Response to Comment on "The universal instability in general geometry" by P. Helander and G. G. Plunk, Physics of Plasmas 22, 090706 (2015)

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In response to a comment[1], we discuss similarities and differences between the universal instability, the ubiquitous mode, and the short-wavelength ion-temperature-gradient (SWITG) mode. Unlike the SWITG mode, the universal instability does not require a temperature gradient, and in contrast to the ubiquitous mode, electron trapping plays no role.

In the comment[1], it is stated that the so-called universal instability studied in our paper[2] was actually described previously in an article[3] written by the authors of the comment. We agree that there are certain commonalities in the discussed derivations – for instance, we agree that the treatment of the ion response at $k_\perp \rho_i > 1$ is a common feature. However, we point out that there are also key differences that distinguish the universal mode from the short-wavelength ion-temperature-gradient (SWITG) mode found in Ref. 3, and also from the similarly named "ubiquitous mode".

The universal instability is destabilized by the passing electron Landau resonance, and, crucially, exists in the *absence* of temperature gradients, which is why it is called "universal". Eqn. (6) of Ref. 3 includes the effect of the electron resonance, but this result applies only to unsheared slab geometry, and the existence of this instability in unsheared slab geometry has not been called into question over the course of a long historical debate. (A similar equation is given in our paper, also corresponding to the unsheared slab, but is meant only to help introduce the problem, and is not intended to be taken as a new result.) It is in *sheared* magnetic geometries that the universal instability long proved elusive, and this is the main topic of our paper. We note that the nonlocal analysis of Ref. 3, which includes magnetic shear, actually excludes the parallel electron resonance, and so cannot describe the universal instability.

Another important aspect of our work is that it considers general magnetic configurations, *i.e.* stellarator geometries, which is a significant departure from previous works on the topic, including those cited in the comment.

Several other papers mentioned in the comment[4–6] investigated (by numerical methods) a more complete gyrokinetic integral equation, which in principle contains all the effects necessary to capture the universal mode in sheared-slab or tokamak geometries. However, none of these papers found such a mode, *i.e.* one driven only by a density gradient. In fact, these three papers all state the necessity of finite temperature gradient for what they therefore label as the SWITG mode.

Finally, the authors of the comment reference the ubiquitous mode[7], which also exists at wavenumbers $k_\perp \rho_i \gtrsim 1$. This mode, however, requires a trapped electron population with a magnetic drift resonance. It is therefore distinct from the universal instability.

REFERENCES

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