# The universal instability in optimised stellarators

P. Costello[1], J.H.E. Proll[2], G.G Plunk[1] M.J Pueschel[2,3,4]

[1] *Max-Planck-Institut für Plasmaphysik, Wendelsteinstraße 1, 17491 Greifswald, Germany*

[2] *Science and Technology of Nuclear Fusion, Department of Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands*

[3] *Dutch Institute for Fundamental Energy Research, 5612 AJ Eindhoven, The Netherlands*

[4] *Institute for Fusion Studies, The University of Texas at Austin, Austin, Texas 78712, USA*

**Abstract**

In tokamaks and neoclassically optimised stellarators, like Wendelstein 7-X (W7-X) and the Helically Symmetric Experiment (HSX), turbulent transport is expected to be the dominant transport mechanism. Among the electrostatic instabilities that drive turbulence, the trapped-electron mode (TEM), which is one of the dominant instabilities in tokamaks, has been shown both analytically [1] and in simulations [2, 3] to be absent over large ranges of parameter space in quasi-isodynamic stellarator configurations with the maximum-*J* property. For some modes of operation of W7-X, the magnetic geometry approximately satisfies the quasi-isodynamic and maximum-*J* properties. It has been proposed that the reduction of the linear TEM growth rate in such configurations may lead to the passing-electron-driven universal instability [4, 5], which is often subdominant to the TEM, becoming the fastest growing instability over some range of parameter space. Here, we show through gyrokinetic simulations using the GENE code [6], that the universal instability is dominant in a variety of stellarator geometries over a range of parameter space typically occupied by the TEM, but most consequentially in maximum-*J* devices like W7-X. We find that the universal instability exists at long perpendicular wavelengths, and as a result dominates the potential fluctuation amplitude and heat-flux spectrum in non-linear simulations. In W7-X, universal modes are found to differ in parallel mode structure from trapped-particle modes which may impact turbulence localisation in experiments.

## References

[1] J.H.E. Proll, P. Helander, J.W. Connor and G. G. Plunk, Physical Review Letters 08 24:245002 (2012)

[2] J. H. E. Proll, P. Xanthopoulos, and P. Helander, Physics of Plasmas, 20(12):122506 (2013)

[3] J.A. Alcusón, P. Xanthopoulos, G. .G Plunk, P. Helander, F. Wilms, Y. Turkin, A. von Stechow and O. Grulke, Plasma Physics and Controlled Fusion 2(3):035005 (2020)

[4] M. Landreman, T.M. Antonsen, and W. Dorland, Physical Review Letters, 114:095003 (2015).

[5] P. Helander and G. G. Plunk, Physics of Plasmas, 22(9):090706 (2015)

[6] F. Jenko, W. Dorland, M. Kotschenreuther, and B. N. Rogers, Physics of Plasmas, 7(5):1904–1910 (2000).