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Simulations of impurity transport with TERESA and GYSELA codes

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Context: gyrokinetic simulations of impurity transport in the core of tokamaks

Objective: Impacts of impurity concentration, charge, mass, gradients & tor. rotation

Method: • 4D bounce-averaged gyrokinetic simulations (TERESA)
 • 5D gyrokinetic simulations with realistic collisions (GYSELA)

Part 1: Impact of concentration

Scan of tungsten concentration in TEM turbulence with TERESA

- TEM growth rate and turbulence intensity ↓ with ↑ tungsten concentration C, linearly for concentrations below 5.10^{-4} ($C Z^2 < 0.8$)
- Consistent with [Dominguez NF'89] [Du NF'14]
- For turbulent transport of W^{40+} , passive treatment valid for $C < 2.10^{-4}$ ($C Z^2 < 0.3$)

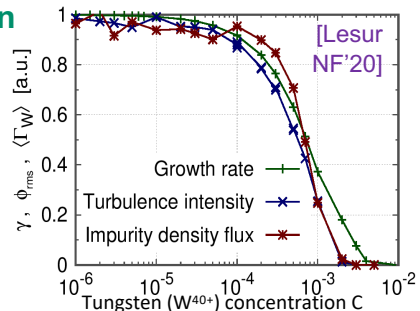


Fig.1. Transition between passive and active W

Part 2: Diffusion, thermo-diffusion, and curvature pinch

Three terms of TIM and TEM turbulent transport can be isolated in TERESA, and parametric dependencies investigated separately

$$\Gamma_Z = -D_Z [\nabla n_Z + C_T \nabla T_Z + C_P \nabla q]$$

Increases (decreases) with increasing Z for TEM (TIM)

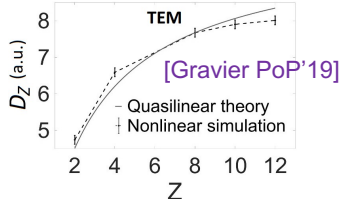


Fig.2. Impurity diffusion against charge number Z

Thermodiffusion:
 $C_T \downarrow$ as $Z \uparrow$ TEM → inwards
 TIM → outwards

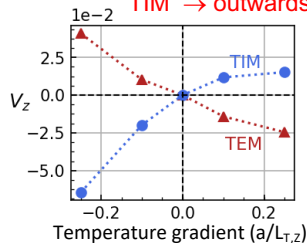


Fig.3. Thermodiffusion velocity V_Z versus impurity temperature gradient

Curvature pinch: inward except for strong reversed magnetic shear

Consistent with [Futani PRL'10]

[Lim PPCF'20]

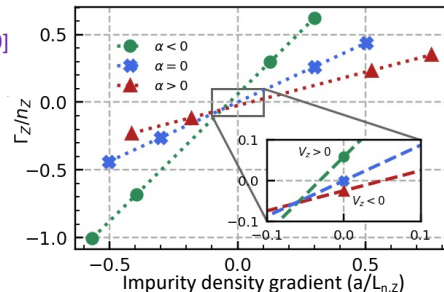


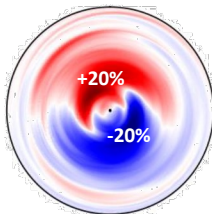
Fig.4. Impurity density flux for $\nabla T_z = 0$, for different signs of magnetic shear α

Part 3: impurity transport in ITG turbulence with realistic collisions

Heat source-driven GYSELA simulations with both neoclassical and turbulent transport

[Estève NF'18] [Donnel NF'19]

- Light Z → turbulent transp. → hollow density profile
- High Z → neoclass. transp. → peaked density profile
- Turbulence generates 20% up-down asymmetry for tungsten, impacting neoclassical transport



[Lim NF'21] Fig.5. Poloidal distribution of tungsten

- Toroidal rotation increases in-out asymmetry and central tungsten accumulation
- Consistent with [Angioni PPCF'14]

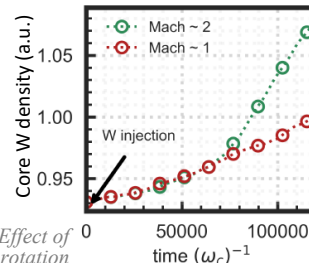


Fig.6. Effect of toroidal rotation