

# TURBULENCE - DRIVEN ANOMALOUS TRANSPORT IN TOKAMAKS

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# STANDARD THEORIES OF TRANSPORT

- CLASSICAL TRANSPORT (BRAGINSKII): Based on standard plasma collisionality in a straight magnetic field geometry.

$$\chi_C = 10^{-2} \frac{m^2}{s}$$

- NEOCLASSICAL TRANSPORT: Incorporates toroidal geometry effects.

$$\chi_{NC} = 10^{-1} \frac{m^2}{s}$$

# ANOMALOUS TRANSPORT

- Driven by turbulence?

$$\chi_A \sim 1 \frac{m^2}{s}$$

## PARAMETERS

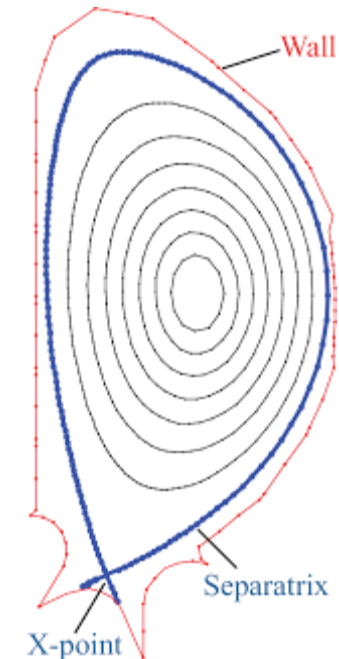
$$n_0 = 10^{13} cm^{-3}$$

$$T = 100 eV$$

$$B = 3 T$$

$$R = 2 m$$

$$a = 0.7 m$$



# THE MODEL

- Hasegawa – Wakatani system

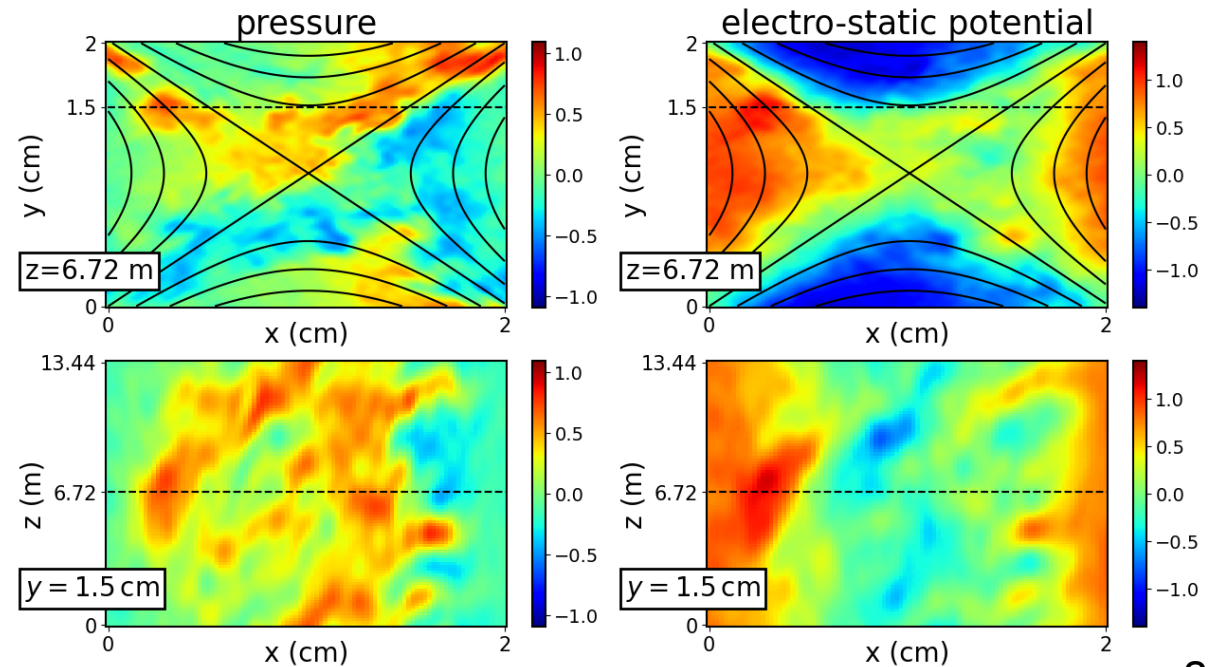
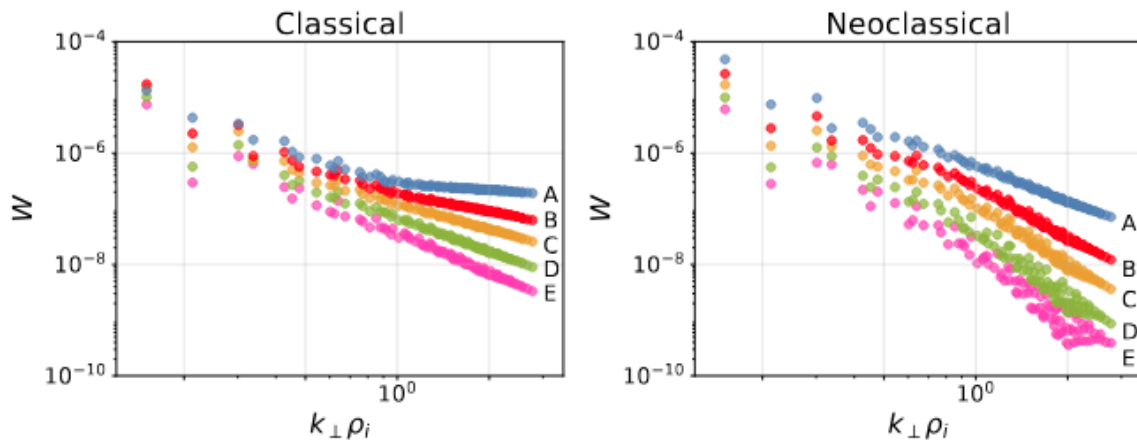
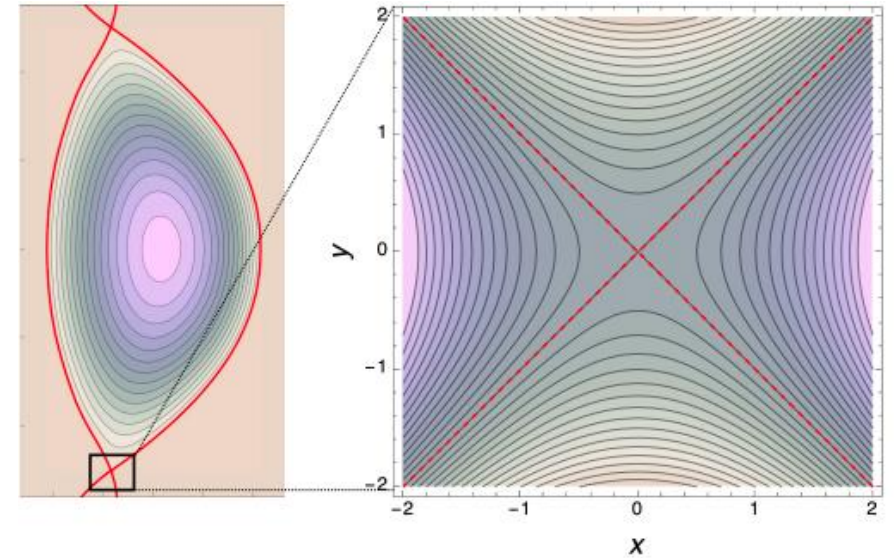
$$\partial_t \nabla_{\perp}^2 \phi + \frac{c_s^2}{\Omega_i} \{ \phi, \nabla_{\perp}^2 \phi \} = c_1 \nabla_{\parallel}^2 (p - \phi) + \nu \nabla_{\perp}^4 \phi$$

$$\partial_t p + \frac{c_s^2}{\Omega_i} \{ \phi, p \} = -\frac{c_s^2}{\Omega_i \ell_0} \partial_y \phi + c_2 \nabla_{\parallel}^2 (p - \phi) + \chi_{\perp} \nabla_{\perp}^2 p$$

$$\ell_0 = 2, 3.5, 5, 7.5, 10 \text{ cm} \quad \chi_{\perp} = \chi_C, \chi_{NC}$$

- Background magnetic field

$$\mathbf{B} = B_p y \hat{e}_x + B_p x \hat{e}_y + B_t \hat{e}_z$$



# METHOD AND RESULTS

- Large number of passive fluid tracers initialized with random positions on the 3D box

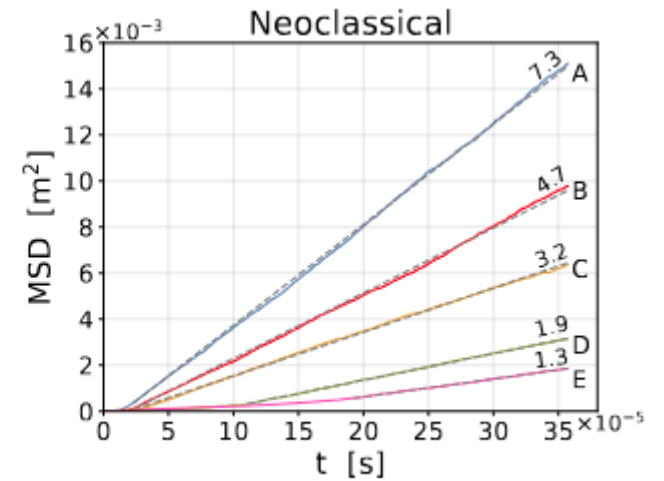
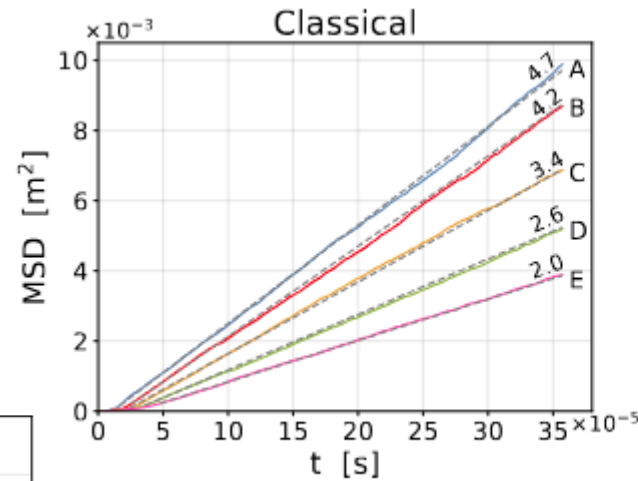
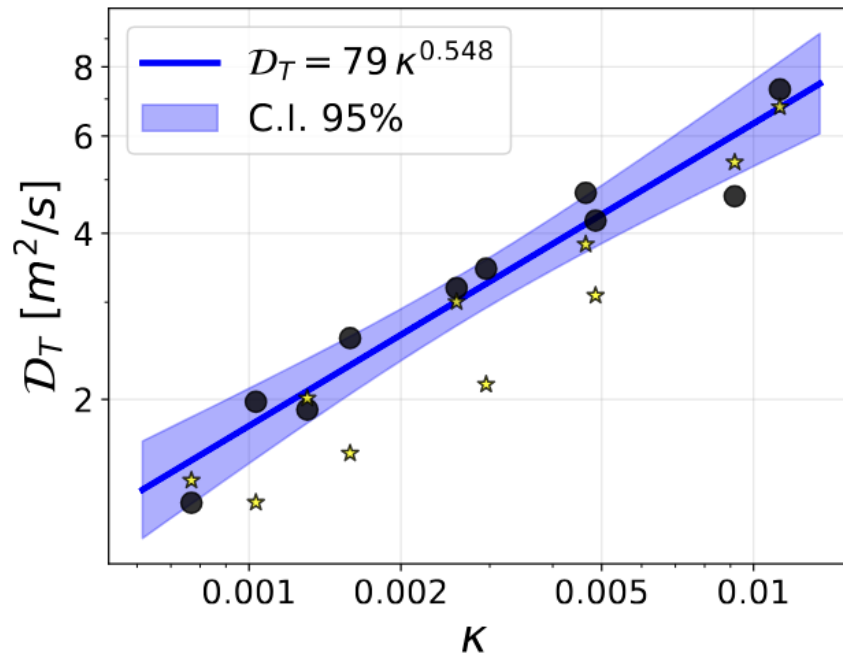
$$\text{MSD}(t) = \langle (x(t) - x(0))^2 + (y(t) - y(0))^2 + (z(t) - z(0))^2 \rangle$$

- Diffusive phase = linear scaling

$$\text{MSD}(t) = 6\mathcal{D}_T t$$

- Scaling law: diffusion vs turbulent energy

$$\mathcal{D}_T = C\kappa^\gamma$$



$$C = 79 \pm 24 \text{ m}^2/\text{s}$$

$$\gamma = 0.548 \pm 0.050$$

$$\kappa = \frac{c^2}{2B_t^2 c_s^2} \langle |\nabla_\perp \phi|^2 \rangle$$

$$\mathcal{D}_T^{QL} = \tau_{ac} c_s^2 \kappa$$

# CONCLUSIONS

- Turbulence is the main ingredient to give account of anomalous transport in the X-point region
- An analog of the fluid K- $\epsilon$  model can be introduced

# STILL TO DO

- Full poloidal annulus
- Curvature
- Temperature

# SYNERGIES

- Astrophysics, collisional scenarios