Summary: "Cross-Disciplinary" sessions

P. H. Diamond

U. C. San Diego and SWIP

Thanks to

Lu Wang
Yusuke Kosuga } Co-organizers
Weixin Guo

AAPPS-DPP 2019 (菊池祭)

Task of Summarizer

Uncover the “Invisible Hand(s)” of the conference…?!

Inventory and OV I

- Numbers:
  - — 4 Plenary
  - — 20 Invited
  - — 5 Oral
  - — 6 Poster
  - — 3 Discussions
- Topical Areas:
  - → Transport ↔ Unifying Theme: Entropy Production; Constraints; Applications
    - — Garbet, Mak, Y. Shi, W. Guo (U30 winner), P. Shi
  - → I.) Inhomogenous Mixing: Memory, Structures and Staircases
    - — Obuse, W. Guo, Ashourvan, Diamond, Q. Yan

Inventory and OV II

□Topical Areas:

→ II.) Flow Pattern Formation: Shear, Rotation

— W. Wang, Kosuga, L. Wang, Tynan, Inagaki, T. Long

→III.) Magnetic Self-Organization: Dynamics, etc…

— Hughes, Sugiyama, Lipeng Wang, Di Giannatale

□Agent of Transport:

→I.) Turbulence: Fluid and superfluid

— Kimura, Yokoyama, Kobayashi

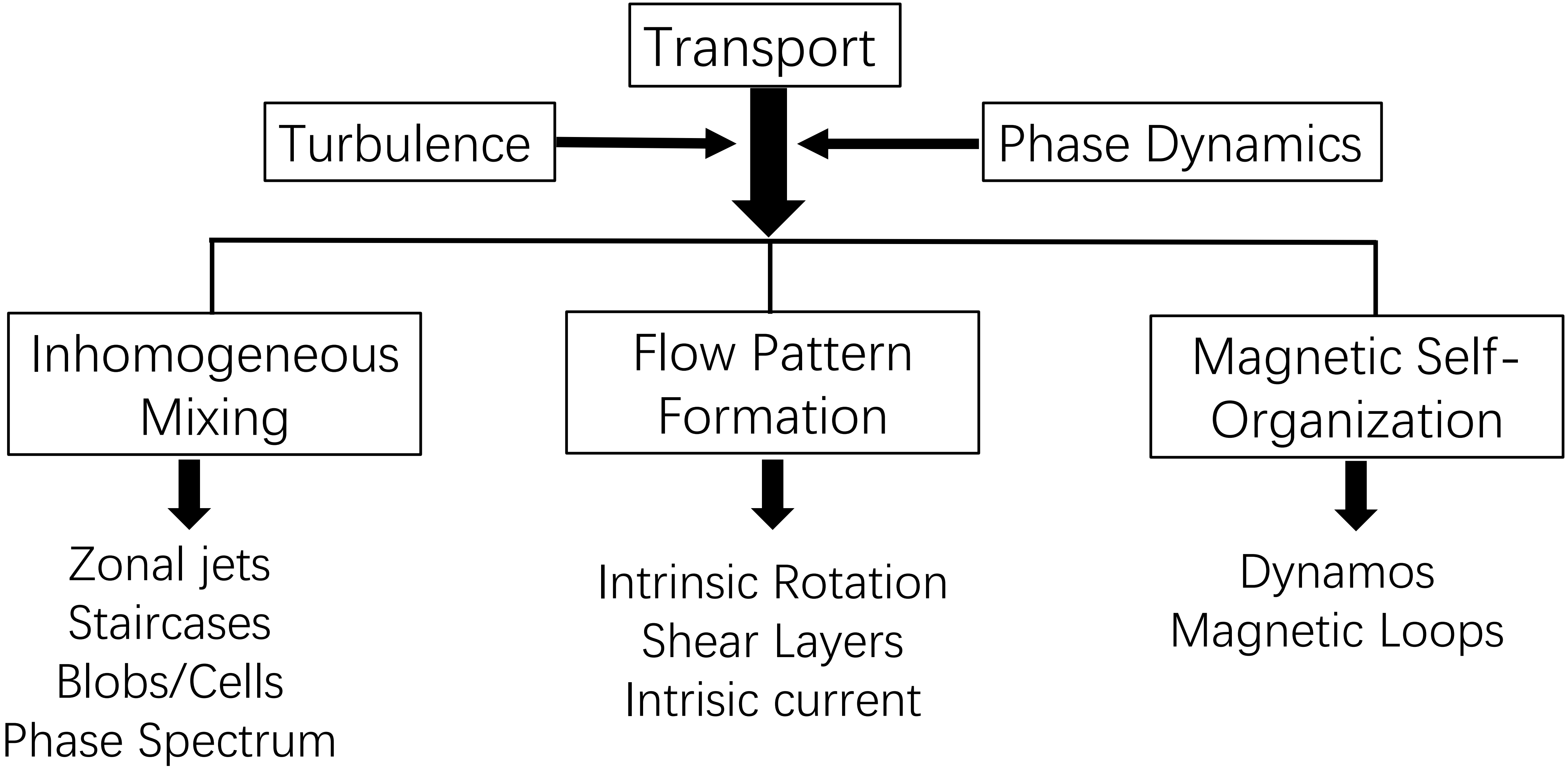
→ II.) Phase Dynamics: Phase and Phase Space

— Z. Guo, Z. Mao, Lesur, Ido, Noreen, Karmakar

Inventory and OV III

- Other:
  - — Hui, Ning, Terasaka, L. F. Wang, Inayoshi, H. Y. Tan, Jha

Theme: Structure Formation



I) Transport

- Some major questions:
  - — is there a unifying principle?
  - — how to treat non-diffusive processes?
  - — fate of Onsager symmetry?
  - — exceptions?

Garbet

Entropy and relaxation processes

Conclusions

- Minimum of entropy production principle coupled to quasi-linear theory predicts fluxes vs forces in turbulent magnetised plasmas.
- Predicts pinches, residual contributions to energy and momentum fluxes, turbulent heating and acceleration.
- Onsager symmetry respected under conditions.
- May fail, typically in systems with long range interactions, with memory effects. Tsallis and Lynden Bell entropy definitions offer alternatives.

Mak

Role of energetically constrained turbulent transport coefficients in ocean climatology

Mean forced by divergence of eddy fluxes (Taylor-Bretherton):

$$\frac{\partial \overline{\boldsymbol{u}}}{\partial t} + f(\overline{\boldsymbol{u}}) = \nabla \cdot \mathbf{T}, \qquad \mathbf{T} = \begin{pmatrix} -\mathrm{M}+\mathrm{P} & \mathrm{N} & 0 \\ \mathrm{N} & \mathrm{M}+\mathrm{P} & 0 \\ -\mathrm{S} & \mathrm{R} & 0 \end{pmatrix}$$

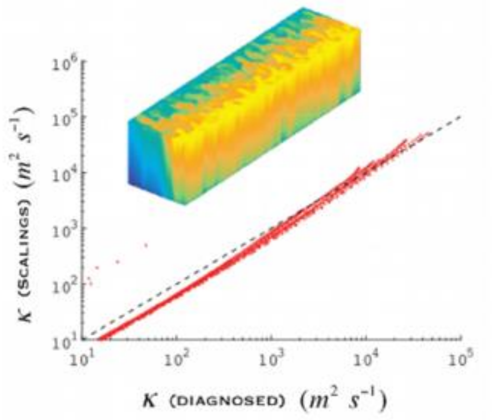
Geometric variables + mathematical inequalities imply scaling for down-gradient buoyancy closure (Gent-McWilliams):

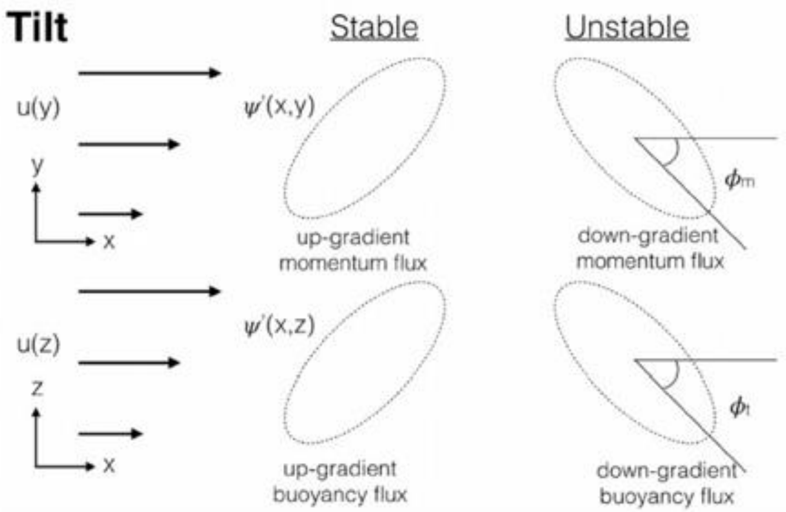
$$\kappa_{\mathrm{gm}} = \alpha E \frac{(\partial \overline{b}/\partial z)^{1/2}}{|\nabla \overline{b}|^2}, \qquad |\alpha| \leq 1$$

* explicit dependence on eddy energy E
* “fudge” parameter α is non-dimensional (instead of e.g. length scale from mixing length), related to eddy geometry

How to diagnose these turbulent diffusivities / transport coefficients from data?

multiple tracer release (Bachman & Fox-Kemper, 2013)
* “overfitting” problem, least-squares fitting
* can diagnose diffusivity tensor components





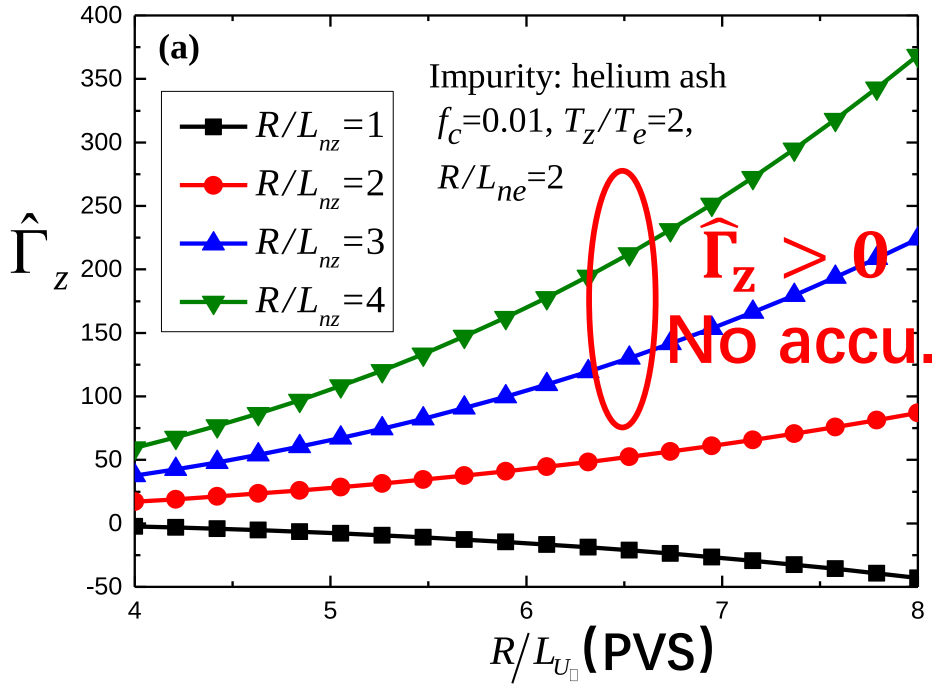
W. Guo (U30)

Impurity transport driven by PVS turbulence

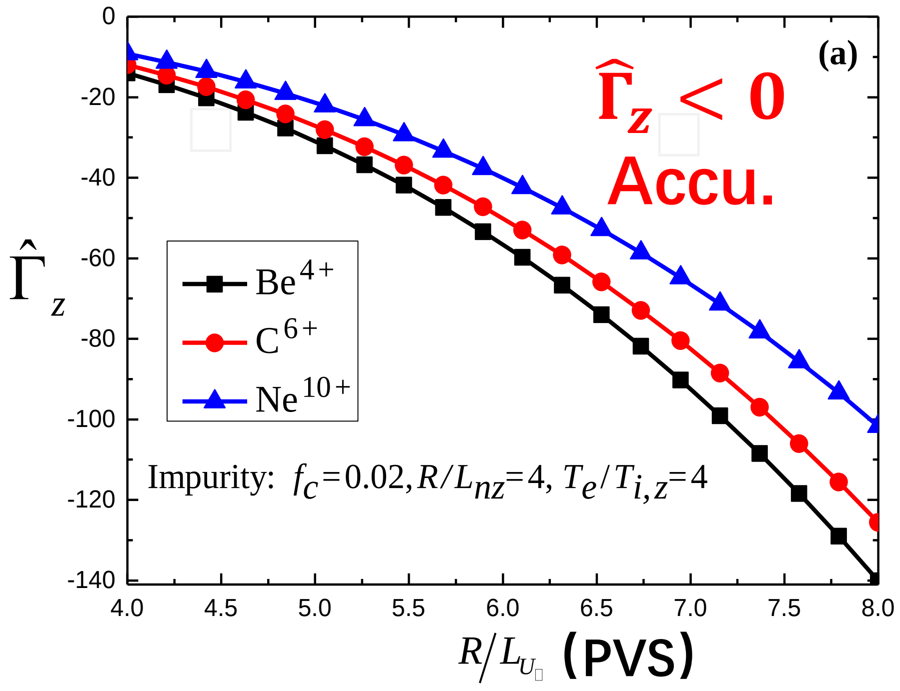
Weixin Guo, Lu Wang*, Ge Zhuang NF 59 (2019) 076012

- □ NBI heat → excite Parallel Velocity Shear (PVS) turbulence
- □ **Gyrokinetic** theory → **study how to expel** impurity by PVS tur.

Helium ash



Light impurity from PWI or injection



$\hat{\Gamma}_z$: impurity flux

✓ PVS tur. can expel helium ash when $R/L_{nz} \geq R/L_{ne}$=2

✓ PVS tur. may be the reason of light impurity accumulation in NBI plasmas for $R/L_{U\parallel} \geq R/L_{nz}$

Y. Shi

Results of ECH effects on NLT and Rotation reversal in KSTAR

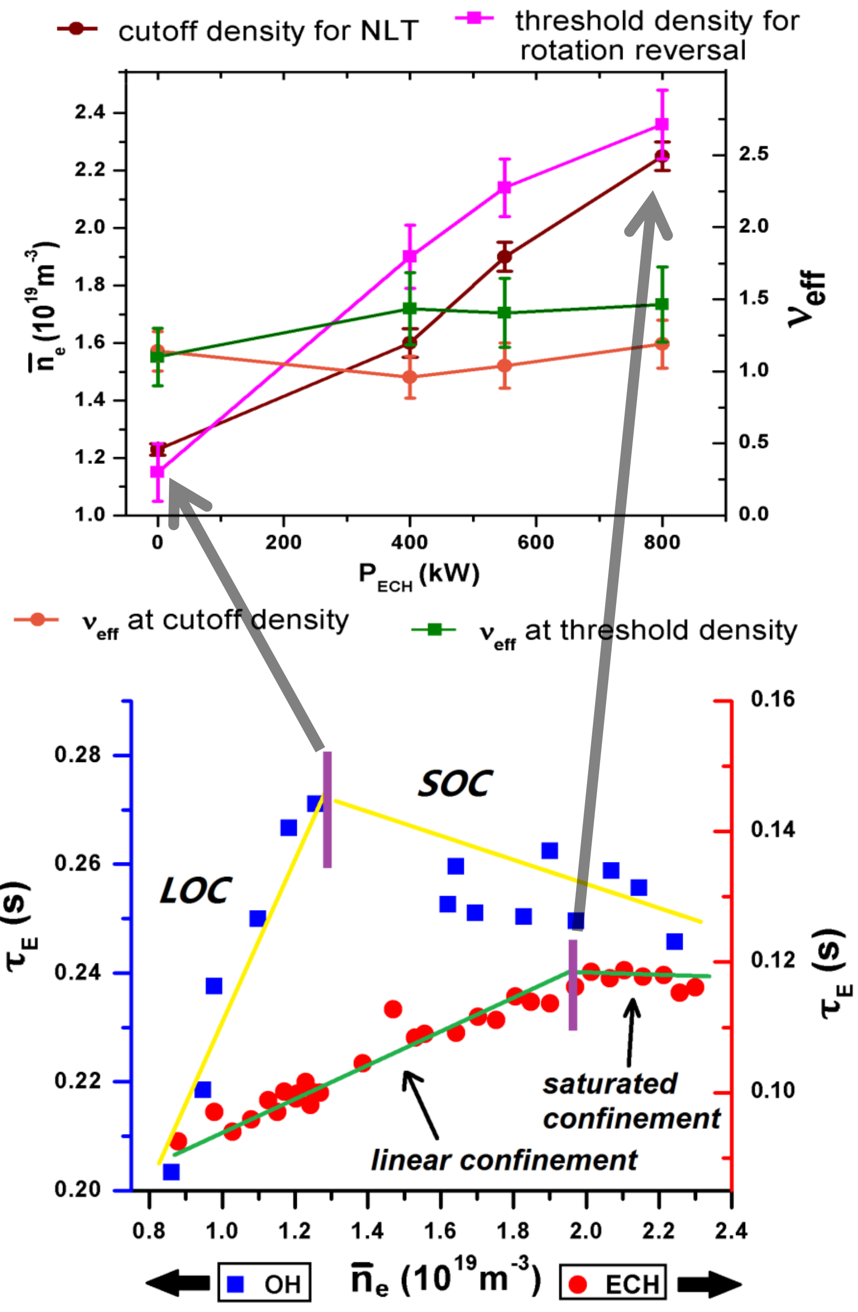
- ν_{eff} at $\rho = 0.5$ is almost same level at the cut-off density of NLT and the threshold density for rotation reversal

- ***The features of linear confinement and saturated confinement also appeared in ECH plasma, which is similar to the linear ohmic confinement (LOC) mode and saturate ohmic confinement (SOC) mode***

Theoretical hypothesis for NLT and rotation reversal
(Diamond PoP 2008, Naulin EPS2014, Hariri PoP 2016)

- **Both cutoff density for NLT and critical density for rotation reversal are related to the plasma confinement change⇒ LOC↔SOC background mechanism is related to TEM/ITG**

→ NL in electron and ion channel

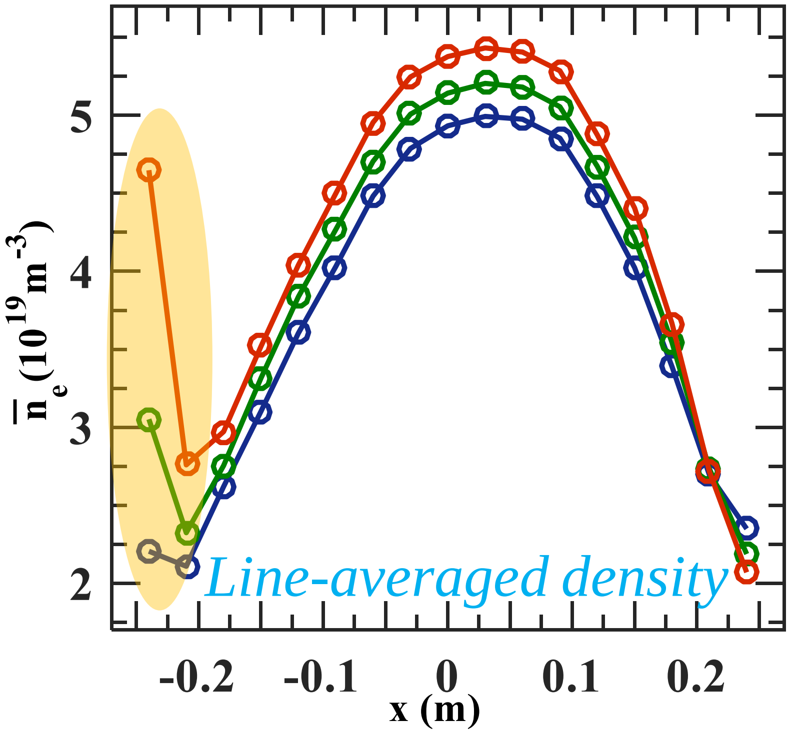


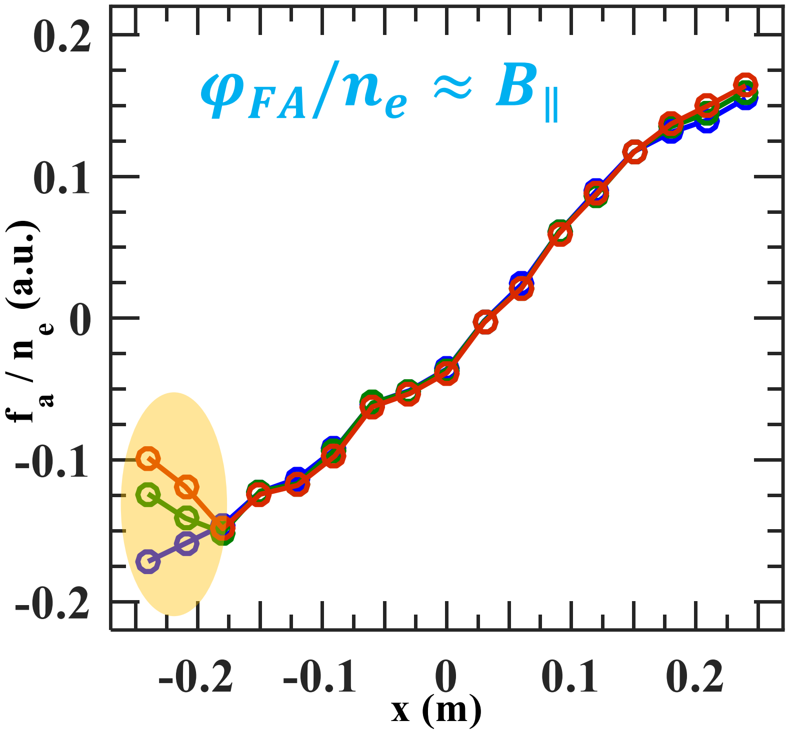
τ_E v.s. density for OH and ECH plasma

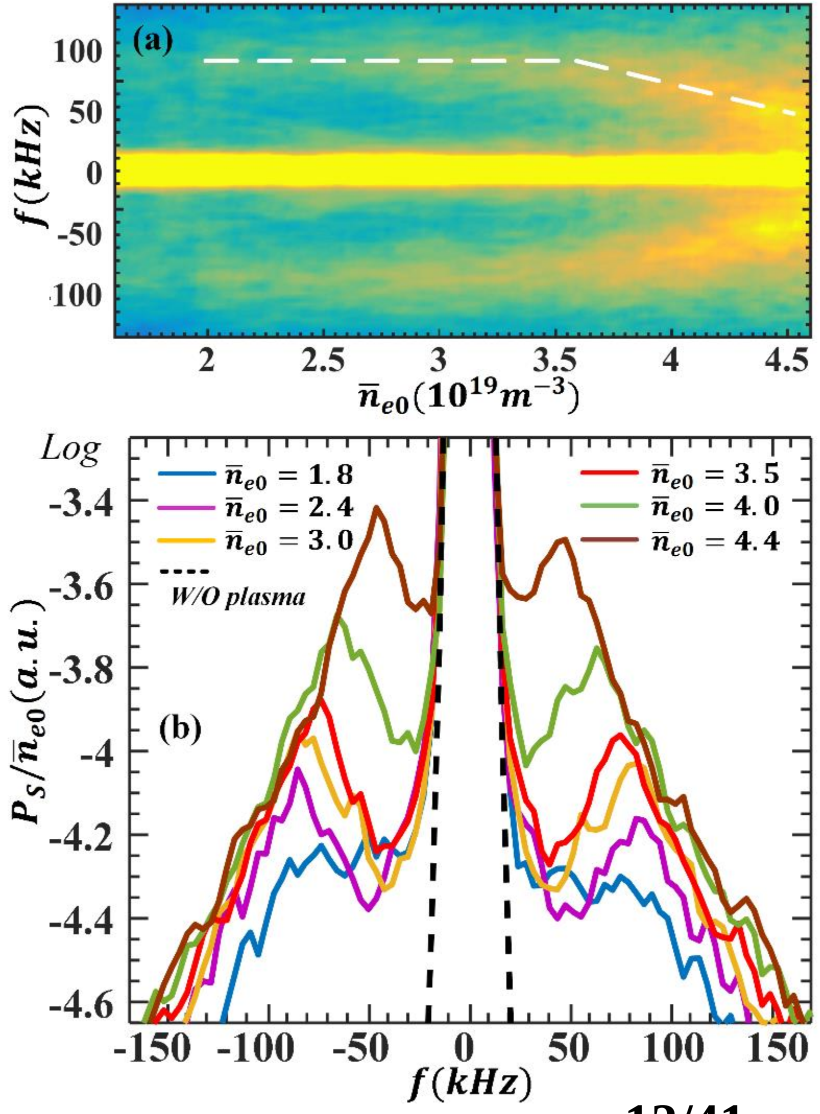
P. Shi

Experimental Investigations of MARFE and Density Limit Disruption on J-TEXT

#1038116: $I_P = 170kA, B_t = 2.1T,$ $n_{e0}(MARFE) = 5 \times 10^{19}m^{-3}$, $n_e(QCM) = 3.5 \times 10^{19}m^{-3}$





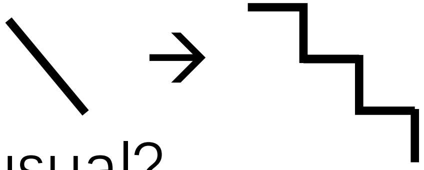


- A strong poloidal asymmetry on electron density and current density, associated with MARFE, which is responsible for density limit disruption, has been frequently observed on J-TEXT.
- Well before MARFE appearance, a quasi-coherent micro-instability is found to enhance rapidly, which is suspected to be the main cause for edge cooling and MARFE exciting.

II) Inhomogeneous Mixing, Staircases

■Some major questions

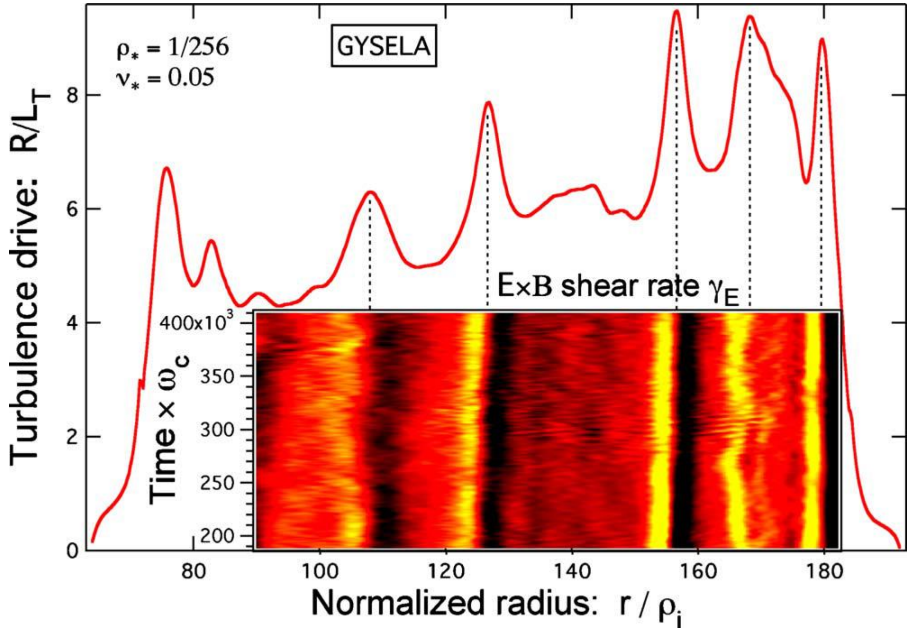
— Why?



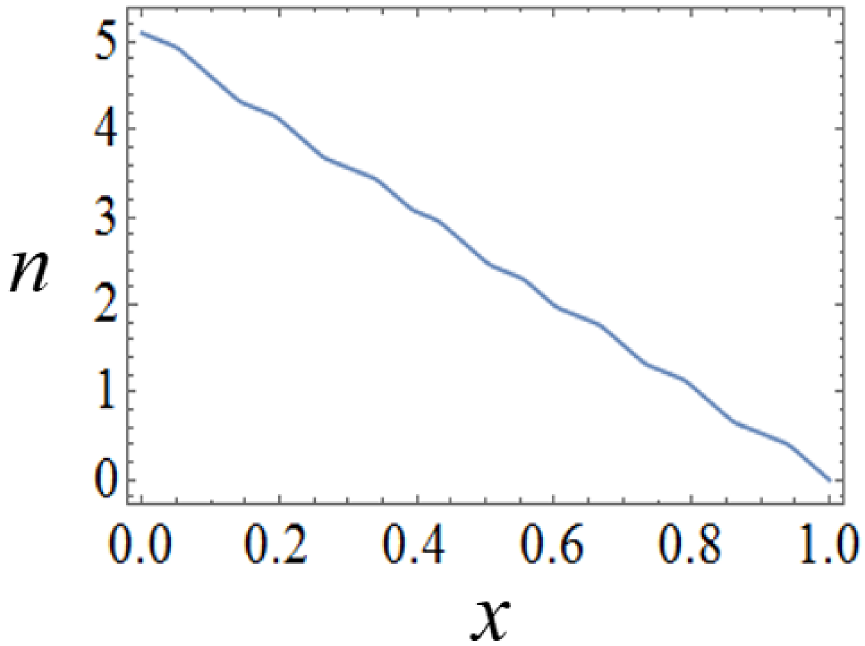
— Exotic or usual?

— Corrugation mechanism

— Scales



[G. Dif-pradalier, *et al*, Physical Rev. E **82**, 025401 (2010)]
[G. Dif-pradalier, *et al*, , Phys. Rev. Lett. **114**, 085004 (2015).]



[Guo, Diamond, et al, PPCF 61 (2019) 105002]

Zonal flow formations in two-dimensional Rossby wave turbulence on a rotating sphere

Obuse

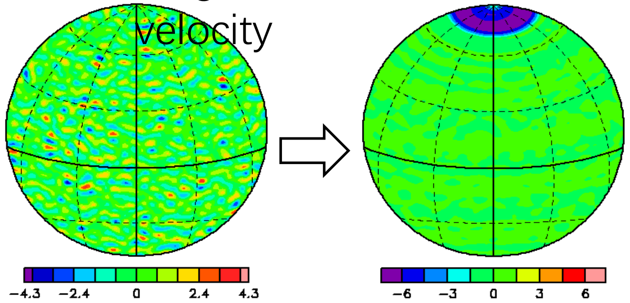
Two-dimensional Navier-Stokes flow on a rotating sphere

Vorticity equation

$$\frac{\partial \zeta}{\partial t} + J(\psi, \zeta) + 2\Omega \frac{\partial \psi}{\partial \phi} = \nu(\nabla^2 + 2)\zeta.$$

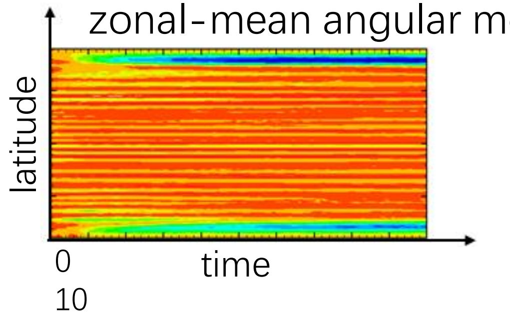
Formation of large-scale circumpolar flow

longitudinal velocity

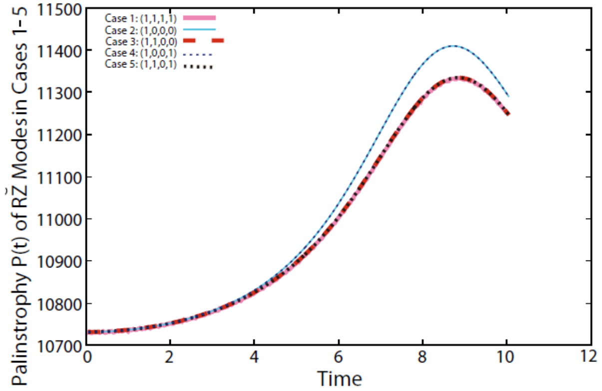


Zonal flow formation still occurs in inviscid limit

zonal-mean angular momentum

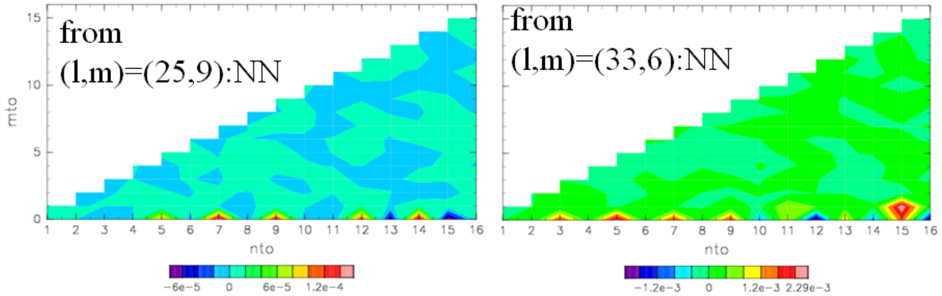


Need to consider both resonant and nonresonant interactions of Rossby



Energy is transferred to resonant-zonal modes by nonresonant inetractions

energy transfer between two modes



Scale selection and feedback loops for staircase

W. Guo

Weixin Guo, P. H. Diamond*, D. W. Hughes, A. Ashourvan and Lu Wang, PPCF 61 (2019) 105002

- Reduced Model from H-W Equation

$$\partial_t n = \partial_x D_n \partial_x n + D_c \partial_x^2 n, \quad (1)$$ → mean density n

$$\partial_t u = \partial_x (D_n - \chi) \partial_x n + \chi \partial_x^2 u + \mu_c \partial_x^2 u, \quad (2)$$ → vorticity u

$$\partial_t \varepsilon = \partial_x D_\varepsilon \partial_x \varepsilon + \chi [\partial_x (n-u)]^2 - \varepsilon_c^{-1} \varepsilon^{3/2} + \mathscr{P}. \quad (3)$$ → turbulent potential enstrophy ε

- $D_n \approx l_{mix}^2 \frac{\varepsilon}{\alpha}$, $\chi = c_\chi l_{mix}^2 \frac{\varepsilon}{\alpha}$, $D_\varepsilon \cong \beta l_{mix}^2 \varepsilon^{1/2}$ → l_{mix} **is important to determine trans.**
- **Feedback loop: Shearing vs Rhines scale**

① $$l_{mix} = \frac{l_0}{[1+u|/(l_0\sqrt{\varepsilon})]^{\kappa/2}}$$

② $$l_{mix} = \frac{l_0}{(1+l_0^2[\partial_x(n-u)]^2/\varepsilon)^{\kappa/2}}$$

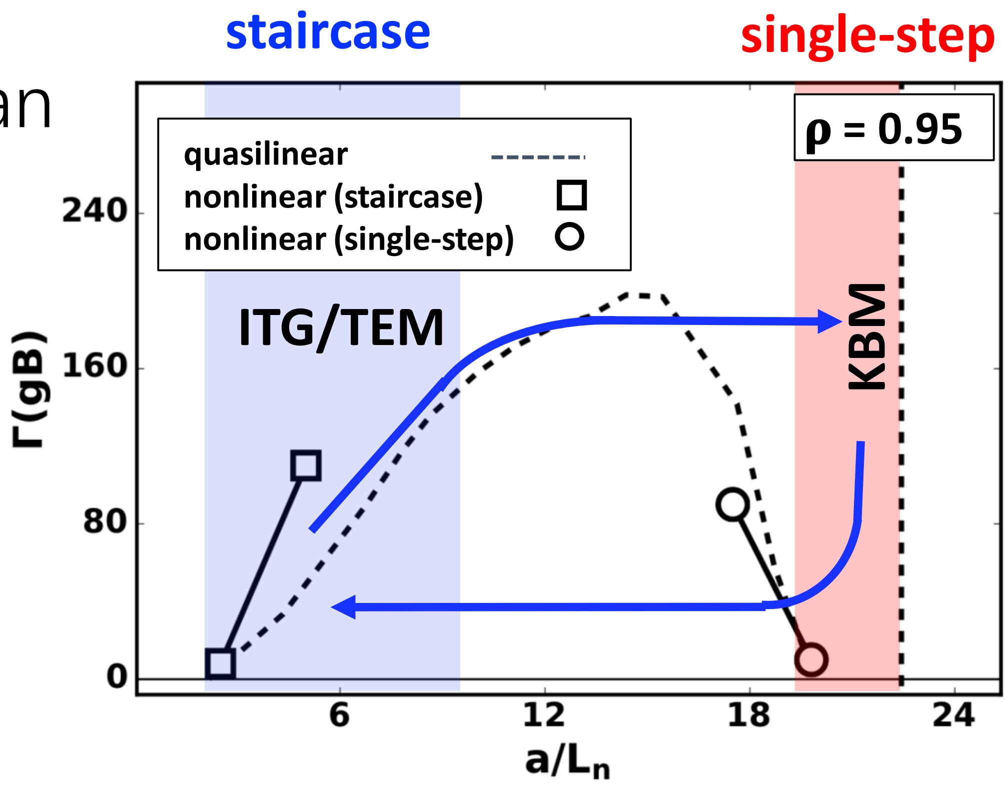
u, $\partial_x n$, $\partial_x u$ → multiple candidates, which mechanism is the most important?

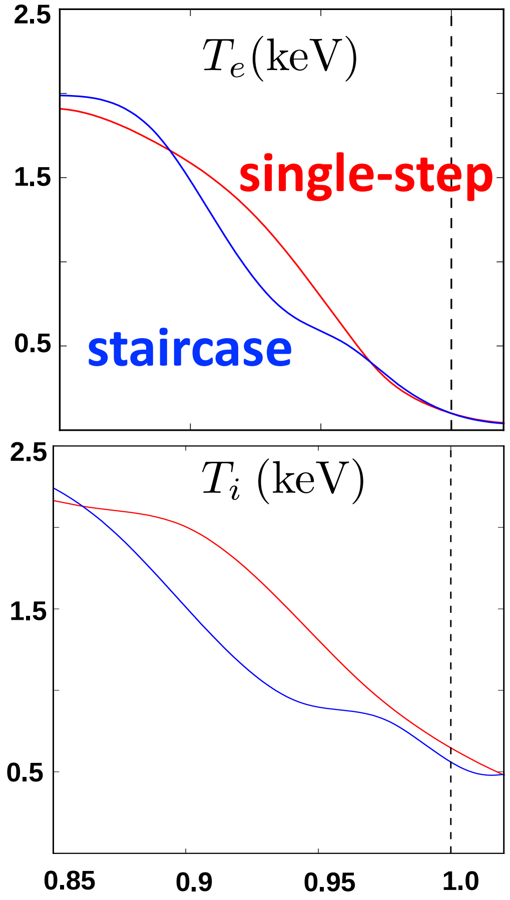
- **Only $E \times B$ shearing → No staircase**
  Rhines scale ($\partial_x n + \partial_x u$) → Recover
  Turn off $\partial_x u$ → Recover pattern

→ Feedback through NL $\partial_x n$ of mixing is key loop

Wide pedestal grassy-ELM regime exhibits staircase pedestal formation[1]

Ashourvan





- **Gyrokinetic analysis shows nonmonotonic flux-gradient relation between the single-step and staircase pedestals (CGYRO)**

  - Transitions driven by modulating flux through pedestal

- **Radially localized turbulence in staircase pedestal leads to *enhanced* pedestal pressure (consistent with ELITE)**

  - Potentially beneficial for confinement in ITER

1. **Arash Ashourvan *et al*, PRL (2019)**

W. Liu

Observation of multiple shear layers and long-range transport events on HL-2A tokamak

Observation in this experiment:

- Multiple **flow reversal** (three or four) layers
- Change of **eddy tilting** at these layers
- Radially modulated **radial correlation length L_r**
- **Reduced permeability** at these layers and **high permeability** between these layers
- **Avalanche-like long-range events** between these layers
- No pronounceable **corrugations** in ∇T_e profile

Analysis:

- All phenomena except the ∇T_e profile satisfy the characteristics of $\boldsymbol{E} \times \boldsymbol{B}$ staircase.
- Possibly the flow shear is not strong enough to corrugate the ∇T_e profile .

Conclusions / Summary

- Magnetic fields suppress turbulent diffusion in 2D MHD by: formation of intermittent ***transport barriers***.
- Magnetic structures:
- Quench not uniform:

Barriers – thin, 1D strong field regions
Blobs – 2D, weak field regions

$$\eta_T = \frac{ul}{1 + \mathrm{Rm}\frac{1}{\mu_0 \rho}\langle \mathbf{B} \rangle^2 / \langle v^2 \rangle + \mathrm{Rm}\frac{1}{\mu_0 \rho}\langle A^2 \rangle / L_{env}^2 \langle v^2 \rangle}$$

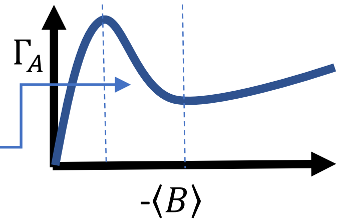
barriers, strong B

blobs, weak B, $\nabla^2 \langle A^2 \rangle$ remains

- Barriers form due to negative resistivity:

$$\eta_T = \sum_{\mathbf{k}} \tau_c [\langle v^2 \rangle_{\mathbf{k}} - \frac{1}{\mu_0 \rho} \langle B^2 \rangle_{\mathbf{k}}]$$

flux coalescence



- Formation of "magnetic staircases" observed for some stirring scale

Q. Yan

Spinodal Decomposition $\Longrightarrow$ 2D Cahn-Hilliard Navier-Stokes (CHNS) system:

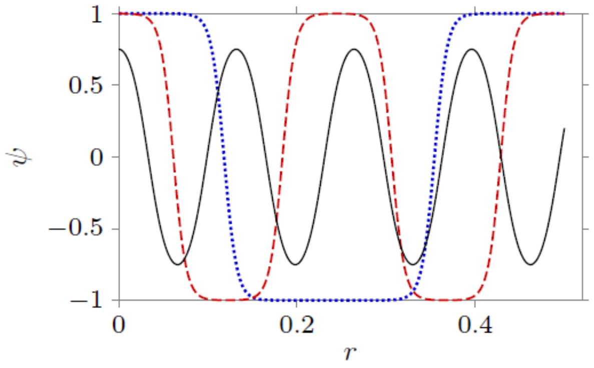
$$\partial_t \psi + \mathbf{u} \cdot \nabla \psi = D\nabla^2[-\psi + \psi^3 - \xi^2 \nabla^2 \psi] \quad (1)$$

$$\partial_t \omega + \mathbf{u} \cdot \nabla \omega = (\xi^2/\rho)\mathbf{B}_\psi \cdot \nabla \nabla^2 \psi + \nu \nabla^2 \omega$$

In prescribed eddy-like velocity flow, target pattern form. Jacobi Elliptic Function solution and linear instability,

$$\psi = \beta \mathrm{sn}\left((\alpha/\sqrt{2}\xi\beta)(r + \lambda/4), k\right) \quad (2)$$

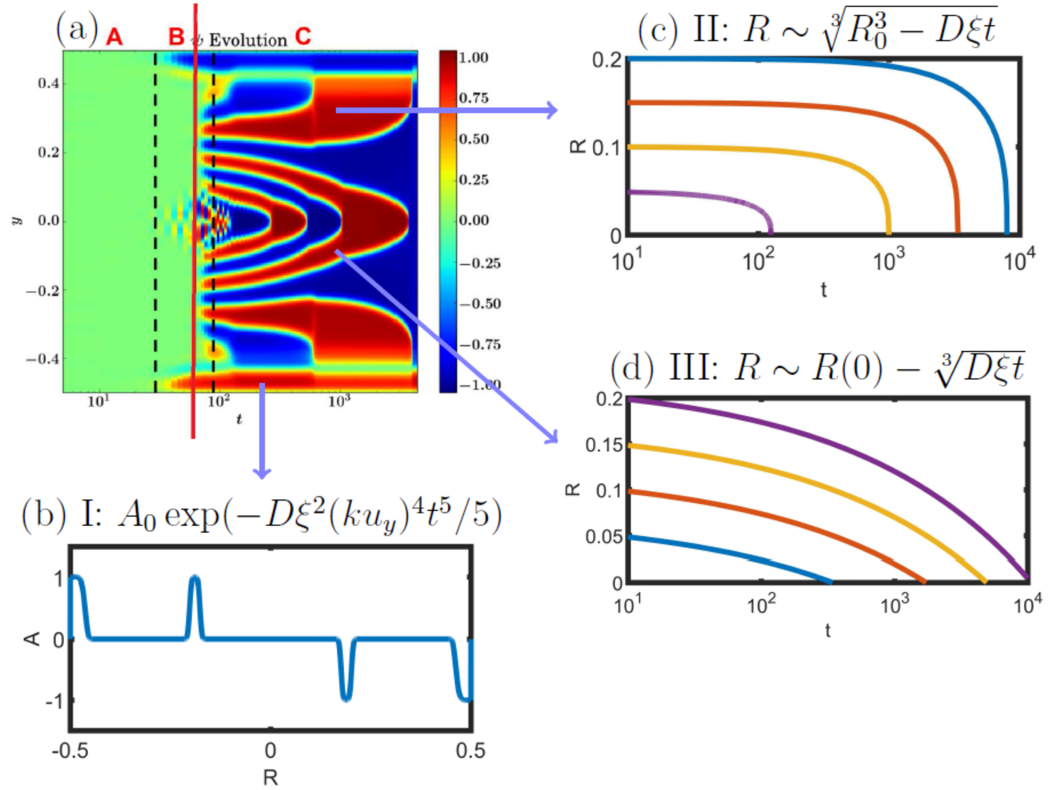
$$\sigma = D[(1 - 3\bar{\psi}^2)k_y^2 - \xi^2 k_y^4] \quad (3)$$



$$\bar{\psi} = \pm 1 \rightarrow \sigma < 0;\ \bar{\psi} = 0 \rightarrow k_{ys} = 1/(\sqrt{2}\xi).$$

Interface diffusion speed,

$$V(x, t_1) = D[\hat{n} \cdot \nabla \mu_1]_-^+ [\psi]^{-1} \sim -D\nabla\kappa \quad (4)$$



Non passive condition is

$$\frac{\xi^2 B^2}{\rho U_v^2}\left(\frac{U_v L_v^3}{D\xi^2}\right)^{3/5} \sim 1 \Longrightarrow M^2 \mathrm{Rm}_e^{3/5} \sim 1$$

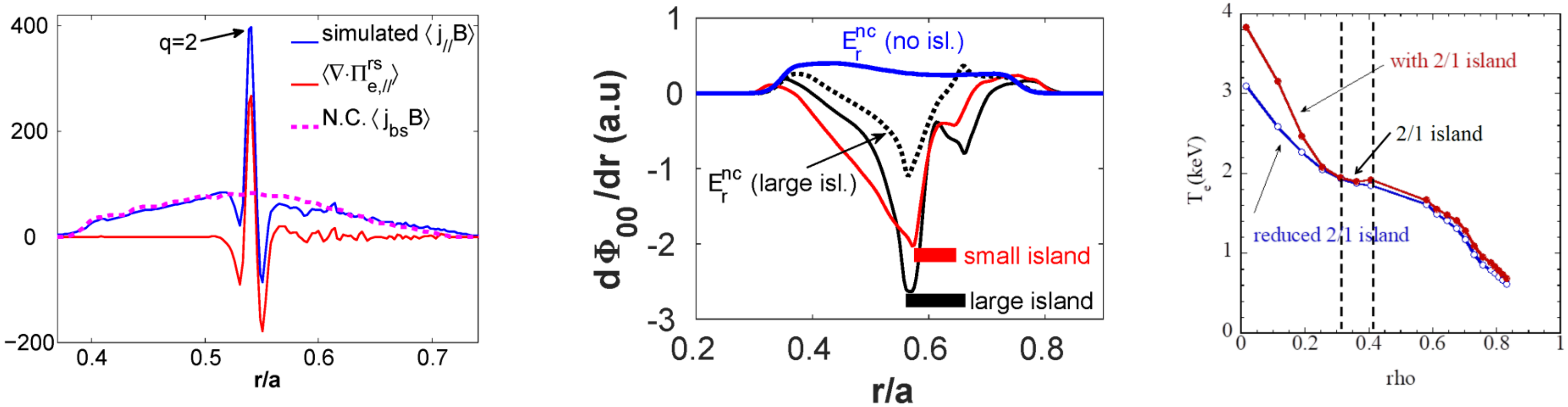
Fig(a) Reprint from Xiang Fan, P. H. Diamond, and L. Chacón. *Phys. Rev. E*, *96:041101, Oct 2017.*

III) Flow Pattern Formation: Shear, Rotation

- Some major questions:
  - — direct evidence for residual stress?
  - — export approaches for flows → currents?
  - — symmetry and self-linkage?
  - — helicity?!

ExB Shear flow structure and plasma self-driven current generation in magnetic island -- a phenomenology for ITB formation at rational magnetic surface

- Turbulence can change plasma self-driven macroscopic current generation and drive **a strong electron current profile corrugation** near rational surface with weak magnetic shear by residual stress, which may seed/drive a magnetic island at the surface



- A localized ExB shear layer is found to form at the inner boundary of island; its shearing rate increases with island width
- Stationary 2/1 potential structure also forms at the same location
- Strong ExB shear layer formed at island inner boundary can be a natural barrier to for plasma transport: -- suppress turbulence locally; -- prevent turbulence spreading from one side to another

L. Wang **Intrinsic current driven by electromagnetic turbulence**

- For EM ETG turbulence in core region: intrinsic current significantly affects the local current density profile
  - ✓ The turbulent flux driven intrinsic current density can reach about 80% of the local bootstrap current density
  - ✓ Less than 1% from turbulent source

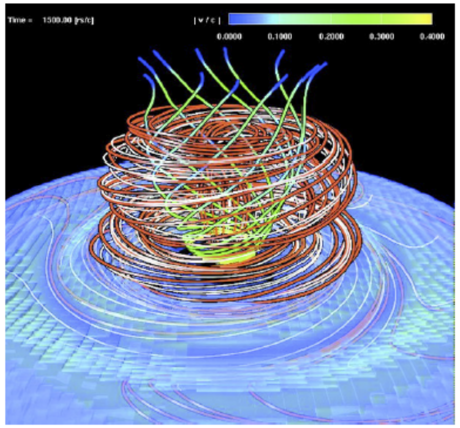
[Wen He, Lu Wang*, Shuitao Peng, Weixin Guo, and Ge Zhuang, Nucl. Fusion 58 106004 (2018)]

- For EM electron DW turbulence in pedestal region: EM effects important
  - ✓ Non-adiabatic contributions are strongly cancelled by the EM effects
  - ✓ Turbulent flux driven part (adiabatic kinetic stress) is dominant as compared to source driven part
  - ✓ Effects of ExB shear are not self-consistent in this work

[Wen He, Lu Wang*, and Ge Zhuang, PPCF 61, 115016 (2019)]

Y. Kosuga

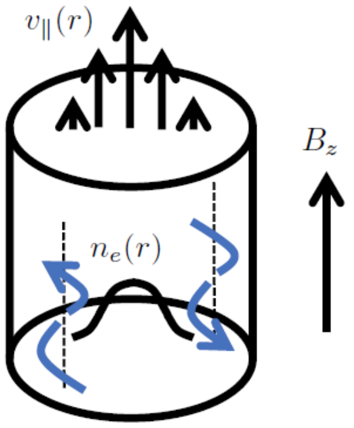
Summary



- Flow helicity dynamics is described for magnetized plasmas.
- Helicity budget for electrostatic turbulence derived.
- Reflectional symmetry breaking related to parallel symmetry breaking.

e.g. for PVG turbulence $k_z k_y \langle v_z \rangle' > 0 \quad k_z = k_y \frac{\langle v_z \rangle'}{2\omega_{ci}}$

$$\langle \tilde{\mathbf{v}} \cdot \tilde{\omega} \rangle = 4 c_s \omega_{ci} \frac{c_s / L_n}{\langle v_z \rangle'} \sum_{\mathbf{k}} k_\perp^2 \rho_s^2 \left| \frac{e \tilde{\phi}_{\mathbf{k}}}{T_e} \right|^2 \propto -\langle n \rangle' \langle v_z \rangle' B_z$$



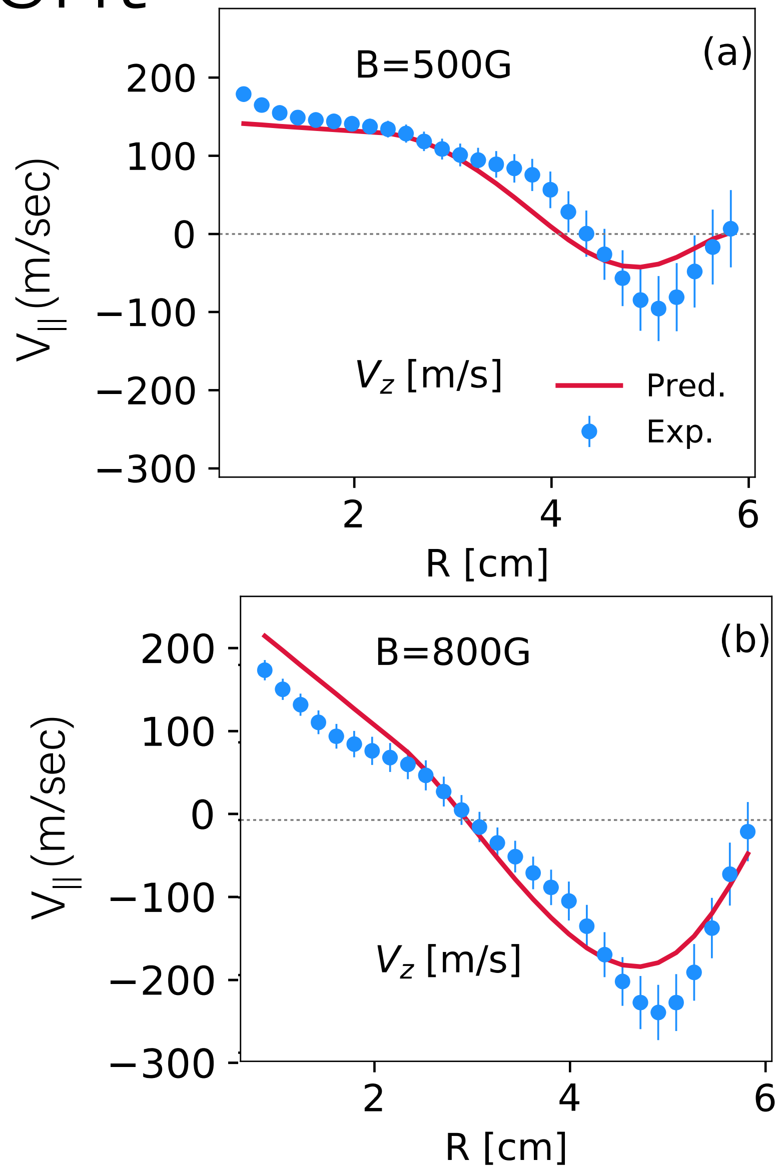
Gas of left-handed helixes

- Implications on flow formation in fusion discussed.

Intrinsic parallel sheared flow development in basic experiment

G. Tynan

- Radially sheared parallel flow develops in linear plasma device as grad-n is increased and collisional drift turbulence develops
- Turbulent-driven residual stress due to spectral symmetry breaking is measured
- Sheared flow is self-consistent with stress & ion-neutral collisional drag
- Dynamical symmetry-breaking model seems consistent w/ experiment



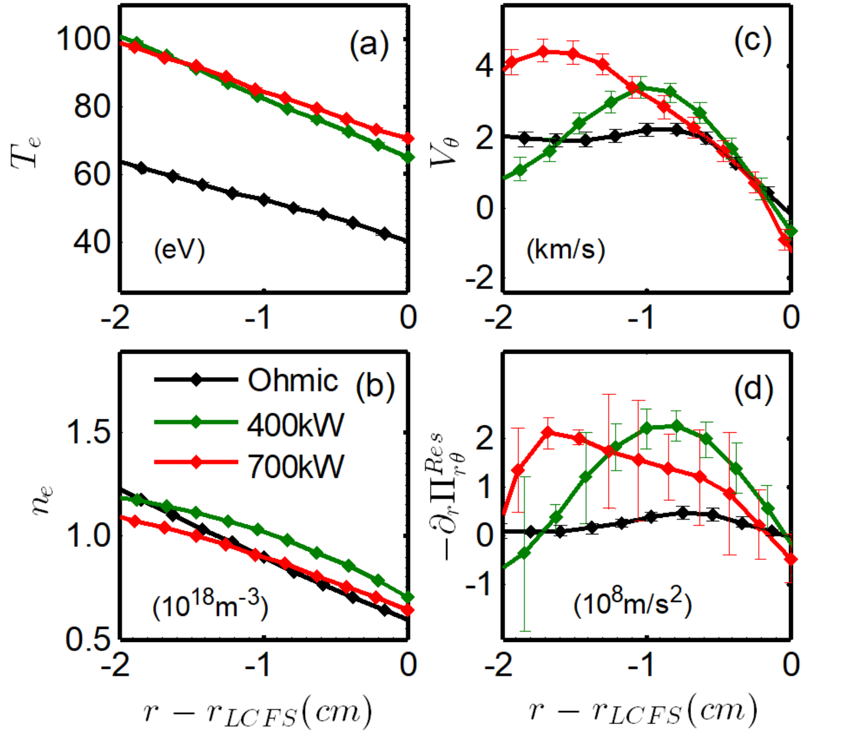
Hong et al, PRL'18

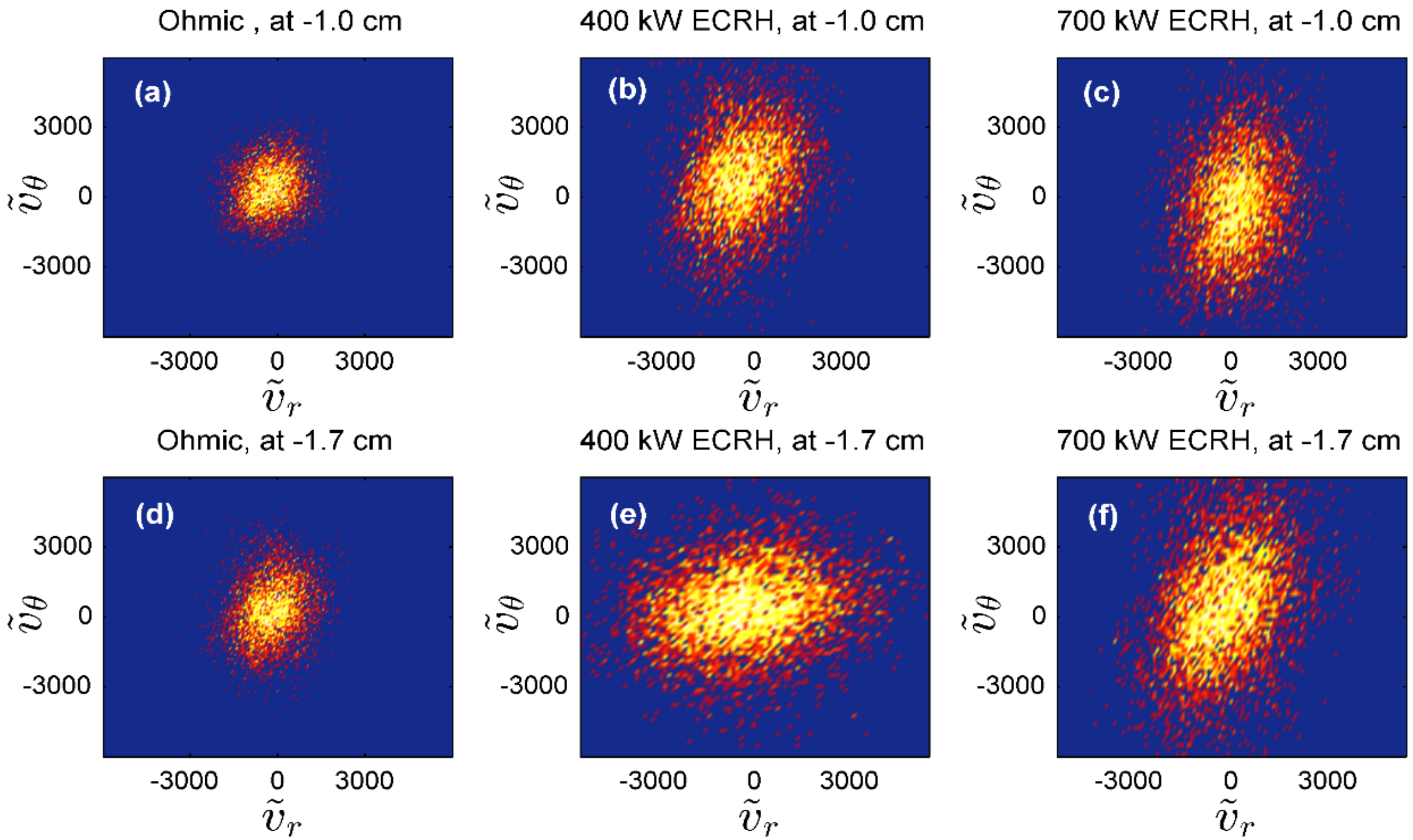
T. Long

Studies of Reynolds Stress and the Turbulent Generation of Edge Poloidal Flows on the HL-2A Tokamak

$$\langle \tilde{v}_r \tilde{v}_\theta \rangle = -\chi_\theta \partial_r \langle v_\theta \rangle + v_r^{eff} \langle v_\theta \rangle + \Pi_{r\theta}^{Res}$$

Reynolds stress	diffusive stress	convection stress	residual stress





T. Long, P.H. Diamond and M. Xu et al 2019 Nuclear Fusion 59 106010

- As ECRH power increases, v_θ increases, the intrinsic poloidal torque increases significantly, the region of the rotation torque extends inwards, thus driving an increasing poloidal flow.
- Dynamics of **spectral symmetry breaking in drift wave turbulence**, in good agreement with this.

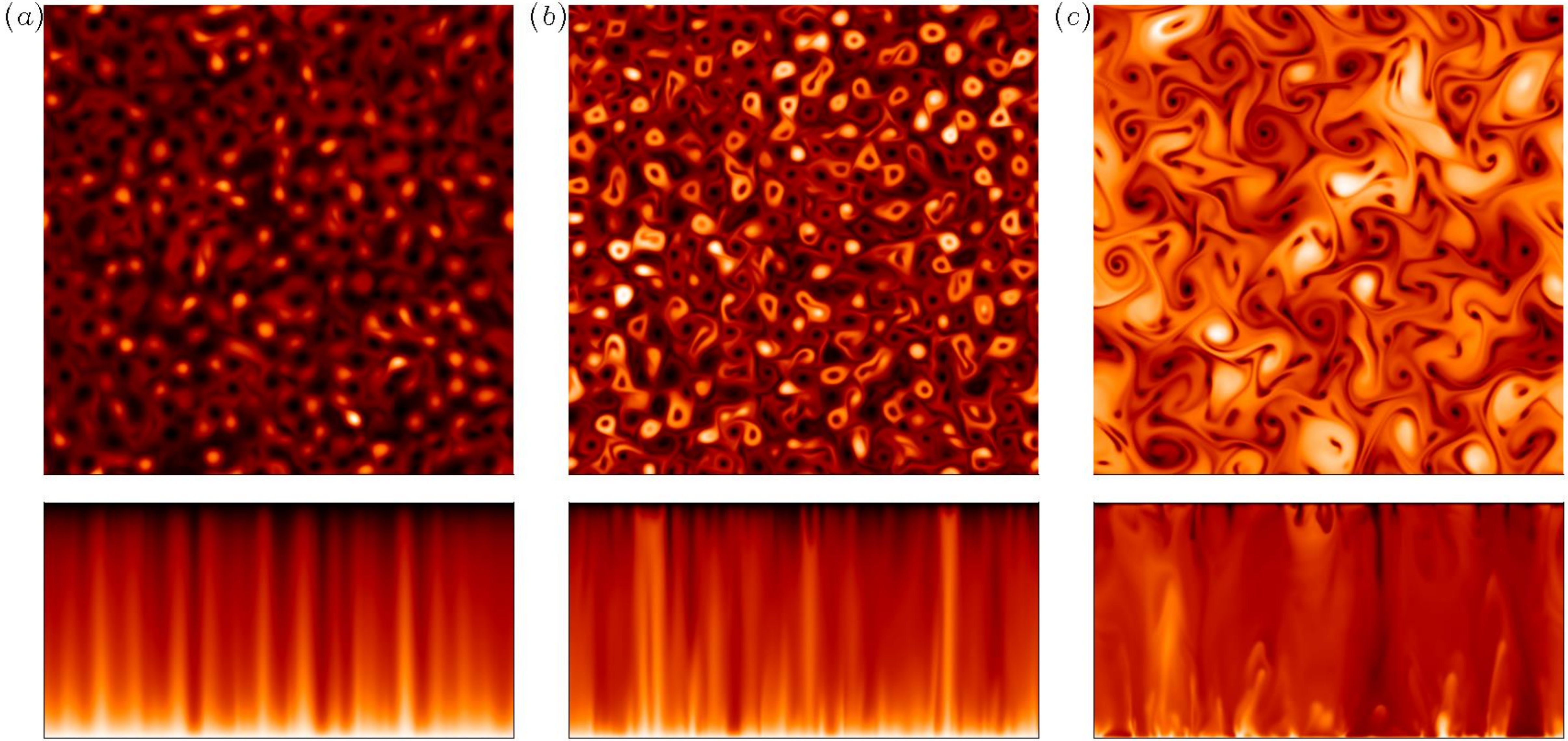
IV) Magnetic Self-Organization: Dynamics

- Some major questions
  - — role of **B** in Dynamo?
  - — **B** , **Ω** and Toylar-Proudman?
  - — how to describe coronal loops?
  - — QSH Barrier?

Hughes **Dynamo action in rapidly rotating convection with no inertia**

- Earth' s magnetic field is maintained by a dynamo, and is characterised by **small inertia** and **small viscosity** (small Rossby number and small Ekman number). A long-standing question is: What is the **balance of forces**?
- We study this problem by studying dynamos driven by rotating convection: we neglect inertia from the outset (thus turning the momentum equation from prognostic to diagnostic), but retain the viscous forces.
- We have identified two distinct types of dynamo: *Weak field dynamos,* in which the magnetic field has only a small (but subtle) influence on the flow dynamics; ***Strong field dynamos,*** **in which the magnetic field, through the Lorentz force, moves the flow to a much larger scale** than it would take hydrodynamically**.**
- Through the use of solenoidal projections, we are able to calculate the dynamically significant components of all the forces. Our key finding is that, in the parameter regime considered, viscosity can never be neglected

Hughes **Dynamo action in rapidly rotating convection with no inertia**



Steady States for Solar Coronal Loops

- First consistent MHD model for the steady state of solar coronal loops at "low" $\beta<1$, as a curved magnetic flux rope containing current
  - Problem well understood for toroidal fusion plasmas: stabilize the major radius expansion instability ($R \leftrightarrow$ loop height)
  - Expand in small inverse aspect ratio $\varepsilon=a/R$
- New results: ∇p and small solar gravity $\rho\mathbf{g}$ are important
  - Scaling of MHD gravity parameter $\hat{G}=ga/v_A^2 \sim \beta\varepsilon^k$ in powers of ε and scaling $\beta\sim\varepsilon^b$ determines the stable states
  - Model fits thin coronal loops $\varepsilon\sim0.02$ in Active Regions; consistent with thicker loops $\varepsilon\sim0.1-0.2$
- Many implications and possible extensions
  - Model needs higher resolution observations of loop

Agents of Transport

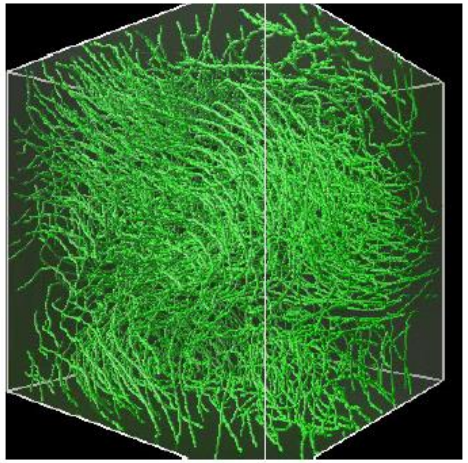
- Some major questions:
  - — vortex reconnection in turbulence, dissipation, structure?
  - — how to describe turbulence spreading?
  - — phase evolution?
  - — impact?

Vortex reconnection and a finite-time singularity of the Navier-Stokes equations

- Vortex reconnection is a fundamental process in both classical and quantum turbulence.
- The Biot-Savart model for an antiparallel vortex pair suggests a finite time singularity of Euler's equation.
- A tent model (with tilted hyperbolae) is introduced to show a specific geometric shape of the vortex curve in the process of reconnection.
- If the tilted hyperbolae are replaced with tilted circular vortex rings, analytic velocity of the vortices can be calculated explicitly.
- With the expression of the analytic velocity, a nonlinear dynamical system for the dynamics of the tipping points can be obtained in terms of for the half of minimum distance $s(\tau)$, the curvature $\kappa(\tau)$ at the tipping point and the radius of the core cross-section $\delta(\tau)$.

Kobayashi-I18 Theoretical study of quantized vortices and quantum turbulence

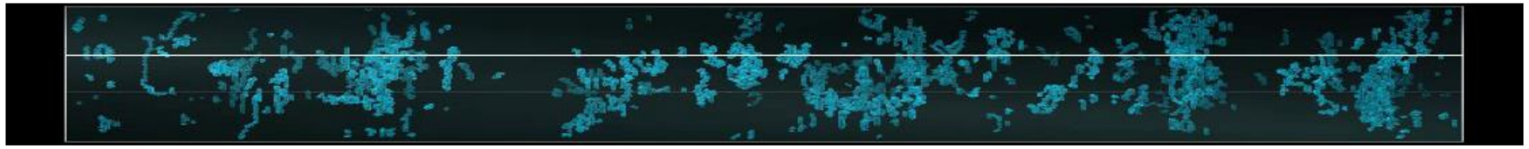
- Fully developed quantum turbulence



Kolmogorov universality : $E(k) \propto k^{-5/3}$

- Phys. Rev. Lett. **94**, 065302 (2005)
- J. Phys. Soc. Jpn. **74**, 3248 (2005)

- Weakly developed quantum turbulence

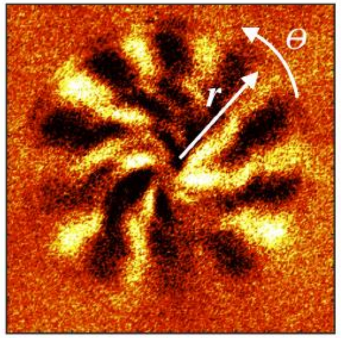


Directed percolation universality : $\rho_{\mathrm{vortex}} \propto (v - v_{\mathrm{c}})^{\beta=0.811}$

Z. Guo

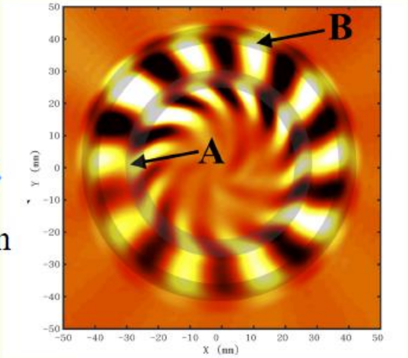
Observation of Phase Curvature Accelerating Zonal Flow

Observation of streamer-ZF interaction in PKU Plasma Test(PPT) linear device:



SVD Decomposition

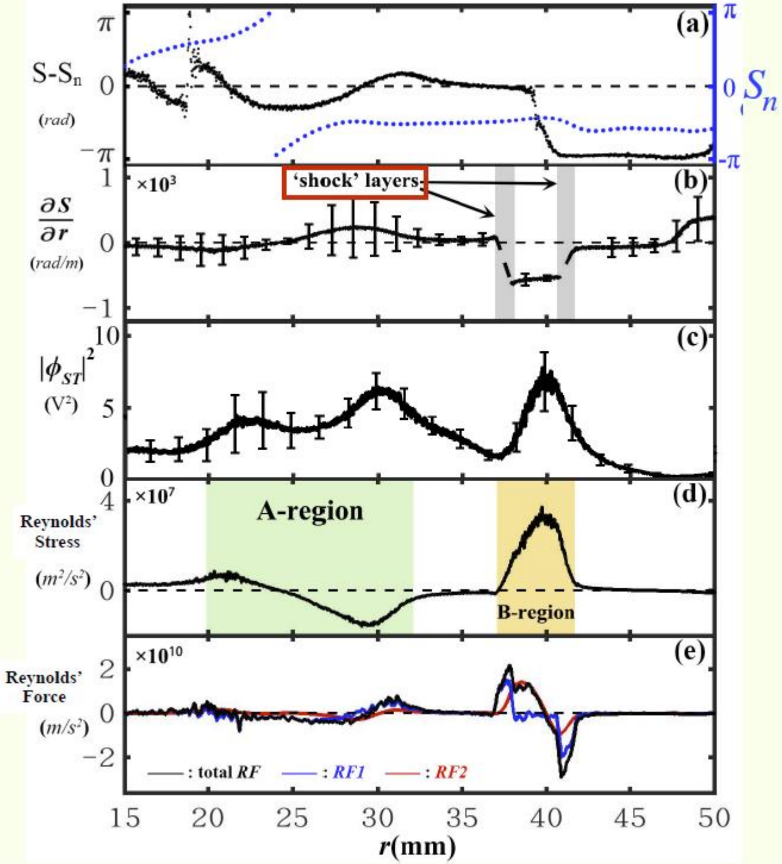
in the outer region



$$RF = \underbrace{2\frac{m}{rB^2}\frac{\partial^2 S}{\partial r^2}\langle \phi_{ST}^2 \rangle}_{RF1} + \underbrace{2\frac{m}{rB^2}\frac{\partial S}{\partial r}\frac{\partial}{\partial r}\langle \phi_{ST}^2 \rangle}_{RF2}$$

$RF1$: Reynolds' force by phase curvature

$RF2$: Reynolds' force by amplitude gradient



Inside the phase-gradient shock layers, the phase curvature plays a prominent role in accelerating the zonal flow.

Conclusion and Future plans

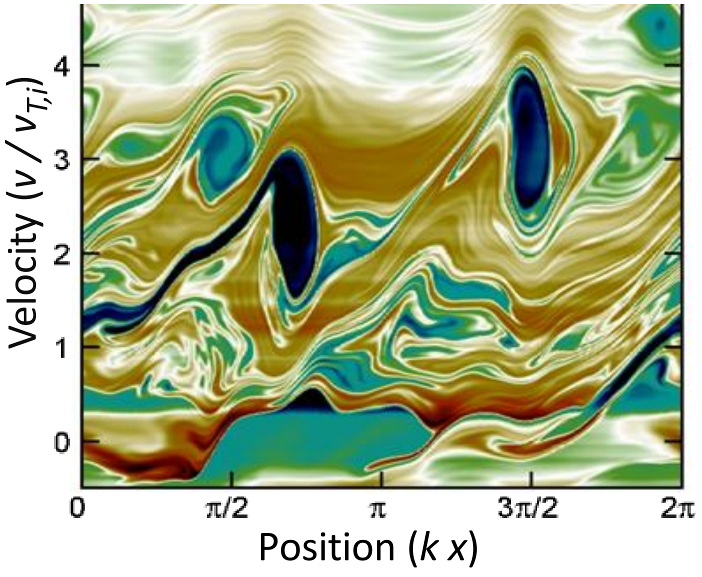
- A new understanding of KH instability is presented.
- We have given instability criterions that triggers instability in adiabatic drift wave-shear flow system.
- What exactly this mode are?
- When shear flow suppress turbulence, what role does flow shear and flow curvature play?

Lesur

Description of turbulent transport in the velocity space

Close to marginal stability, and below in particular (subcritically), phase-space structures can dominate transport, and anomalous resistivity

$\Rightarrow$ Nonlinear growth rate



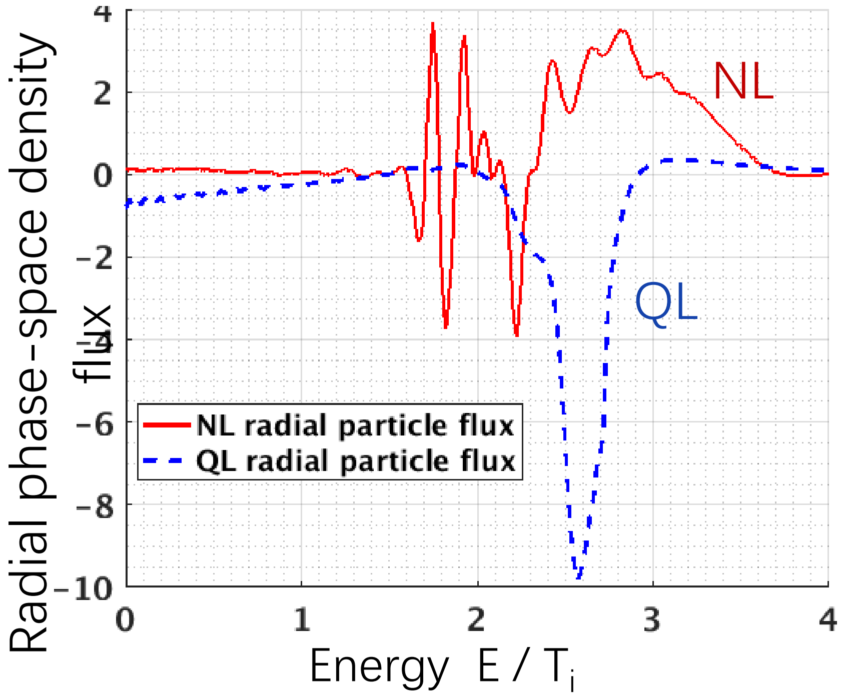
$$\gamma_\Psi \approx \frac{16}{3\sqrt{\pi}} \frac{\Delta v}{v_R} \frac{\gamma_L}{\omega_p} \gamma_d .$$

Lesur '13

In tokamaks, drift-holes cause strong departures from quasilinear theory

$\Rightarrow$ Kubo number K *Médina '18*

- Global K $\lesssim$ 1
- Local K $\gg$ 1



Conclusions → Take-away Messages

→**Mean field methods** now advanced: Pinch, non-diffusive stress, turbulent sources, $Q_{e,i}$

But, many challenges:
—Nonlocal
—Quasi/Weakly CM, EHO……
⇒ regulates particle transport

→**Mixing is inhomogeneous** ↔ corrugated profiles

—Bistable mixing, Q time delay……
— Challenges: mean field, minimum entropy production picture
— Ubiquitous: Tore Supra, JET, DIII-D, KSTAR, HL-2A……
⇒ **NOVEL pedestal ↔ complex, self organized state.**

→**Theory of intrinsic rotation now is applied to current**. Turbulence driven current **significant** relative to bootstrap.

Conclusions → Take-away Messages

→**Phase Dynamics**

—phase evolves dynamically — major departure mean field/QL

— $\langle \tilde{v}_r \tilde{v}_\theta \rangle = \sum_k |A_k|^2 \, k_\theta \partial_r \psi_k$

$\partial_t \psi_k =$...... $\partial_t |A_k|^2 =$......

— locking, slips, cycles, synch……

— evidence: basic experiments (PKU PPT)

— relevant QCM phenomena?!

→**Force Balance States (MAC) are subtle……**

—need retain inertia, viscosity even if weak

—field dynamos possible, both weak, strong?

✓ Similar problem:
$E_r \leftrightarrow$ radial force balance

→**Directed percolation is useful**, framework for "phase transition" in turbulence **(including spreading)**

—D.P model of growth of quantum phase of superfluid turbulence.

Discussion I: Memory in Turbulence

— Ku<1 (Ku=$\frac{\tilde{v}\tau_c}{\Delta}$) → Mean Field / QL applies (!?)

But:

— Ku≥1, **M.L.T** → Ku~1? Approach ↑ ↓
Percolation theory? Other?

— Physics of { Fractional Kinetics / Continuous Time Random Walks } Prediction?

— Zwanzig-Mori Formalism — Memory Function

- tractability in non-trivial regimes?
- projection — how?

Discussion II: Role of Basic Experiments

— Extensive work on fluctuations, flows, shear suppression

But,

— should address:

- dual populations, transition evolution
- avalanching need $\rho_* \downarrow$ $\leftrightarrow$ Pulsed source
  Flux-Gradient Relation? $\leftrightarrow$ Tracers
- shear layer collapse

— What ever happened to TWT?

- revisiting QL, mode-mode couplings for resonant particles
- phase space granulation

Discussion III: What is new?—Staircases, Phase Dynamics

— Staircases

- mechanism: Bi-stable mixing?
  Mixing length (Kadomtsev '66) → **2 scales**
- "negative viscosity" + feedback ⟹ staircases??
- how to control?! $\langle v_E \rangle'$, zonal interplay?

— Phase dynamics

- how to calculate transport with dynamic phase?
- scale of synchronization?
- from weak, wave turbulence → filaments, turbulence?!

Thanks for your attention!