Non-local Structure and Transport in Toroidal Flux-Driven ITG Turbulence

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1. Background: Self-organized criticality in toroidal ITG turbulence

- Self-organized critical transport
- While temperature corrugation propagates in fast-scale (~2 \( \times 10^{-5} \)), self-organized transport provides a self-organized transport.
- Such a type of simulation captured a new class of flow pattern as called E \& B shear flow and steepens temperature profiles.
- Time-averaged temperature profile.

2. Purpose of our research

- We newly developed a 5D toroidal global gyrokinetic code and checked the validity through several benchmark tests (neoclassical, R-H, linear, nonlinear ITG tests). Main features are

3. Simulation condition

- While temperature corrugation propagates in fast-scale (~2 \( \times 10^{-5} \)), global temperature profile is tied to a functional form.
- Self-organized critical transport
- E \& B shear propagates in slow-scale (~2 \( \times 10^{-5} \)) to outer region, where a break of resilience is observed.

4. Non-local heat transport - avalanches and explosive global transport

- After explosive global transport, meso-scale local transport with \( \delta\theta \approx 0 \) grows, which quickly dissipates radially extended vortices.

5. Profile resilience/stiffness

- Temperature profile is tied to an exponential functional form, while temperature scale largely changes in outer region.
- In outer region, neoclassical heat flux increases due to the effect of sink operator and (2) E \& B shear spectrum is pepped up especially in \( \nu_r \theta / R_0 \).

6. Role of zonal/mean flow shear to explosive global transport

- The neoclassical mean flow shear can cancel the global profile variation effect, i.e., diamagnetic shear.

7. Power scan test

- Flux-driven turbulent transport is dominated by three process: (1) fast-scale avalanches, (2) explosive global transport and (3) slow-propagation of E \& B shear.
- Explosive global transport is triggered by the instantaneous formation of radially extended potential vortices, which is enhanced by the neoclassical mean flow shear through the cancelation of global profile variation effect, i.e., diamagnetic shear.

8. Implementation of kinetic electron (on going)

- Growth rate decreases as mass ratio becomes smaller.
- Implicit scheme with GCR method can reduce CPU time.
- Toroidal collision-less simulation always numerically diverges...

9. Conclusion and future plans

- Flux-driven turbulent transport is dominated by three processes: (1) fast-scale avalanches, (2) explosive global transport and (3) slow-propagation of E \& B shear.
- A self-organized resilient profile keeping the exponential function form is established even in the presence of zonal/mean flow. Such a resilience is also confirmed from step-up/down switching test for heat input power (not shown in this poster).
- A break of resilience is observed in outer region, where radial convection of temperature corrugation coupled with E \& B shear occurs, exhibiting a weak transport barrier formation in high power regime.

- Future plans
- Implementation of general magnetic configuration + Edge boundary effect
- Implementation of kinetic electron
- ITG-TEM mode
- Study of transport barrier formation in flux-driven ITG turbulence