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Impact of plasma flow velocity shear and neutrals on edge plasma instabilities

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Whereas it is widely believed that velocity shear could suppress plasma instabilities and stimulate the transition from low (L-) to high (H-) confinement modes, the underlying physics of plasma instability suppression is still not clear. Often it is assumed that the stabilization of plasma instability characterized by the growth rate γ_{inst} occurs when by the velocity shear $|V_0'|$ exceeds γ_{inst} (e.g. see Refs. 1, 2). One of the complications of the analysis of the velocity shear effect on plasma instabilities is the non-Hermitian nature of the differential equations describing an impact of velocity shear on plasma/fluid instabilities [3]. However, we find that the situation is more complex and just effective Richardson number $Ri = (\gamma_{inst}/|V_0'|)^2$ cannot describe overall impact of $|V_0'|$. Employing radial” density profile $n(x) = \bar{n} + (\delta n/2) tanh(x/w)$ (where w is the effective width of the density profile and $\bar{n} \gg \delta n$ are some constants) and analyzing the localized modes, we find [4] that for $\kappa = |k_y w| \gg 1$ (k_y is thepoloidal” wave number) the growth rates of both fluid Rayleigh-Taylor (RT) and plasma interchange (I) modes could be significantly reduced even for $Ri \gg 1$ (see Fig. 1a).

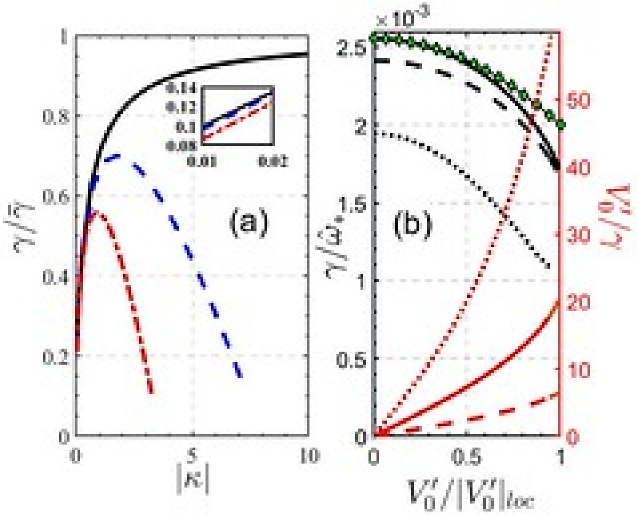

Figure 1: The growth rate of the most unstable I mode. a) The curves of solid black, dashed blue, dash-dot red are for $|V_0'|/\bar{\gamma} = 0, 0.2$, and 0.4. b) The growth rate and $|V_0'|/\gamma_{inst}$ of the most unstable RDW mode. The solid, doted, and dashed are for $k_y\rho_s = 0.5, 0.3$, and 1.

On the contrary, the resistive drift waves (RDW) are not stabilized even for $Ri \ll 1$ (see Fig. 1b, where $\hat{\omega}_* = k_y \rho_s C_s / L_n$, $\nu_\| / \hat{\omega}_* = 50$, $\nu_\| = k_z^2 T_e / m\nu_{ei}$ is the effective parallel electron diffusion frequency, and $w/\rho_s = 30$). However, the localized RDW modes cease to exist at $|V_0'| > |V_0'|_{loc} \approx 0.66(1 + k_y^2\rho_s^2)^{-1}(\rho_s/w)C_s/L_n$. In addition, we find that, whereas the eddies of both RT and I modes in the presence of $|V_0'|$ become tilted into y-direction, Fig. 2a, those of the RDW become just shifted into radial direction, Fig. 2b, The results of numerical analysis of non-modal solutions of the RDW for $|V_0'| > |V_0'|_{loc}$ will be presented.

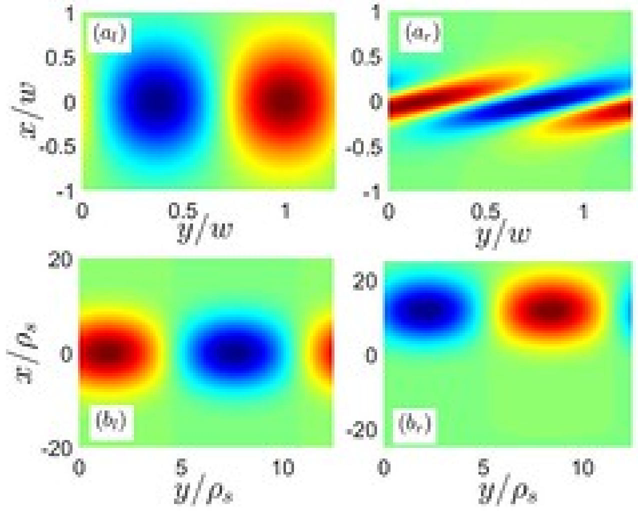

Figure 2: Eddies of a) the I mode and b) the RDW mode w/o (left) and with (right) velocity shear.

Unlike the effect of velocity shear, the results of the studies of an impact of neutrals on edge plasma instabilities and turbulence are somewhat controversial. Whereas some experiments show no effect of neutrals on edge plasma turbulence, others demonstrate an importance of neutrals for L- to H-mode transition (e.g. see Refs. 5, 6). Similarly, whereas some simulations show that neutrals result in increasing edge plasma turbulence, some others claim opposite effect (e.g. see Refs. 7, 8). One of the complexities of the incorporation of neutral effects into plasma instabilities, turbulence, and transport is the wide range of neutral-plasma interaction regimes (from kinetic to fluid) defined by the ratio of the wave length (frequency) of different plasma modes to neutral-ion collision mean free path (neutral-ion collision frequency).
We report here the results of a careful analysis of the effect of neutrals (ranging from kinetic to fluid transport regimes) on interchange, RDW, and grad(T_e) instabilities [9] and find that in practice neutral make a very minor impact on these instabilities, although in dense divertor plasma an impact of neutrals on plasma stability could be important (see Ref. 10 and the refernces therein). However, we find that neutrals can significantly alter the generation of zonal flow by plasma turbulence (e.g. by DW turbulence [11]) and by that modify edge plasma turbulence and transport.

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