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Advances in Stellarator Gyrokinetics

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We summarise a number of recent advances in gyrokinetic theory and simulations of microinstabilities and turbulence in stellarators, and compare with tokamaks.

Trapped-electron modes (TEMs) can be very different in different types of devices, because these instabilities are excited by trapped electrons in regions of unfavourable magnetic curvature. Tokamaks and stellarators are fundamentally different in the sense that the regions of trapping and bad curvature overlap in tokamaks but need not do so in stellarators. In particular, quasi-isodynamic stellarators can have the property that the bounce-averaged curvature is favourable for the great majority of all trapped particles. Analytical theory suggests that TEMs are then stable in large parts of parameter space, and this prediction is confirmed by GENE simulations, which show that these modes are more stable the more the regions of bad curvature and magnetic trapping are separated from each other. As predicted by analytical theory, the electrons are far less destabilising in the stellarator. Not only is the growth rate lower, but the most unstable mode has a shorter perpendicular wavelength, which could result in less transport.

Linear simulations of linear ITG modes in W7-X and LHD geometry using the EUTERPE show that the growth rate is similar in these two devices and that the mode structure is affected by details in the magnetic geometry. GENE simulations of saturated turbulence show that the density fluctuations are much less evenly distributed over the flux surface than in typical tokamaks. Instead of covering the entire outboard side of the torus, the turbulence is localised to narrow bands in regions of bad magnetic curvature. Possibly as a consequence of this localisation, the transport scaling is more sensitive to the normalised gyroradius and becomes stiffer when this parameter is small. This happens although these simulations are local in the radial direction, and the situation is different from that in tokamaks, where flux-tube simulations yield the same results as simulations of entire flux surfaces.

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