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# Global Gyrokinetic Particle Simulations of Microturbulence in W7-X and LHD Stellarators


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## ABSTRACT


- Recent progress on microturbulence in LHD and W7-X using global gyrokinetic GTC code is reported.
- Linear ITG turbulence simulations show the same eigenmode growths, frequencies and structures as EUTERPE code. Nonlinear simulations show that the main ITG saturation mechanism is the Zonal flows.
- First global helical TEM turbulence is reported in W7-X.
- The dynamics of zonal flows in 3D equilibria show characteristic low frequency oscillations (LFO).
- Neoclassical simulations in GTC find an ambipolar electric field with either ion or electron root. Such radial electric field has impact on ITG turbulence.


## 1) BACKGROUND

- The optimized W7-X stellarator has show a reduced neoclassical transport comparable to Tokamaks.
- Recent experiments in W7-X suggest that turbulence accounts for a large portion of transport.
- The 3D geometry of stellarators makes the theoretical analysis quite complex. Gyrokinetic simulations are providin an insight to microturbulence.

## 2) GLOBAL ITG TURBULENCE

- ITG eigenmode structure appears to be extended in the magnetic field lines direction, peaking at the outer side of the torus (bad curvature regions) and narrow in the perpendicular direction.
- In LHD, the eigenmode structure is at the outer mid-plane similar to ITG in a tokamak. However, in W7-X it is localized at some toroidal regions (where the magnetic field strength peaks) due to the mirror-like magnetic field configuration.

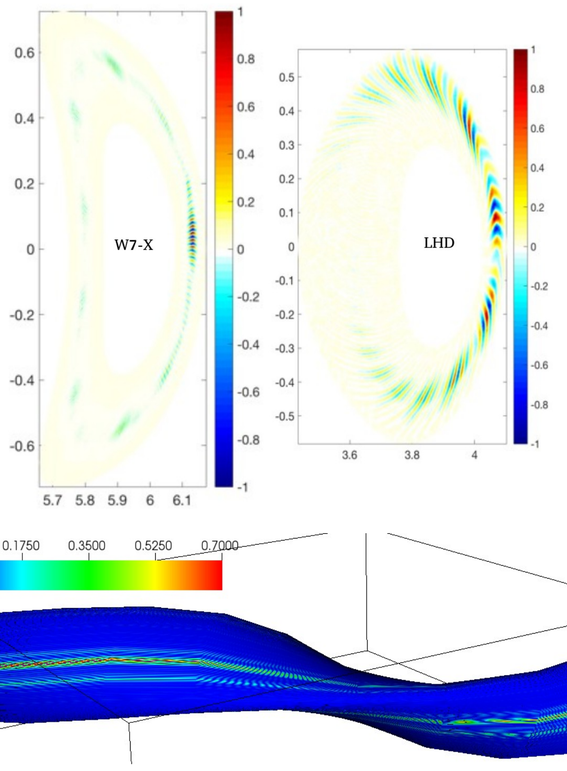


*Fig.1 Elect. Potential in ITG simulation*




*Fig.2 ITG eigeinmode in W7-X*

## 3) NONLINEAR ITG TURBULENCE SATURATION

- Self-generated zonal flows are the main mechanism for ITG saturation in LHD and W7-X.
- During saturation radial turbulence spreading is observed in global simulations

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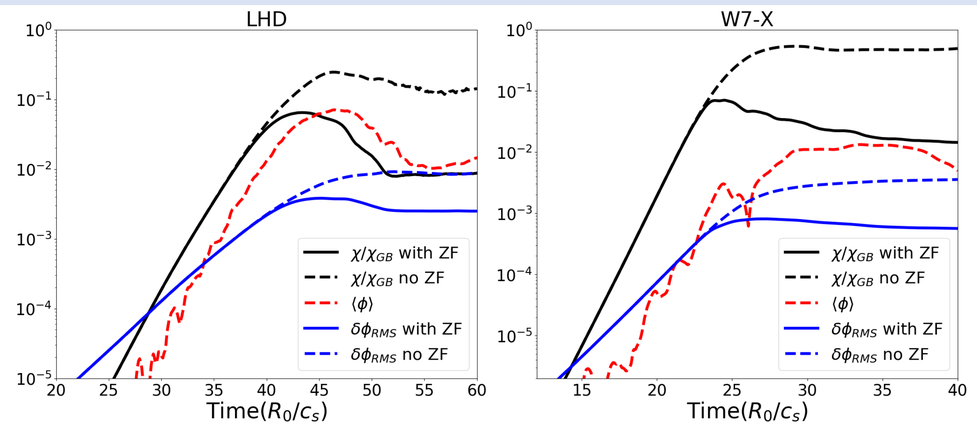



*Fig.3 ITG nonlinear saturation*

## 4) HELICAL TRAPPED ELECTRON MODE

- Helical trapped electron mode (HTEM) emerges in W7-X when kinetic electrons are included in the simulations.
- HTEM are extended along the field lines, localized in the toroidal direction but peaking in the regions where low magnetic field strength and bad curvature overlap.

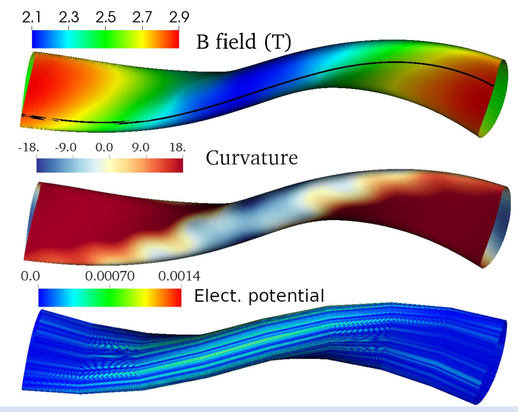
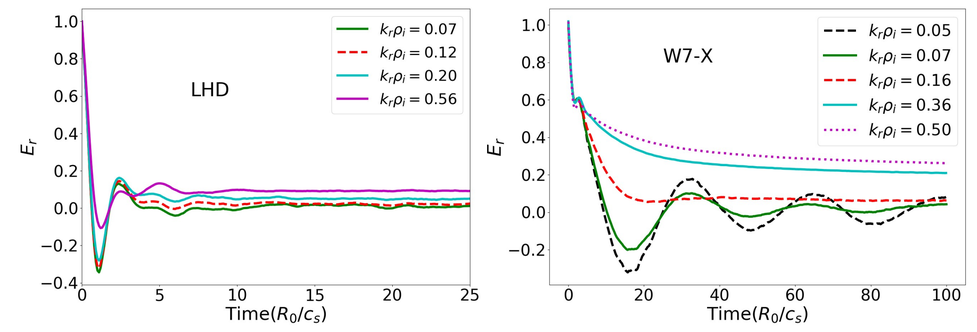



*Fig.4 Magnetic field, curvature and potential in HTEM*

## 5) ZONAL FLOW DAMPING IN STELLARATORS

- Simulations of zonal flow damping in 3D geometries exhibit a low frequency oscillation (LFO).
- In LHD, GAM frequency is also visible during zonal flow relaxation but in W7-X is strongly damped.
- The reason of LFO is the trapped particles due the main helical magnetic inhomogeneity.




## 6) NEOCLASSICAL ELECTRIC FIELD

- Neoclassical transport in stellarators may cause a radial electric field due the non-ambipolarity of particle fluxes.
- GTC find an ambipolar electric field with either ion or electron root depending on the temperature ratio.
- Ion root has little impact on ITG growth an turbulent transport.
- However the impact of electron root significantly reduces ITG turbulence

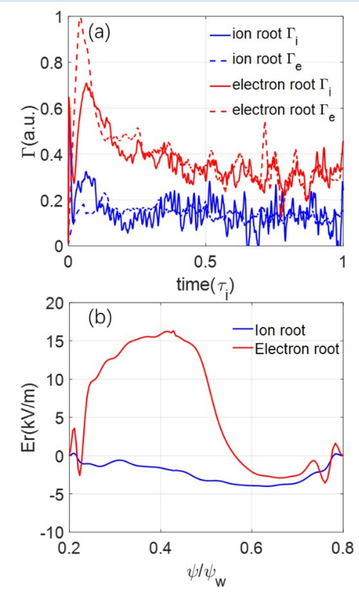



*Fig.6 Neoclassical transport*

## ACKNOWLEDGEMENTS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