

Impact of penalized SOL boundary conditions on plasma turbulence

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CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France





HPC plasma modeling



GYSELA GYrokinetic SEmi LAgrangian



- Electrostatic ITG
- Global
- 5D full-f

Huge computational effort 10⁴processors 10 millions h/monoproc

Penalization for plasma-wall interaction

- Plasma open system \rightarrow boundary = Heat sink
- Affect edge-core turbulence [Dif-Pradalier PFR 2017]
- Realistic boundary = 2 directions
- Penalized immersed boundary as edge fluid codes [Bufferand, JNM, 2013],
 [Isoardi, JPC, 2010]









- Restoring towards exponential profiles
- Heat sink = Cold
- Resolution demanding $(v_{\parallel}, \mu) \& (r, \theta)$
- I transport in SOL, interrupts current loop
- Adiabatic electrons = NO $\perp e^-$ transport



The reversed Er builds a transport barrier



- || electron dynamic in the SOL $\rightarrow \langle \phi \rangle_{FS} = \Lambda T_e$
- *core* dominated by ion physics
- Reversed Er self-consistently generated (as experimental measurements)
- \rightarrow Edge transport barrier (not steady state simulation)



A strong *E* × *B*shear drives axisymmetric instability





> Axisymmetric simulation, evolving <u>only n=0</u> \rightarrow « Neoclassical »

- Threshold on ExB shear
- ExB shear = poloidal velocity \rightarrow Kelvin-Helmholtz

→ Plasma polarization is sufficient to drive turbulence



SOL impact on turbulent fluctuations



- ITG modes
- Same core turbulence



Global = core + edge + SOL





- 2) Instability even in axisymmetric framework
- 3) Qualitative $\delta n/n$ experimental trend

- Many different non-linear phenomena at a time: Kelvin-Helmholtz, ITG, spreading, flows
- Push towards steady-state boundary layer

Limiter boundary leads to new physics in GYSELA simulations









Back-up slides

Cea Evidence of edge-core interplay





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The weak transport barrier depends on core dynamics







E_r Reversal at separatrix modifies SOL poloidal symmetries



LIMITER brakes the current loop \rightarrow SOL poloidal asymmetries

SOL Polarization

Reversed $E_r \leftrightarrow v_{\theta}$

Inverse rotation btw core/SOL





- Vertical drift + SOL flows
- HFS density accumulation
- Barrier at separatrix



Initial transient in the SOL





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Axisymmetric simulations: barrier on the profiles







Recovering $\delta n/n$ behavior















Self-organized heat sink



- 1. Heat & momentum sink
 - \rightarrow Cold immersed boundary
 - \rightarrow Poloidally asymmetric
 - \rightarrow || transport in SOL
- All heat reaching the limiter is removed
- □ SOL = boundary for core
- ❑ Drift killed in the boundary



Heat Sink Self-organized

Adiabatic electrons

NO Particle sink,

Constrained ⊥ particle transport

NO recombination





Adiabatic electrons

Flux surface averaged profiles

