Micro-stability properties of a high beta 1GW spherical tokamak

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Spherical tokamaks (STs) offer an attractive route towards a compact high performance fusion reactor as historically they have achieved high plasma beta and strong shaping that facilitate plasmas with high bootstrap current. While scaling laws can be used to estimate confinement in a reactor relevant ST, their usefulness is limited if the plasma regime is a substantial extrapolation from the parameter space used to generate these laws. In reality the confinement will be set by the turbulence that would arise in such a device, and any reduced transport model needs to describe the relevant characteristics of the dominant turbulence.

The local initial value gyrokinetic solvers, GS2 and CGYRO are used to analyse the nature of the modes that arise in a conceptual 1 GW ST. The dominant linear instabilities were found to be collisional micro-tearing modes (MTM) and kinetic ballooning modes (KBM) at the ion scale, and a collisionless MTMs towards the electron scale. Furthermore, when $k_y\rho_s > 10$ the equilibrium examined was found to be completely stable, with no electron temperature gradient (ETG) mode. The KBMs and collisionless MTMs were suppressed by the anticipated level of flow shear, while the collisional MTMs were robust and are therefore expected to be the dominant source of transport nonlinearly. These MTMs had extended eigenfunctions in ballooning space indicating that nonlinear simulations may require very high radial resolution approaching the electron scale.

The dependence of these linear modes on different equilibrium parameters are examined to determine possible routes to stabilise each mode. With this information, potential options for generating a more stable equilibrium are discussed and a marginally stable plasma equilibrium is found. Nonlinear gyrokinetic simulations are performed to determine the saturated nonlinear flux though, due to the high radial resolution required by the collisional MTMs, obtaining converged simulations is challenging. The saturation mechanisms of these MTMs will be discussed, and the validity of the quasi-linear approximation and the saturation model for a TGLF-like model is examined in a high beta ST regime.