Simulation of tokamak SOL turbulence

SOL

Objective

Drift-reduce

Example of drift-reduced

Example of turbulence

RB and DV

 $a - L_n/R$ 

Non-linear R

Non-linear

Conclusions

## Simulation of tokamak SOL turbulence



Annamaria Mosetto, Federico Halpern, Paolo Ricci

CRPP, EPFL, Lausanne

# Scrape Off Layer (SOL)

Simulation of tokamak SOL turbulence

SOL

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Example of a drift-reduced equation

Example of turbulence

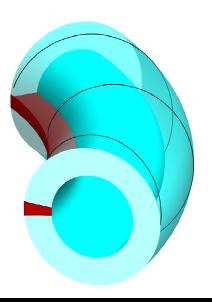
RB and D\

 $q - L_n/F$ 

Non-linear R

Non-linear

Conclusio



- open magnetic field lines
- low temperatures
- collisional plasma
- atomic physics

## **Objectives**

Swiss Physical Society, Joint Annual Meeting

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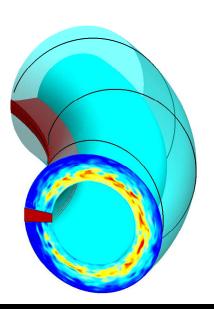
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## Objectives:

- properties of the SOL turbulence
- instabilities and drives
- non-linear saturation mechanism

#### How?

- simple geometry : toroidal limiter
- global self-consistent code

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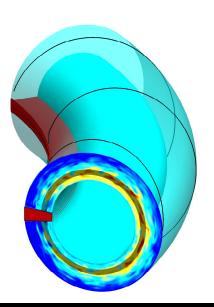
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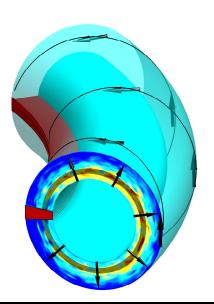
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## The drift-reduced Braginkii equations

Simulation of tokamak SOL

SOI

Objectives

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Example of drift-reduced

Example o

RB and D

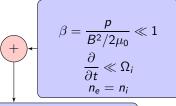
 $q - L_n/R$ 

Non-linear R

Non-linear

onclusions

collisional plasma : Braginskii two fluid model (e-i) equations : density, velocity and temperature



- separation of perpendicular and parallel dynamics
- elimination of the fast gyromotion from the description
- only the drift velocities are retained

Electrostatic drift reduced Braginskii equations

## Continuity equation for the electrons

Simulation of tokamak SOL turbulence

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Example of a drift-reduced equation

Example o turbulence movie

RB and DW

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Non-linea DW

$$\frac{\partial n}{\partial t} = \frac{c}{B} \left[ \Phi, n \right] + \frac{2c}{eRB} \left( \frac{\partial p_e}{\partial y} - en \frac{\partial \Phi}{\partial y} \right) - \frac{\partial \left( nV_{||e} \right)}{\partial z}$$

- VFxB convection
- *v<sub>de</sub>* convection
- compressibility due to curvature
- $\mathbf{v}_{||e}$  convection

## Example of turbulence movie

Simulation of tokamak SOL

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# Example of turbulence movie

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Non-linea

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RB and DW instabilities

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Non-linear R

Non-linea DW

|                           | Resistive Ballooning (RB)                   | Drift wave (DW)   |
|---------------------------|---|---|
| drive                     | $V_d \& \nabla p \& R$                      | $\mid \mathbf{E} \times \mathbf{B} \& \nabla p$                 |
| growth rate               | $\sim c_s \sqrt{\frac{2}{RL_n}}$            | $\sim \frac{c_s}{L_n}$  |
| parallel dy-<br>namics    | $k_{  } \sim rac{1}{qR}$                   | $k_{  } \neq 0$   |
| perpendicular<br>dynamics | $k_{min} < k_y < k_{max}$                   | $k_y  ho_s pprox 1$   |
| physical pro-<br>perties  | destabilized by resistivity (non adiabatic) | destabilized by resistivity or electron inertia (non adiabatic) |

# $\overline{q-L_n/R}$ linear phase space

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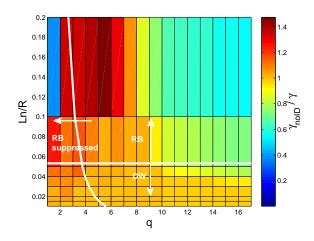
Example o turbulence

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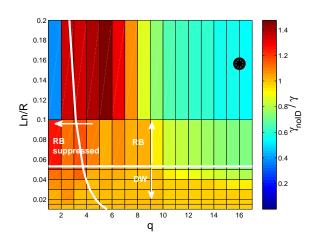
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# $\overline{q-L_n/R}$ linear phase space

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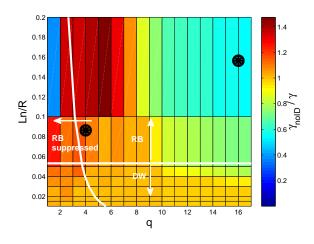
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Non-line



## Non-linear simulation for the RB instability

Simulation of tokamak SOL

SOL

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Example of turbulence movie

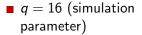
instabilities

 $q - L_n/R$ 

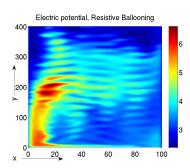
Non-linear RB

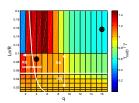
Non-linear DW

onclusion

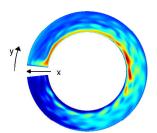


■  $Ln/R \approx 0.16$  (computed parameter)





Electric potential, Resistive Ballooning



## Non-linear simulation for the DW instability

Simulation of tokamak SOL

SOI

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instabilities

 $q - L_n/R$ 

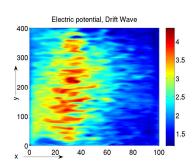
Non-linear R

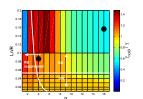
^\_\_\_l...i...

DW

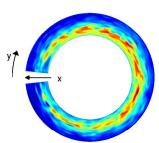
q = 4 (simulation parameter)

■  $Ln/R \approx 0.09$  (computed parameter)





Electric potential, Drift Wave



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RB and DV instabilities

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DW

- simulation of the self-consistent SOL turbulence dynamics
- two instabilities regime : DW and RB. Good agreement with the linear studies
- linear study, easy-to-use method to interpret the non-linear results :
  - DW : small Ln/R ratio, small q, high toroidal mode number
  - RB : high Ln/R ratio, high q, small toroidal mode number
- Work in progress and envisaged :
  - magnetic shear
  - electromagnetic effects
  - ion temperature
  - divertor geometry