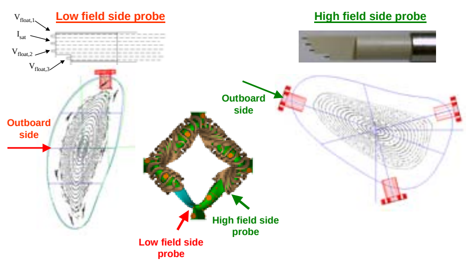


$B = B_0[1 - \varepsilon_h \cos(N - m\phi)]$ | $B = B_0[1 - \varepsilon_h \cos(N - m\phi) + \varepsilon_M \cos(N\phi)]$

•To verify improved neoclassical transport, anomalous transport will have to be accounted for between configurations with and without quasi-symmetry

Langmuir Probes Used to Measure Edge Plasma

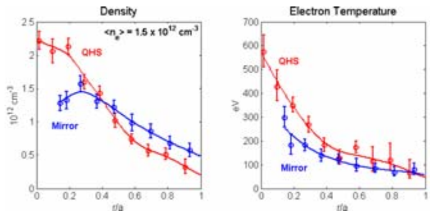
- Ion saturation current and floating potential measurements are acquired at two different toroidal locations
- Two probes in regions of bad & good curvature (low field and high field regions)
- Tungsten tips separated ~3 mm poloidally
- Can infer k_θ, n-φ cross phase ⇒ $\Gamma = k_\theta |B| |N| |\Phi| \sin(\alpha_{n\text{-}\varphi})$



Edge Turbulence is Similar in Quasi-Symmetric and Non-symmetric configurations

ECRH Plasmas Produce Low Collisionality Electrons

•Profiles from Thomson scattering for central resonance heating
•$T_i \approx 25$ eV from Doppler spectroscopy

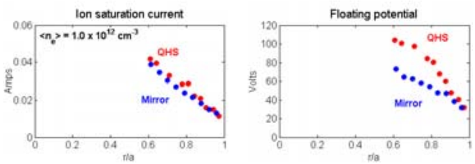


QHS Parameters

$$\nu_{*e} = \frac{\nu_e}{\varepsilon_h^{3/2} v_{Te}/q_{eff}R} \sim 0.1 \qquad \langle\beta_e\rangle \approx \frac{1}{4500} < \frac{m_e}{m_H} < \beta_e(0) \approx \frac{1}{500}$$

•Electron thermal diffusivities in quasi-symmetric and non-symmetric configurations are similar at the edge, ~10 m²/s (see poster by J. Canik).

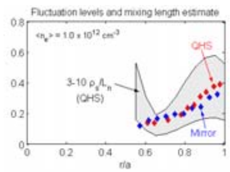
Mean Edge Profiles



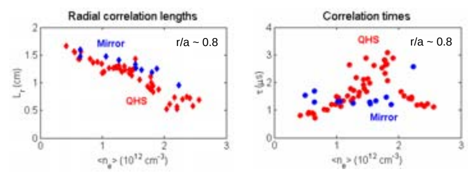
Comparable Fluctuation Intensity, Correlation Lengths & Times

•Fluctuation levels (from ion saturation current) at the edge are same in QHS and Mirror – similar to mixing length estimates (3-10 ρ_s/L_n)

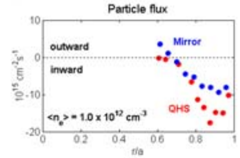
•With $T_e \approx 40$ eV $\quad \frac{\tilde{n}}{n} \approx \frac{\tilde{\varphi}}{T_e}$



•Correlation lengths ($L_r \approx k_\theta^{-1}$) and times are similar over a range of densities.
•$k_\theta\rho_s \approx 0.15$
•Turbulent diffusivities (L_r^2/τ) are ~ 20 m²/s at high density – on the order of local transport analysis at the edge

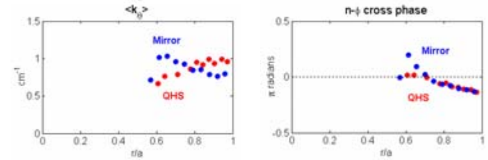


Measured Particle Flux is Directed Inward

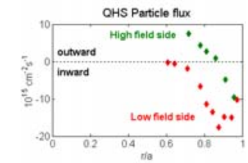


•At this density, resulting turbulent driven particle flux is inward

•Spectrum-averaged poloidal wavenumber and n-φ cross-phase are very similar between configurations



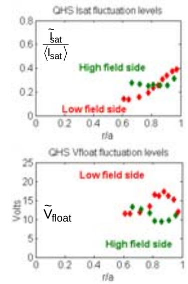
Inward Transport Measured at Two Toroidal Locations



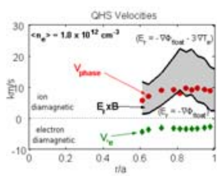
•Transport is inward directed near the separatrix at both low field and high field toroidal locations

•I_{sat} fluctuation levels are similar at the far edge (r/a = 0.8 – 1.0)

•Floating potential fluctuations at the high field side are as low as ~50% those at low field side



Many Features Consistent with Electron Drift Waves

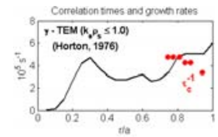


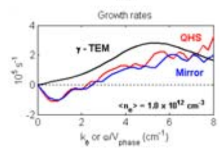
•With ∇T_e estimate included, mode velocity ($V_{phase} - V_{E\times B}$) is in electron diamagnetic drift direction

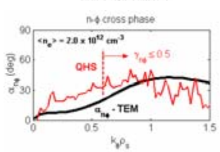
•Inverse correlation times comparable to maximum linear growth rates predicted for axisymmetric TEM (Horton, 1976)

•Growth rate spectra determined from bispectral analysis (Kim et al., 1996) comparable to TEM linear growth rates

•At higher density ($\langle n_e \rangle = 2.0 \times 10^{12}$ cm⁻³) measured cross phase slightly larger than linear TEM theory

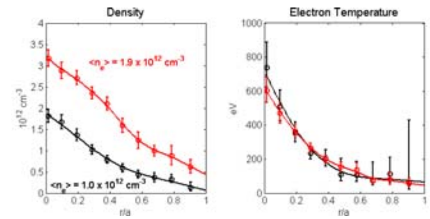




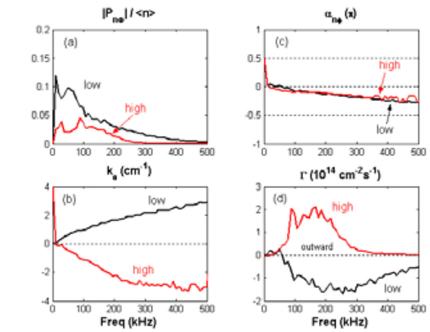


Outward Transport Measured at High Density

Profiles at Two Densities are Similar



Turbulence Characteristics are Similar But Opposite Sign of k_θ-$\alpha_{n\varphi}$ ⇒ Γ



•n-φ cross phase remains the same

•Poloidal wavenumber similar in magnitude, but negative due to reversed phase velocity

•There is also evidence for significant super-thermal electrons at low density (see poster by A. Abdou)

Shear Rates Are Larger at Low Density

•Floating potential profiles change significantly with density

•E_r×B shear rate, ω_E, calculated for quasi-symmetric geometry (Hahm, 1997) using floating potential, are larger at low density

•Inward edge transport measured in CHS and H-1 with significant E_r shear, $L_r\omega_E$ > V_{phase} (Shats, 2000).

Assume Isotropic

$$\omega_E = \frac{\mathbf{k}_\perp}{k_\psi} \frac{|\nabla\psi||\mathbf{B}\times\nabla\psi|}{B^2} \times \left|(\iota - N)\frac{\partial}{\partial\psi}\left[\frac{1}{(\iota - N)}\frac{\partial}{\partial\psi}\Phi_0(\psi)\right]\right|$$