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## CHARACTERIZATION OF THE ELECTRIC POTENTIAL ACROSS THE TOKAMAK

E. Caschera, Guilhem Dif-Pradalier, Ph Ghendrih, C. Gillot, V. Grandgirard,  
C. Passeron

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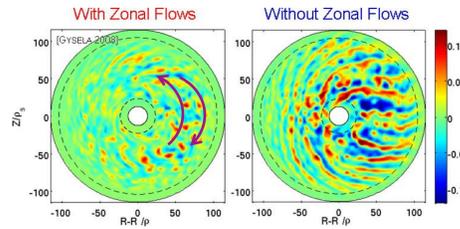
E. Caschera, G. Dif-Pradalier, Ph. Ghendrih, C. Gillot, V. Grandgirard, C. Passeron

## Summary

The poloidally and toroidally symmetric mode of the electric potential is self-consistently generated by turbulence. Its radial derivatives (the Zonal Flows and the electric shear) substantially affect confinement properties. We study the radial shape of the electric potential through statistical analysis on data from GYSELA, global gyrokinetic and flux-driven code. Two main features are retained in the simple projection on parabolic functions: the maximal depth and the slope (i.e. the electric field) at the edge. A preliminary trend is found in relation to the energy confinement: the well is deeper for increasing confinement.

## Zonal Flows shear radially elongated turbulent eddies

Zonal Flows  $\leftrightarrow$  mode (0,0) of the potential  $\phi_{00}$



$$v_{E \times B} = \frac{E \times B}{B^2}$$

$$v_\theta \propto \partial_r \phi_{00}$$

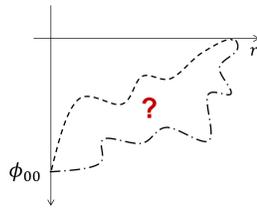
Zonal Flows

$$\partial_r v_\theta \propto \partial_r^2 \phi_{00}$$

Electric Shear

- Self-consistently generated by plasma evolution
- Contributes to enhance confinement

Which radial profile for  $\phi_{00}$ ?

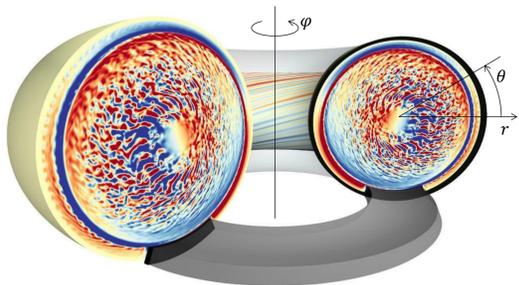


## Global, gyrokinetic and flux driven = Self-organized system

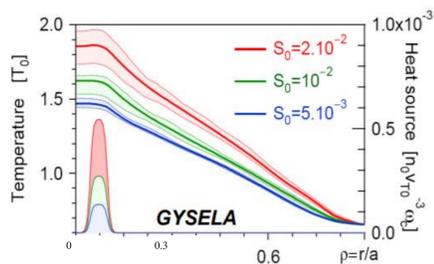
- $\phi_{00}$  is a global structure
- Fast time scale evolution/build-up
- No analytical prediction

### GYSELA

- GK Vlasov (5D) + Q.N
- GLOBAL = full torus, full-f
- $S_{heat} \rightarrow$  Self-organized



GYSELA



## GYSELA data: orders of magnitude

### Standard simulation

Run time  $\sim 10^7$  h/monoproc

2D data stored  $\sim 10$  Gigabyte

3D data stored  $\sim 1$  Terabyte

5D data  $\sim 1$  Terabyte/iteration

DATABASE of  $\sim 40$  good simulations previously collected

Only a fraction of stored data is normally analyzed

### Ongoing projects

- Development of SQLite database
- Define the standard shape

### Long term objectives

- Recognize a good simulation
- In-run check: save cpu hours

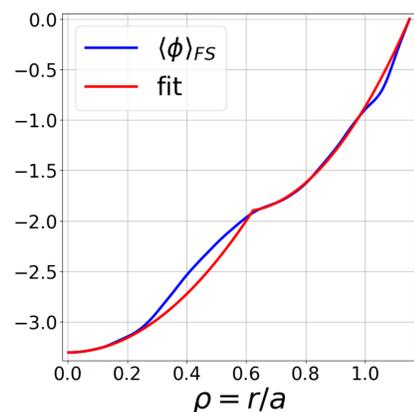
## A minimal model retains the ends

### Highlights/Constraints:

- Symmetric at  $\rho = 0$
- Grounded at the boundary
- Negative to confine ions while electrons are adiabatic

### Interesting points:

- Minimum of the well
- Electric field at the edge
- Allow some flexibility in-between



Minimize

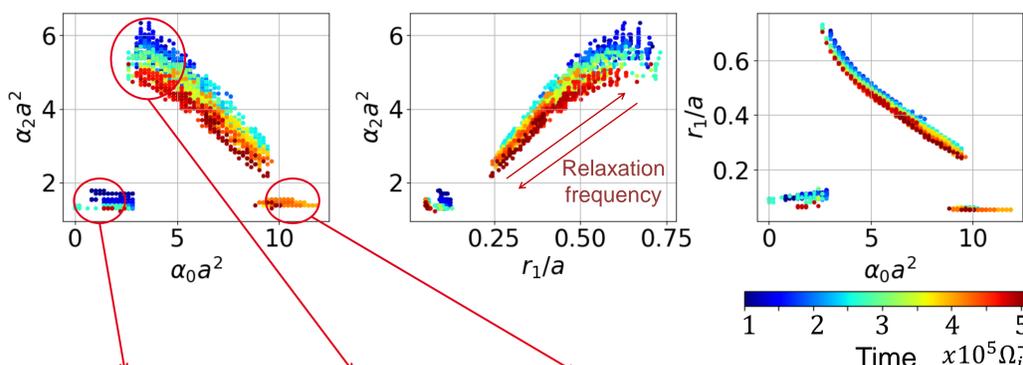
$$\epsilon = \int |\phi - fit| d\rho$$

$$fit(\rho) = \begin{cases} \alpha_0 \rho^2 + \phi_{00}^{(\rho=0)} & \rho < \rho_1 \\ \alpha_2 (\rho - \rho_{max})^2 - E_{r_{max}} (\rho - \rho_{max}) & \rho \geq \rho_1 \end{cases}$$

Each time step

## What is normal? Can detect bifurcations?

➤ The flatter in the center, the steeper at the edge  $\rightarrow$  Shape stiffness (?)



One parabola is sufficient

Reversed shear at  $\rho \sim 0$

## Observation: Depth increases with «quality» of confinement

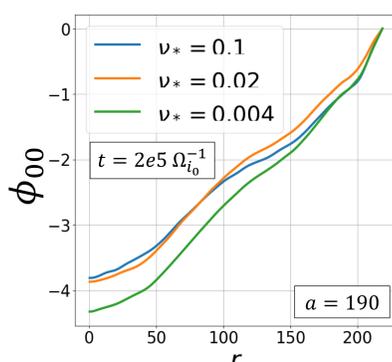
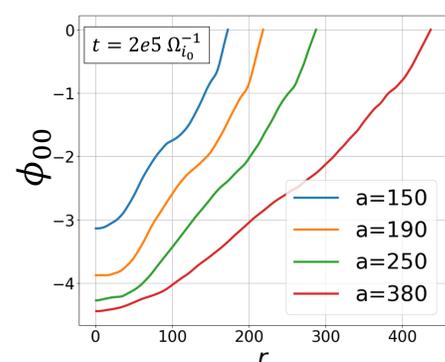
Energy confinement time scaling

[C.C. Petty et al. PoP, 2004]

$$\Omega_i \tau_E^{EGB} \propto \rho_*^{-3} \nu_*^{-0.14}$$

$\rho_* \propto 1/a$  : Plasma size

$\nu_*$  : Collisionality

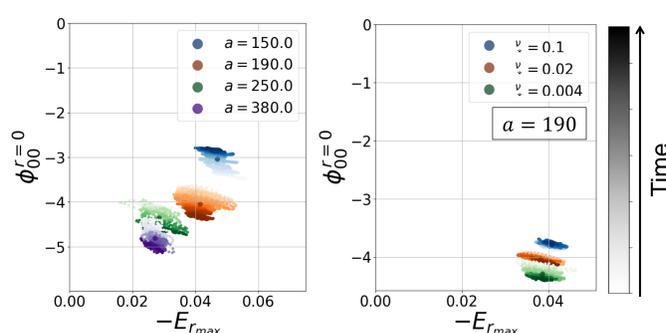


- ❑ Suggests  $E(r_{max}) = const \rightarrow$  Fix point ?
- ❑ the easiest picture of a single pendulum

- ❑ Trade-off between neoclassical transport and zonal flows damping

## A more careful look and complexity emerges

No universal behavior



$\nu_* \rightarrow$  Constant  $E(r_{max})$  and power law of  $\phi_{00}(r=0)$

$a \rightarrow E(r_{max})$  decreases with plasma size and  $\phi_{00}(r=0)$  is not a power law

