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Comment on "The universal instability in general geometry" [Phys. Plasmas 22, 090706 (2015)]

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It is pointed out that the destabilization mechanism recently discussed by Helander and Plunk in relation to the universal instability was studied previously by Smolyakov *et al.* [Phys. Rev. Lett. **89**, 125005 (2002)]. Moreover, the contribution of the trapped particles as discussed by Helander and Plunk is closely related to the mechanism of the ubiquitous instability previously studied by Coppi and Pegoraro [Nucl. Fusion **17**, 969 (1977)]. *Published by AIP Publishing.*
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Recently, the discussion of the so called universal instability has re-emerged[1–3] in relation to the numerical simulations[2] that show the existence of the short wavelength instability driven by density gradient. Analytical arguments presented in Ref. 1 show that the mode requires a relatively large value of $k_\perp \rho_i$ parameter and is driven by the resonant response of passing electrons with $\omega \ll k_{||} v_{Te}$, and, in general, does not require temperature gradients. We would like to point out that this mechanism was studied previously in Ref. 4. It was shown in Ref. 4 that the nature of the unstable short wavelength mode is related to the specific response of the perturbed ion density which remains non-adiabatic in the limit of large $k_\perp \rho_i$. In general expression for the perturbed ion density

$$\tilde{n} = -e\phi/T_i + \left(1 - \frac{\omega_*}{\omega}\right)\Gamma_0\left(k_\perp^2 \rho_i^2\right)\frac{e\phi}{T_i}, \qquad (1)$$

the ratio

$$\omega_* \Gamma_0\left(k_\perp^2 \rho_i^2\right) \sim \frac{k_y}{\sqrt{k_\perp^2 \rho_i^2}} \rightarrow const \qquad (2)$$

remains finite in the limit $k_\perp \rho_i \gg 1$, as is shown in Eq. (3) of Ref. 4. This ion density response together with non-adiabatic contribution of passing electrons, shown in Eq. (5) of Ref. 4, result in the dispersion equation given by Eq. (6) of Ref. 4. The last three terms in this dispersion equation exactly reproduce the dispersion relation in Ref. 1, namely, the third equation without number after Eq. (6) in Ref. 1. The first term in the dispersion equation (6) of Ref. 4 describes the effects of ion parallel motion that are discussed in the Appendix of Ref. 1. The approximate dispersion equation from Eq. (6) agrees very well[4] with the full kinetic dispersion in the shearless local limit and $k_\perp \rho_i \geq 1$.

The effects of the magnetic shear and toroidal geometry on the ion short wavelength mode were also studied in Ref. 4 with nonlocal differential equation. This analysis was further confirmed and extended within the nonlocal integral equation solutions in sheared slab[5] and tokamak geometry.[6,7] These works presented detailed analysis of the eigen-mode structure of the short wavelength instabilities in the $k_\perp \rho_i \geq 1$ regime.

It is worth noting that the non-adiabatic nature of the ion response for $k_\perp \rho_i \geq 1$, which is essential for the modes studied in Refs. 4, is a crucial element for the ubiquitous mode instability driven by trapped electrons.[8] The authors of Ref. 1 note that the trapped particle contribution may also result in the instability. The latter is a mechanism for the ubiquitous mode.[8]

In summary, a large body of previous work has identified a class of the instabilities in the short wavelength regime $k_\perp \rho_i \geq 1$. These modes, the universal instability, the ubiquitous mode, and short wavelength temperature gradient mode share some essential common physics and may involve several mechanisms of destabilization: non-adiabatic ion response, resonant passing electrons and trapped particles. We also note that sub-Larmor scales instabilities for modes with non-zero ballooning angle were also investigated in Refs. 9 and 10. The instabilities in the intermediate region between standard ion-temperature-gradient (ITG) and electron-temperature-gradient (ETG) modes may be important for the problem of anomalous electron transport and may also result in the synergetic coupling of the electron and ion transport.

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