

# On the self-consistent evolution of the zonal state

## Colloquium

ASIPP – Hefei, November 9, 2023

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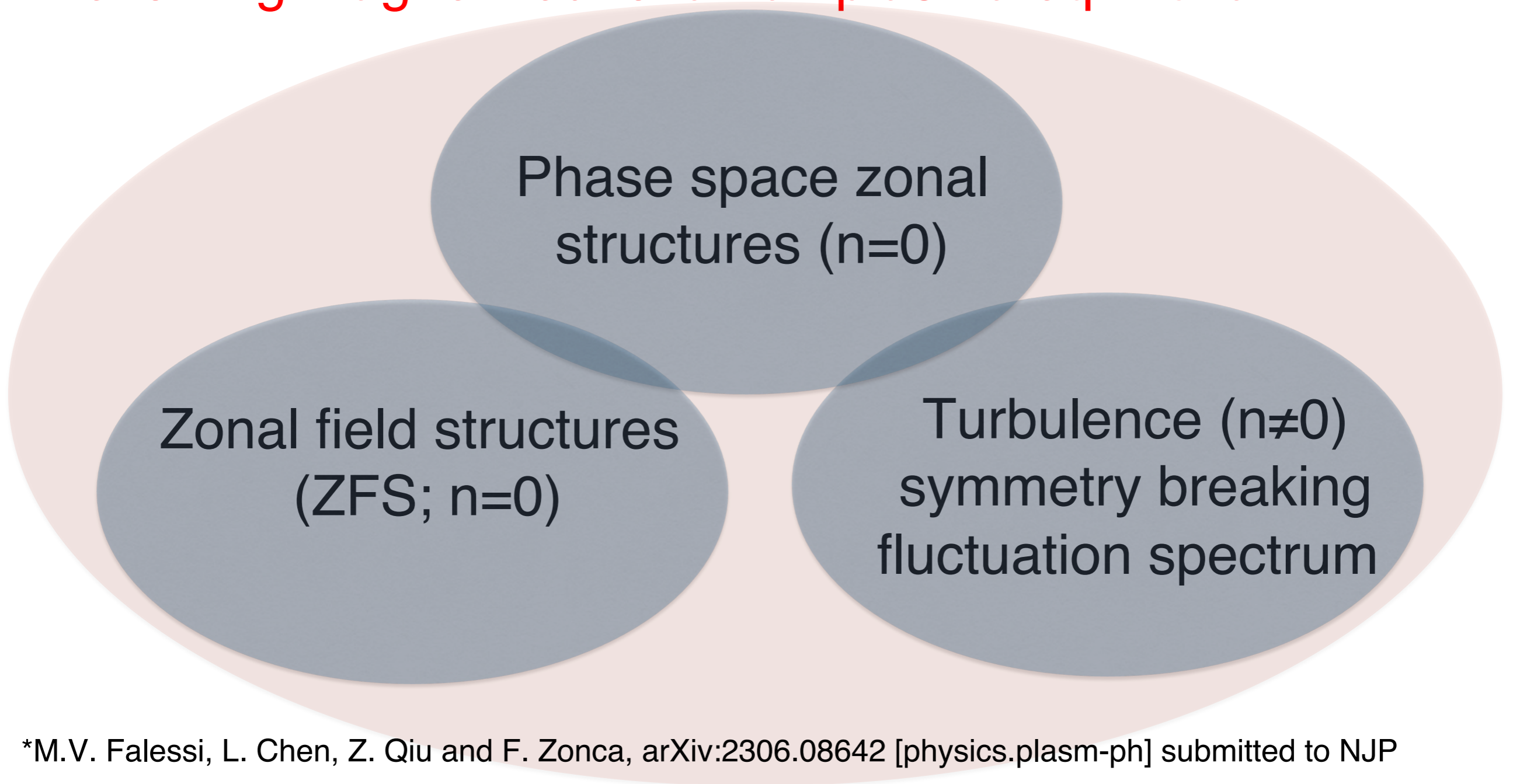
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# Background: the zonal state

- The zonal state (ZS) represents a **portrait of nonlinearly evolving magnetized tokamak plasma equilibria\***:



\*M.V. Falessi, L. Chen, Z. Qiu and F. Zonca, arXiv:2306.08642 [physics.plasm-ph] submitted to NJP

# Gyrokinetic transport theory

- Based on these concepts we can develop **a gyrokinetic transport theory<sup>\*,\*\*</sup>**:
  - Based on the NL GK equations
  - Describing **transport in phase space** rather than profile evolution of model distribution function
  - Capturing **nonlocal transport, meso-scales, avalanches** and deviation from local thermodynamic equilibrium
  - Suitable for constructing a **hierarchy of reduced transport models** up to the energy confinement time scale
  - Reducing to usual description in the proper limit

\*M.V. Falessi and F. Zonca, Phys. Plasmas **26**, 022305 (2019).

\*\*F. Zonca, L. Chen, M.V. Falessi and Z. Qiu, JPCS **1785**, 012005 (2021).

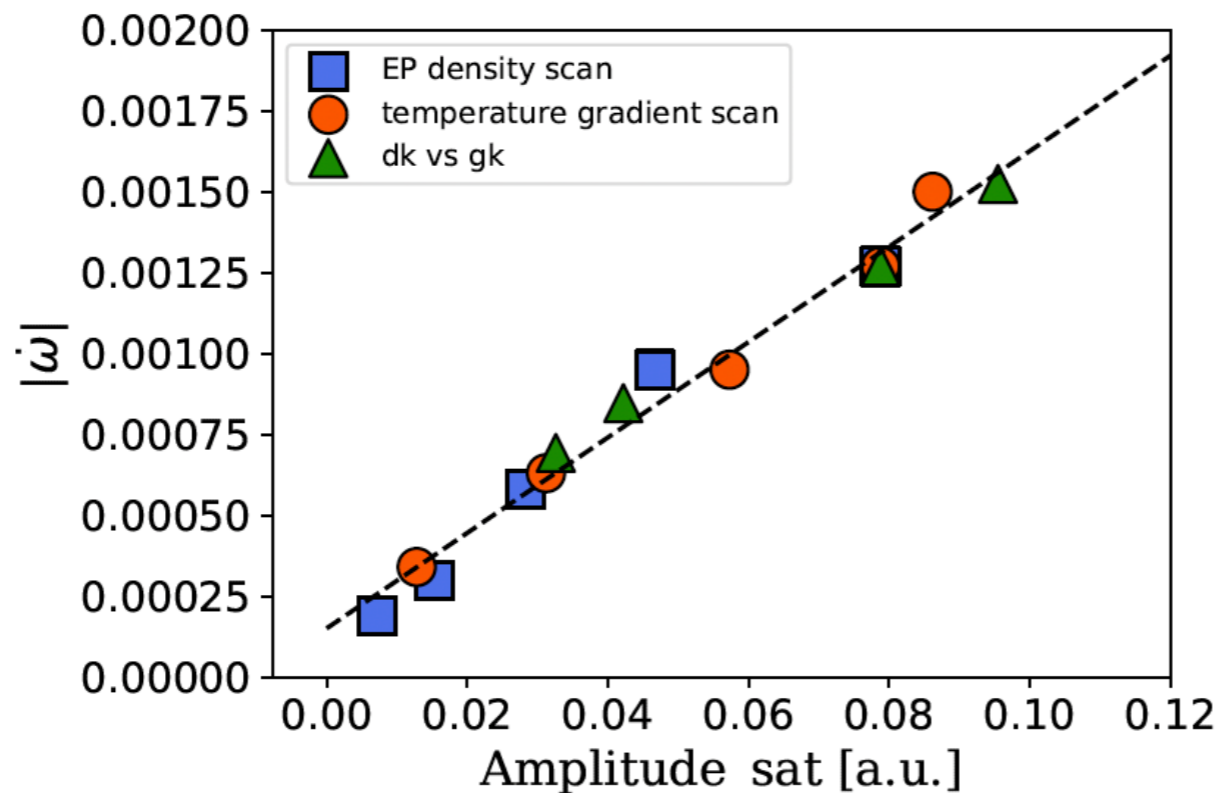
# EGAM frequency chirping

- **Universal feature**, in common with EPM, fishbone and Chorus in Earth's magnetosphere (ZCFQ FEC 2023): **linear scaling of chirping rate with fluctuation amplitude**

$$\frac{\partial \omega_G}{\partial t} = R \omega_{tr}^2$$

$$\omega_{tr}^2 = \omega_{res} \frac{\partial \omega_{res}}{\partial \mathcal{E}} \frac{e}{m} \left[ \overline{e^{iQ_G} \cos l \vartheta_c J_0 |\delta \phi_G|} \right]$$

- Recent simulation results by X. Wang et al. (EPS&FEC 2023)



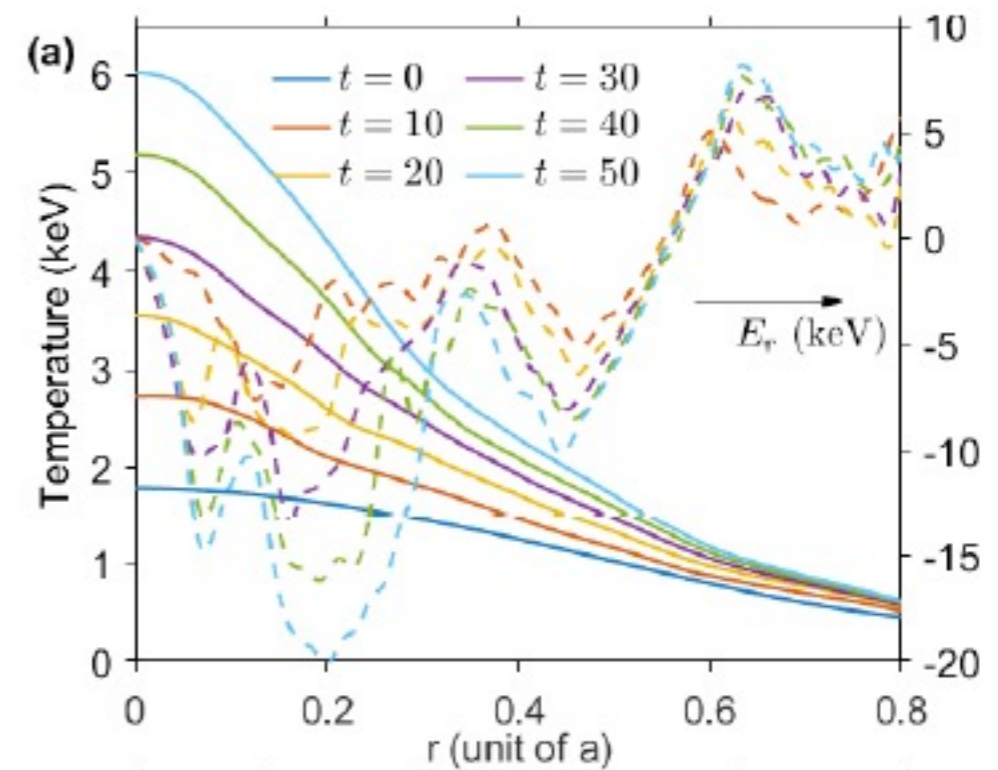
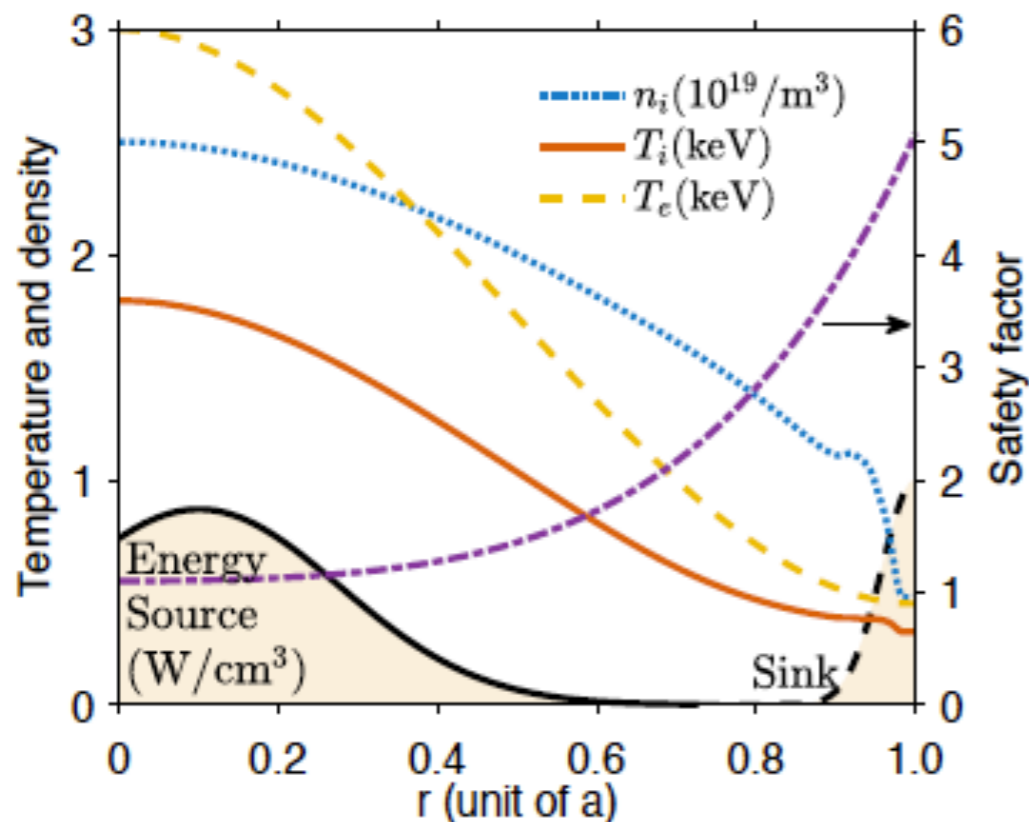
X. Wang et al “Nonlinear dynamics of nonadiabatic chirping-frequency Alfvén modes in Tokamak plasmas”  
PPCF to be published - ORB5 simulations

# Recent results from NLT

## □ Self-organization of internal transport barrier in turbulent fusion plasmas (SJ Wang et al)

[arXiv - PHYS - Plasma Physics](#) Pub Date: 2023-10-02 , DOI:[arxiv-2310.01355](#)

## □ Neighboring Equilibrium Update (NEU) method (ref to C&Z NF 2007 and Falessi&Z POP 2019)

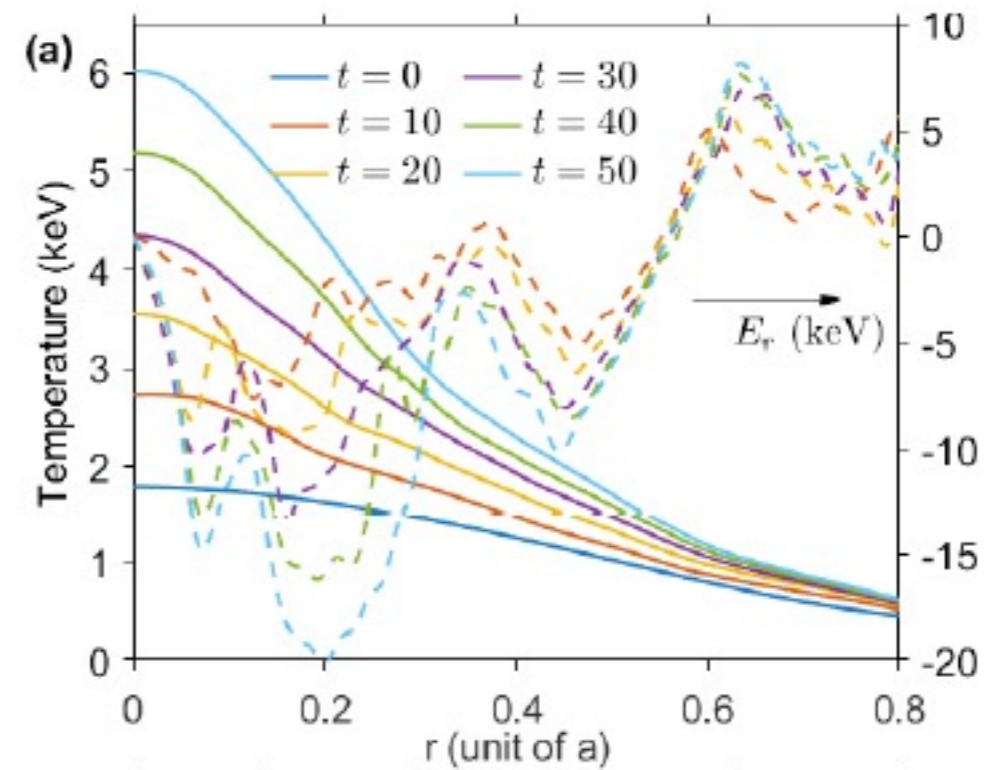
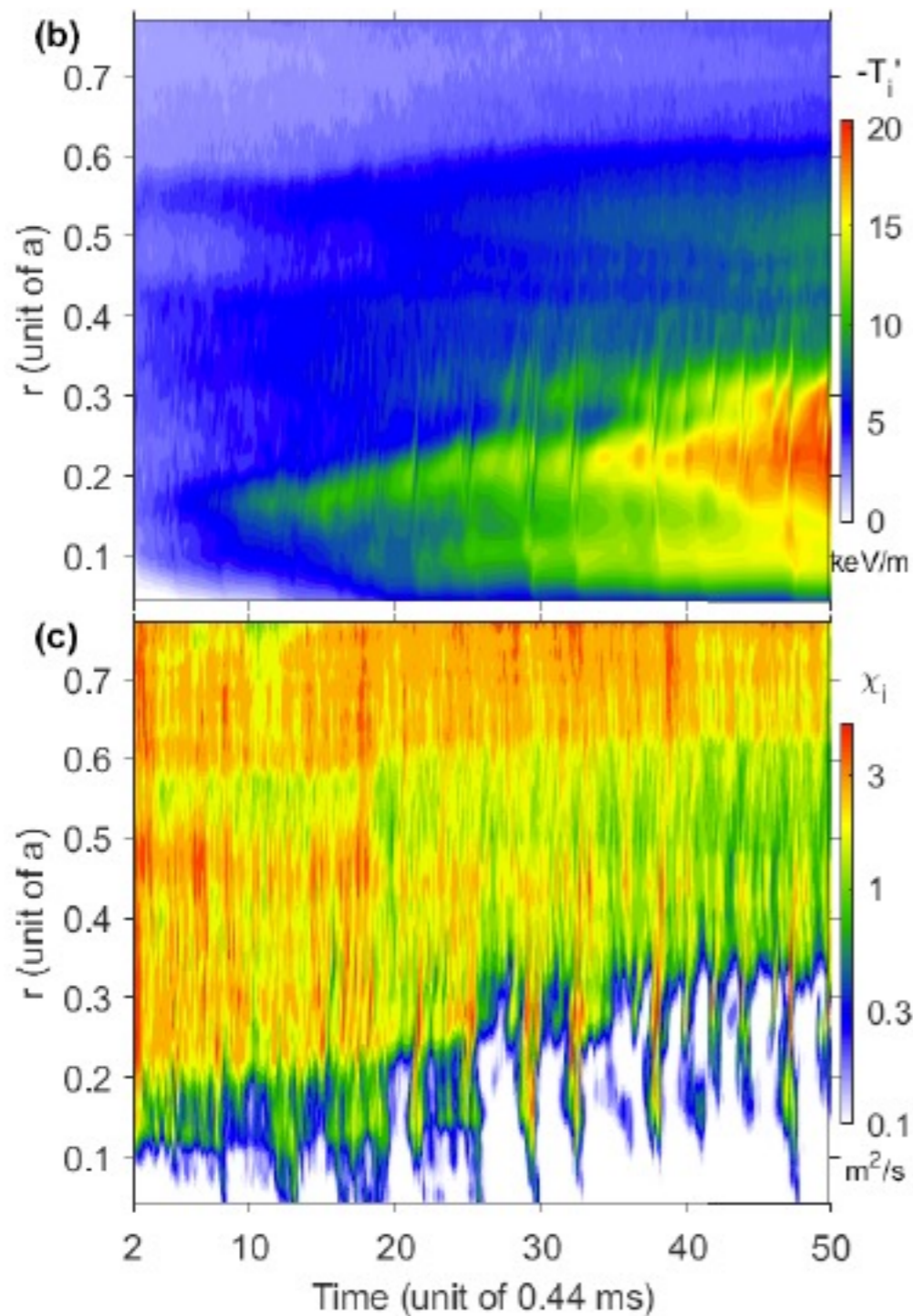


Time normalized to  $100 R/c_s$

Fig. 1 Equilibrium and heating profiles.

The main parameters here are chosen to model a DIII-D-like deuterium plasma[17]. The major/minor radius

# Recent results from NLT



Time normalized to  $100 R/c_s$

# Discussion

- ❑ PSZS transport theory and evolution of the ZS are the general framework that can be adopted for description of these physics
- ❑ Theoretical framework is embedded in NEU approach
- ❑ Issues arising:
  - Separation of spatiotemporal scales (FCQZ, PPCF to be submitted)
  - ITB formation as phase transition