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Role of avalanche transport in competing drift wave and interchange turbulence

Philippe GHENDRIH, Guilhem DIF-PRADALIER, Olivier PANICO, Yanick SARAZIN, Hugo Bufferand, Guido CIRAULO, Peter DONNEL, Nicolas FEDORCZAK, Xavier GARBET, Virginie GRANDGIRARD, Pascale HENNEQUIN, Eric SERRE, Patrick TAMAIN

Abstract. We complete the 2D 2-fields turbulence model previously used with an interchange-like instability by slightly modifying the parallel loss terms to drive drift wave instabilities. We show that the instability driven by temperature fluctuations of the sheath losses is identical to that of the drift wave turbulence. The linear analysis is performed and used to select control parameters that yield identical maximum growth rates for the interchange alone and drift wave alone instability. Combining the two instabilities doubles the maximum growth rate. The non-linear simulations are used to analyse the SOL width. The simulations allow one to identify a low field side SOL region where interchange and drift wave are unstable and a high field side SOL region where only the drift wave is unstable. The SOL profiles appear exponential in the region close to the source but depart from a simple exponential fall-off in the far SOL. The low field side SOL width is found to be larger in the interchange alone case, slightly smaller when both instabilities are present and finally narrower when only the drift waves. For the high field side SOL, without interchange, the drift wave SOL width is observed to be identical to that on the low field side and larger than that when both instabilities are at play. The Sherwood dimensionless parameter, ratio of convective particle flux divided by the diffusive particle flux, is used to compare the efficiency of turbulent transport. The profiles of the Sherwood parameter for time and flux surface averaged transport indicate that turbulent transport is dominant close to the separatrix but is less effective towards the far SOL. The Sherwood parameter evolution, determined with the flux-surface averaged transport, indicates that outward avalanche transport with corrugations governs the case with interchange only. When combining the two instabilities, outward avalanche transport is less pronounced and inward avalanche transport is observed, reducing the overall turbulent transport efficiency. The interchange transport with drift waves only compared to interchange only is found to be inhibited.

2 fields:
density n / vorticity W
or
Thermal energy / vorticity
2D slab
radial x , poloidal y

$$\partial_t n + B \left[\phi, \frac{n}{B^2} \right] + \frac{B}{e} \left[\frac{1}{B^2}, p_e \right] - D_{\perp} \nabla_{\perp}^2 n = S_n - \nabla_{\parallel} \Gamma_{\parallel}$$

$$\partial_t W + \frac{1}{B} \left[\phi, W \right] + \frac{B}{n} \left[\frac{1}{B^2}, p_e \right] - \nu_{\perp} \nabla_{\perp}^2 W = \frac{1}{n} \nabla_{\parallel} J_{\parallel}$$

$$\partial_t n + \frac{1}{L_n} \partial_y \phi + \left[\phi, n \right] - D_{\perp} \nabla_{\perp}^2 n = S_n - \sigma_n n + \bar{\sigma}_n \phi$$

$$\partial_t W + g \partial_y n + \left[\phi, W \right] - \nu_{\perp} \nabla_{\perp}^2 W = -\bar{\sigma}_n n + \sigma_{\phi} \phi$$

Buoyancy effect for W (small for n) $\Rightarrow g$ term
Parallel loss terms: linearised

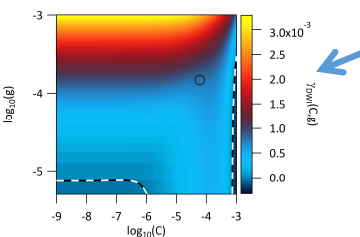
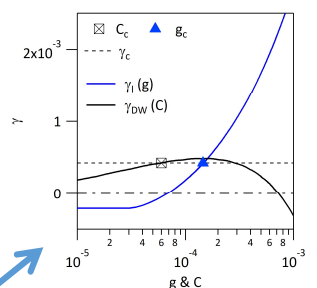
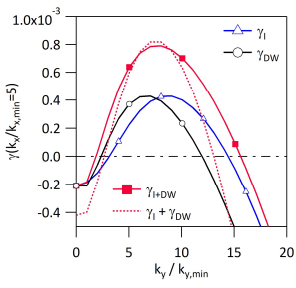
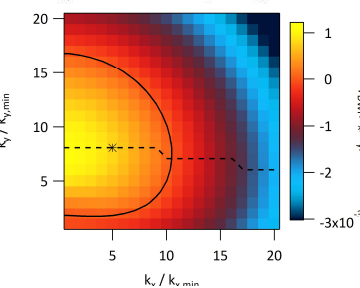
Dispersion relation (linearised & Fourier space)

$$\gamma \hat{n} + \frac{ik_y}{L_n} \hat{\phi} + D_{\perp} k^2 \hat{n} = -\sigma_n \hat{n} + \bar{\sigma}_n \hat{\phi}$$

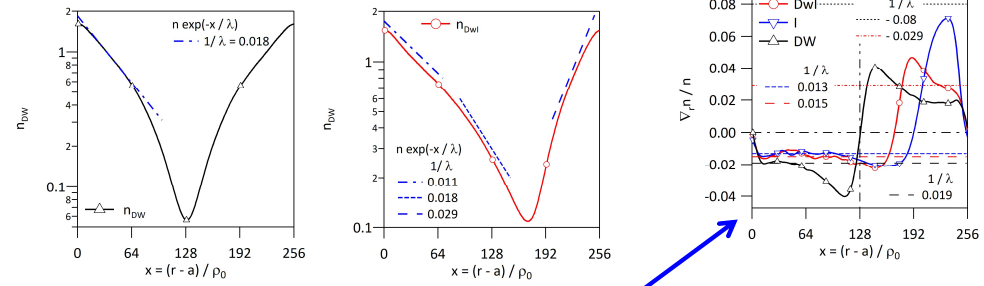
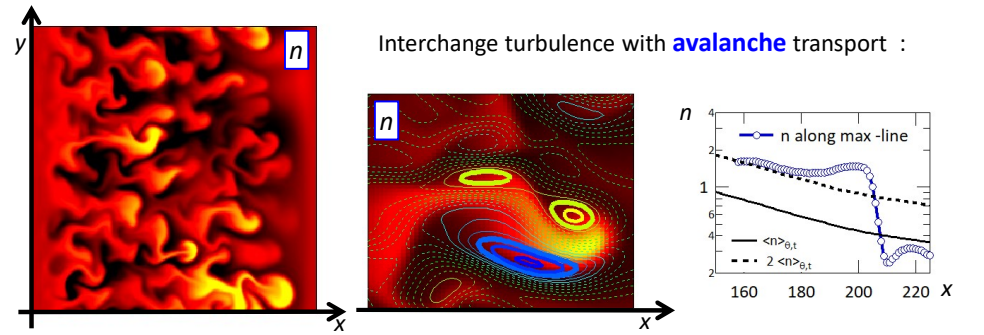
$$(\gamma + A_n)(\gamma + A_{\phi}) - B_n B_{\phi} = 0$$

$$\gamma \hat{\phi} - i \frac{ky}{k^2} g \hat{n} + \nu_{\perp} k^2 \hat{\phi} = -\frac{\sigma_{\phi}}{k^2} \hat{\phi} + \frac{\bar{\sigma}_{\phi}}{k^2} \hat{n}$$

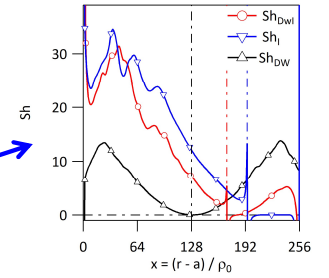
Damping: $A_n = Dk^2 + \sigma_n$ $A_{\phi} = \nu k^2 + \frac{\sigma_{\phi}}{k^2}$
Coupling: $B_n = ik_y \frac{1}{L_n} - \bar{\sigma}_n$ $B_{\phi} = -ig \frac{k_y}{k^2} - \frac{\bar{\sigma}_{\phi}}{k^2}$



What value for k_x ?
Maximum of $\gamma(k_x, k_y)$ $k_x \geq 5$
Interchange: $g \neq 0, \sigma_n = \sigma_{\phi} \neq 0, \bar{\sigma}_n = \bar{\sigma}_{\phi} = 0$
Drift wave: $g = 0, \sigma_n = \sigma_{\phi} = \bar{\sigma}_n = \bar{\sigma}_{\phi} = C \neq 0$



SOL profile, exponential fall-off (?)
High field and Low field side
SOL width = e-folding length
 $\lambda_1 > \lambda_{Dwl} \gg \lambda_{DW}$
Competing instability mechanisms
Competing convective/diffusive
Sherwood number



Sherwood number (Nusselt for particles):

$$Sh = \frac{\Gamma_{turb}}{\Gamma_{diff}}$$

$$\Gamma_{diff} = \langle -D_{\perp} \nabla_{\perp} n \rangle$$

$$\Gamma_{turb} = \langle n v_E \cdot \hat{r} \rangle$$

average = y (flux surface)
average = y & t

$l =$ avalanches
 $l =$ corrugations
 $l + DW$: less avalanches
 DW : even less

Same ballistic velocity:
 $\approx 5 \rho_* c_s$

