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Ballistic Propagation of Turbulence Front in Tokamak Edge Plasmas

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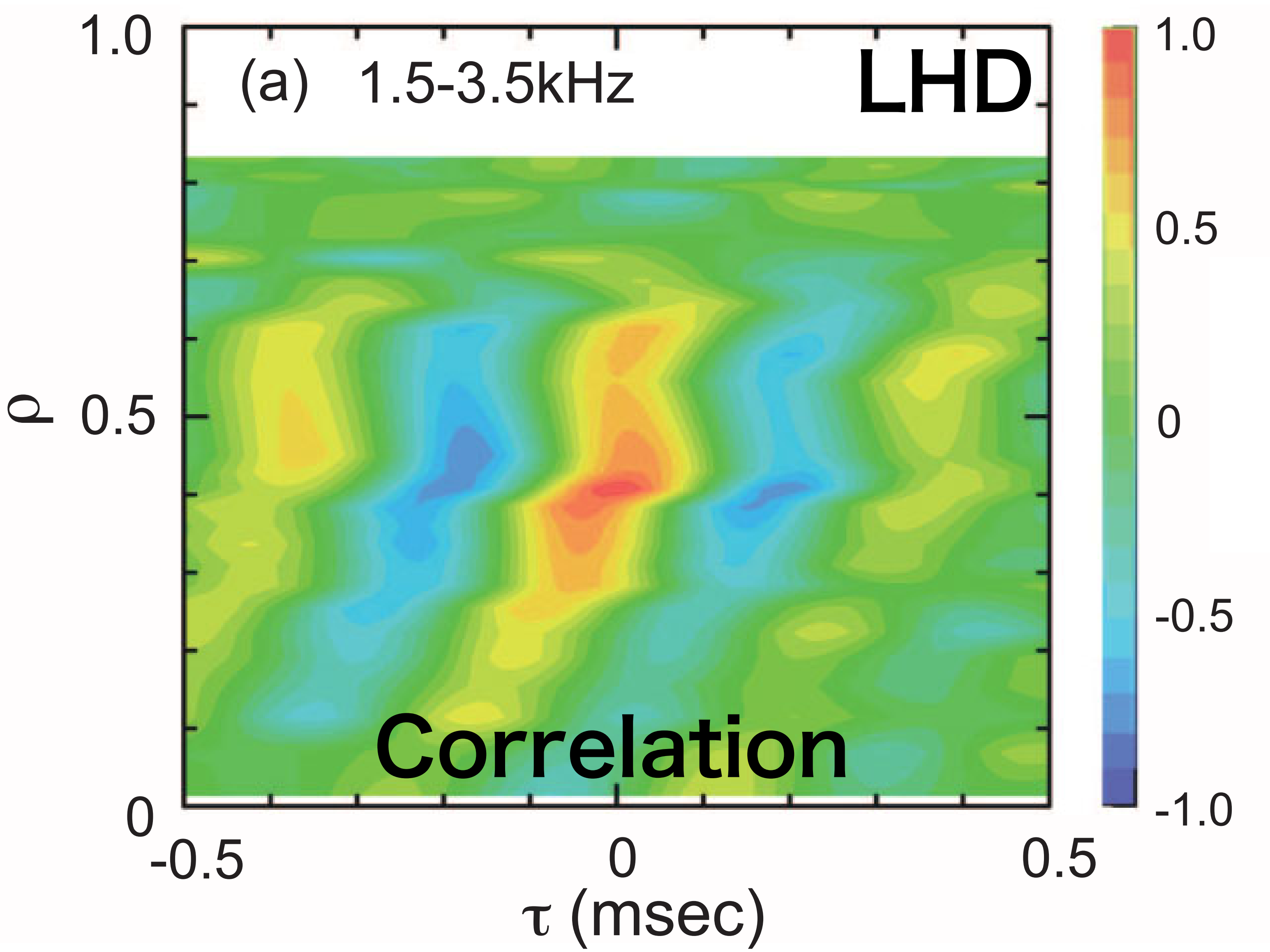
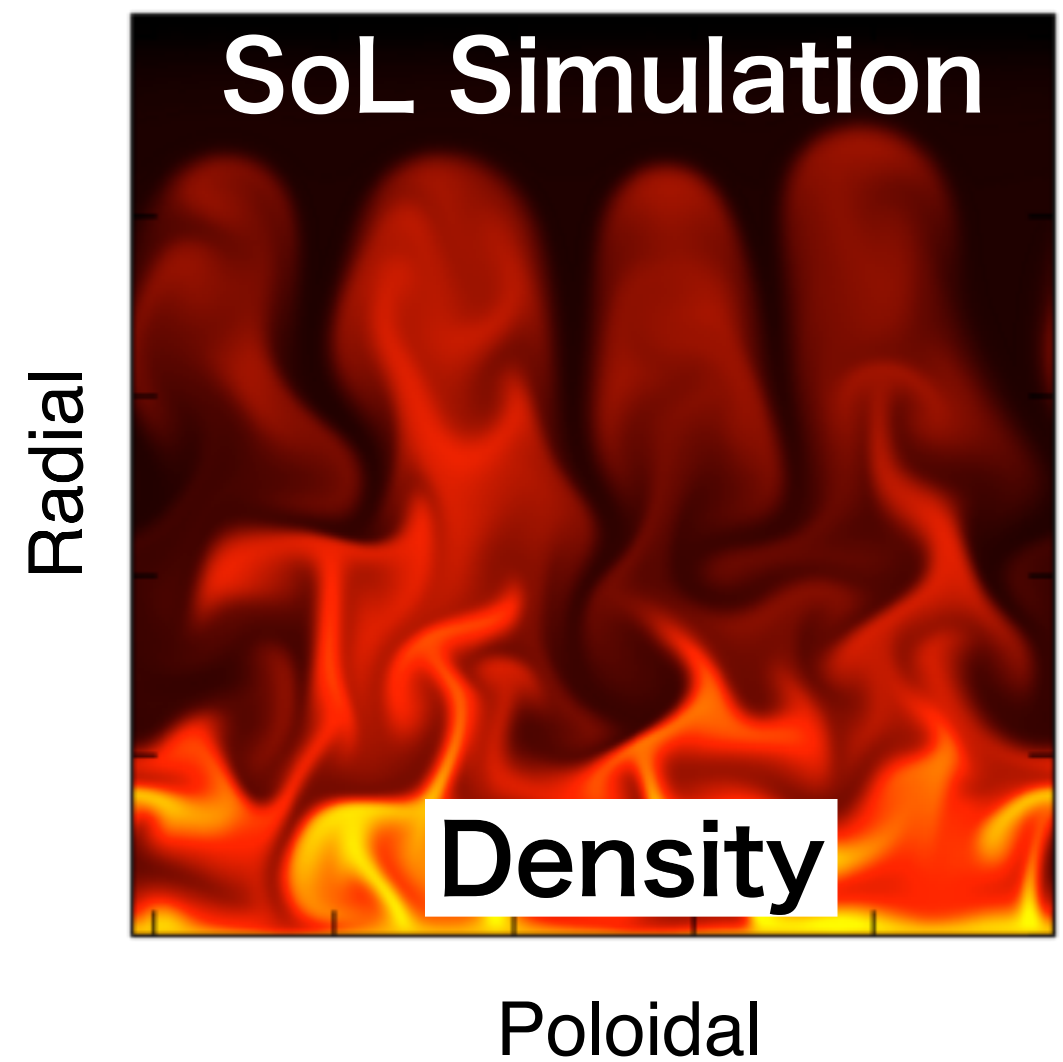
Introduction

Ballistic propagation is considered to play an important role in the turbulent transport.

Statistical characteristics → not yet enough



S. Inagaki *et al.*, PRL **107** 115001 (2011)



S. Sugita *et al.*, JPSJ **81** 044501 (2012)

In this presentation...

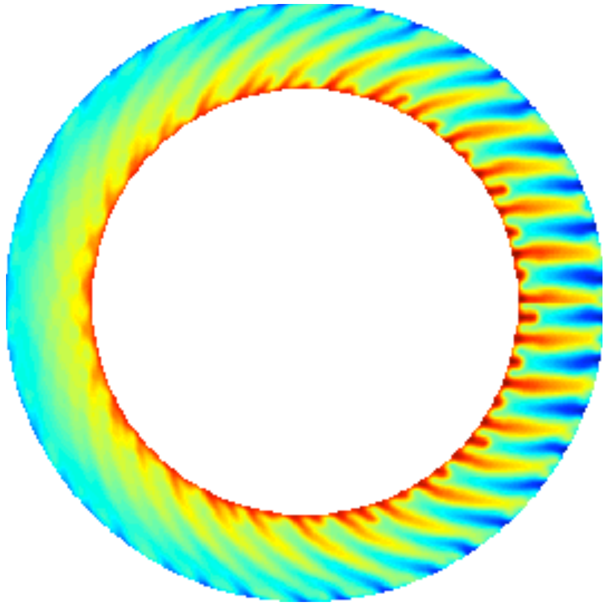
- Dynamics in resistive ballooning mode (RBM) turbulence is studied.
- Turbulence front propagation is emphasized.
- Statistical properties of propagation front are analyzed.

Equation and Configuration

Electrostatic RBM model

$$\frac{\mathrm{d}}{\mathrm{d}t}\nabla_\perp^2\phi = -\nabla_\parallel^2\phi - \mathbf{G}p + \mu\nabla_\perp^4\phi - \nabla_\perp^2\phi_{0,0}$$

$$\frac{\mathrm{d}p}{\mathrm{d}t} = \epsilon_\mathrm{c}\mathbf{G}\phi + \chi_\parallel\nabla_\parallel^2 p + \chi_\perp\nabla_\perp^2 p + S\left(r\right)$$



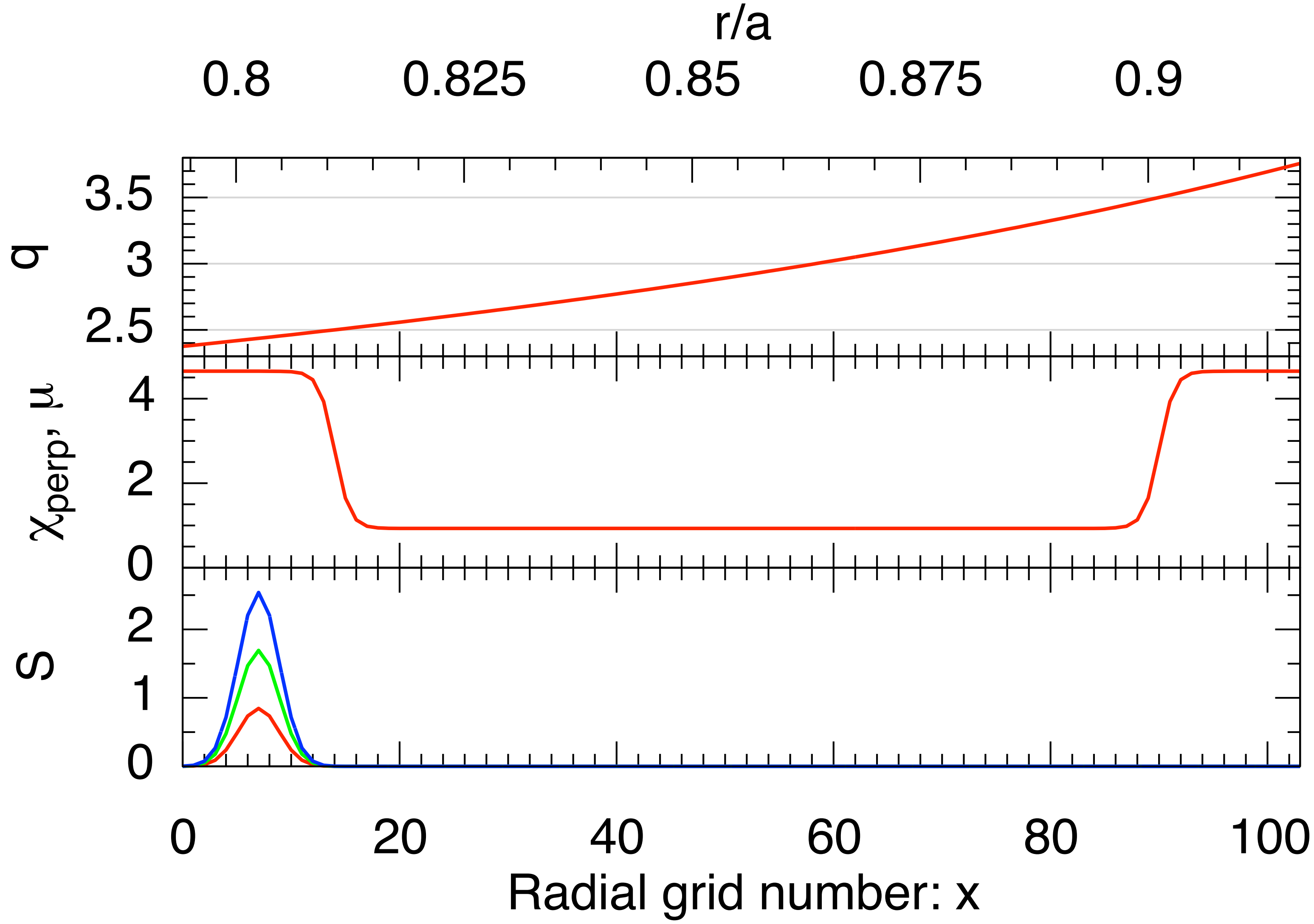
Normalization

$$\tau_\mathrm{int} = \sqrt{\frac{RL_p}{2}\frac{1}{c_\mathrm{s}}}$$

$$\sim \text{few micro-sec.}$$

$$\xi_\mathrm{bal} = \sqrt{\frac{m_i n\eta_\parallel}{\tau_\mathrm{int}}\frac{L_\mathrm{s}}{B}}$$

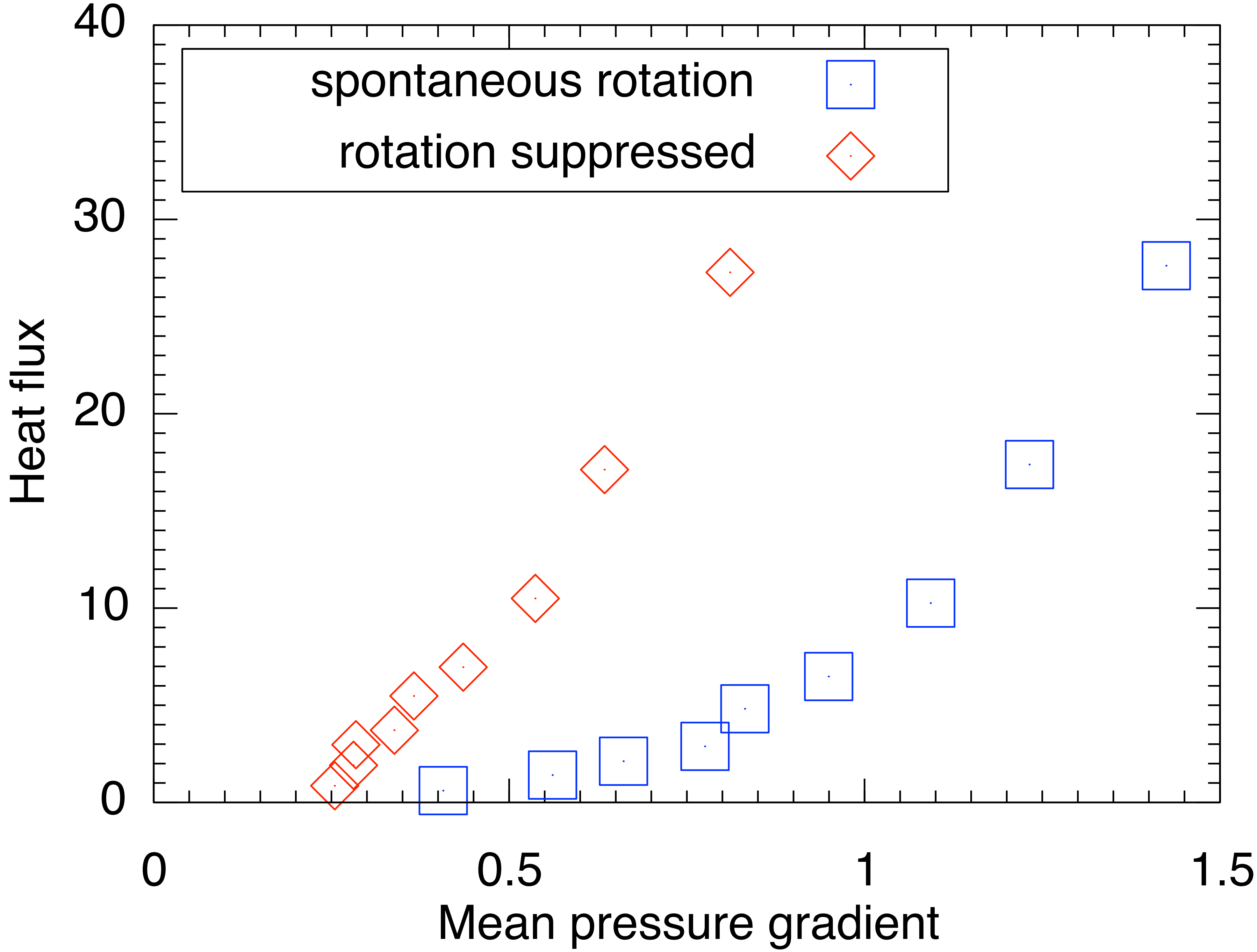
$$\sim \rho_i \sim 1\mathrm{mm}$$



Gradient-flux Relation

Target of this work is “rotation suppressed” case.

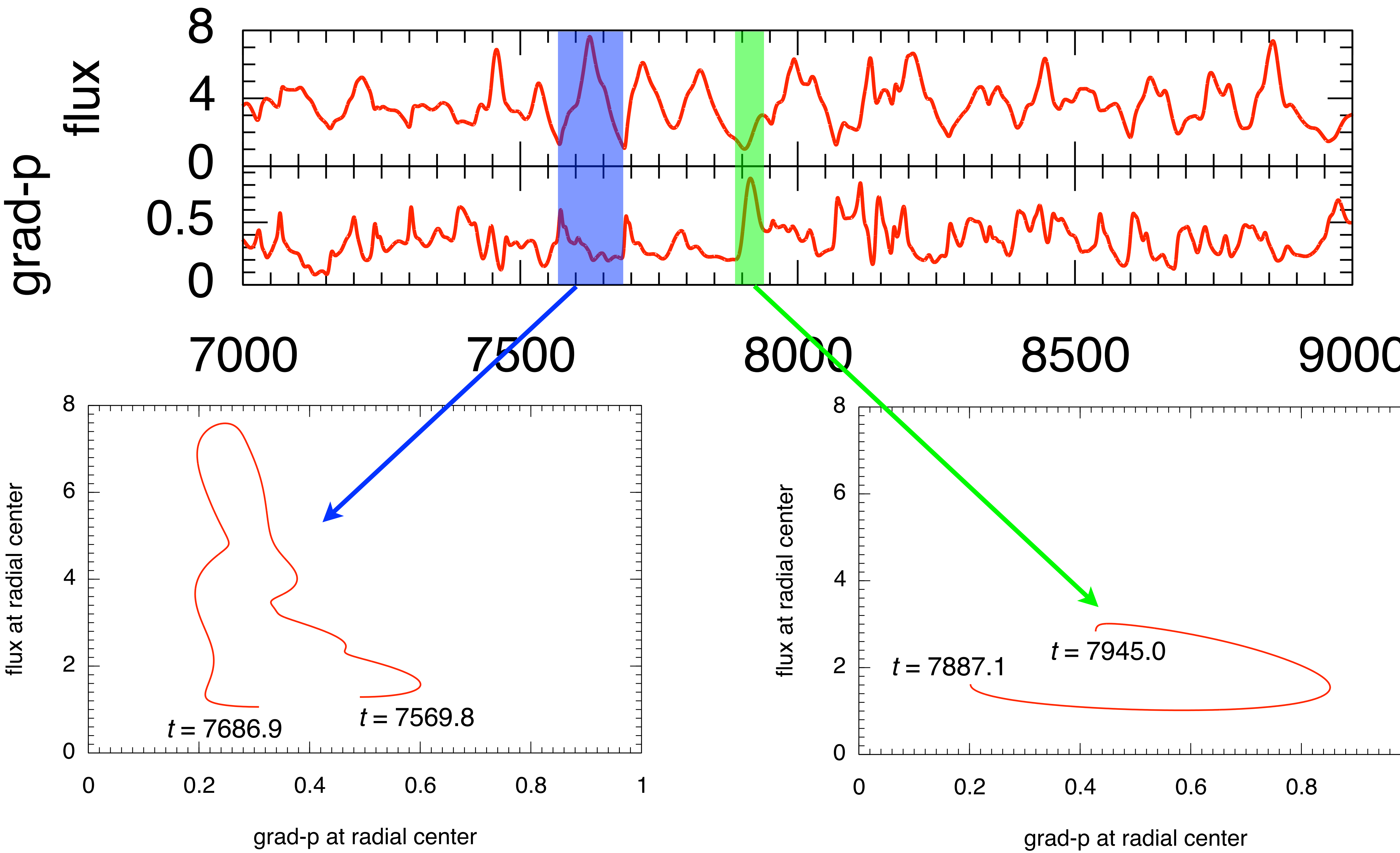
Two players: gradient & transport



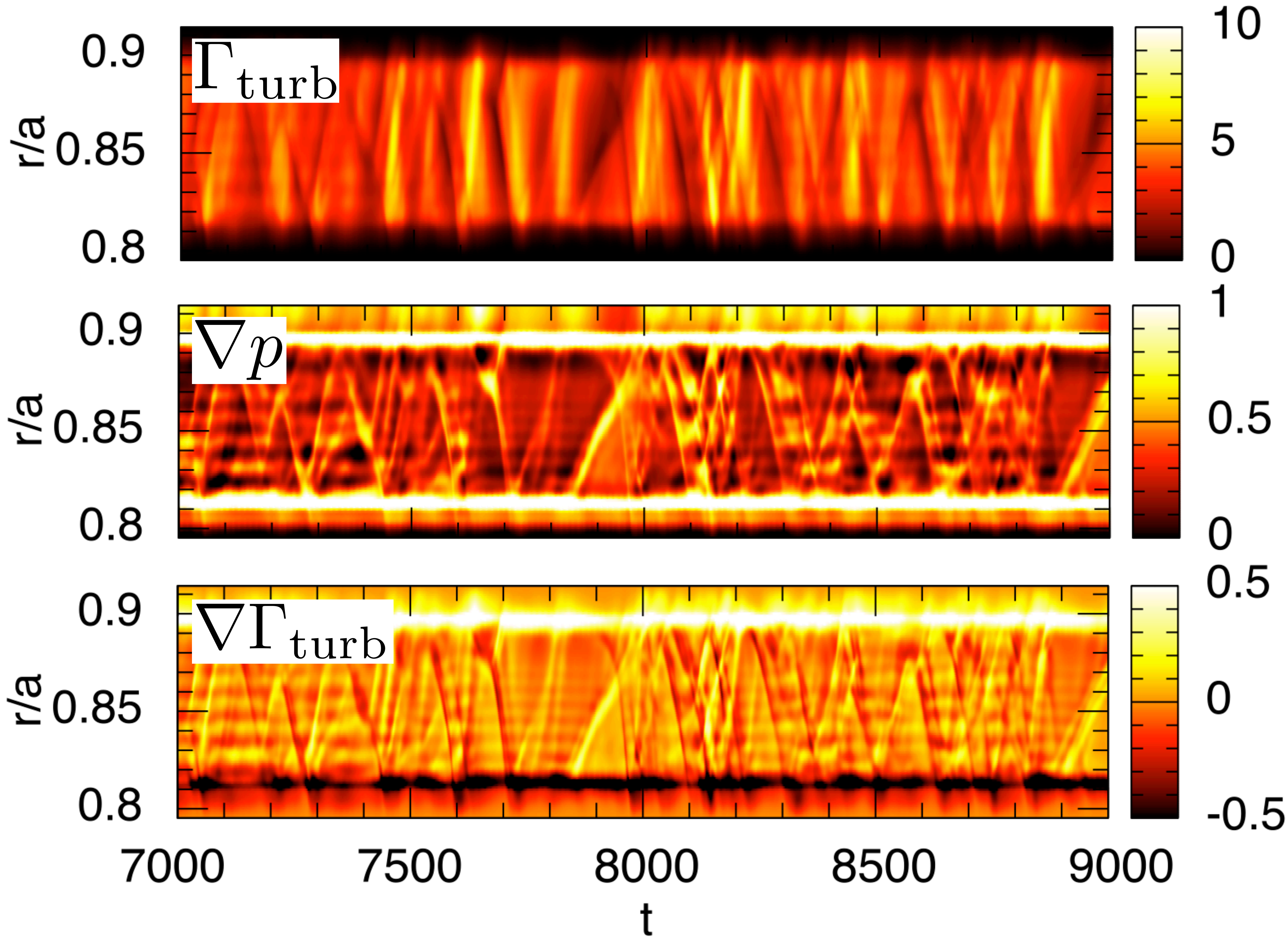
Local Gradient-flux Relation

Dynamics of local (radial center) quantities.

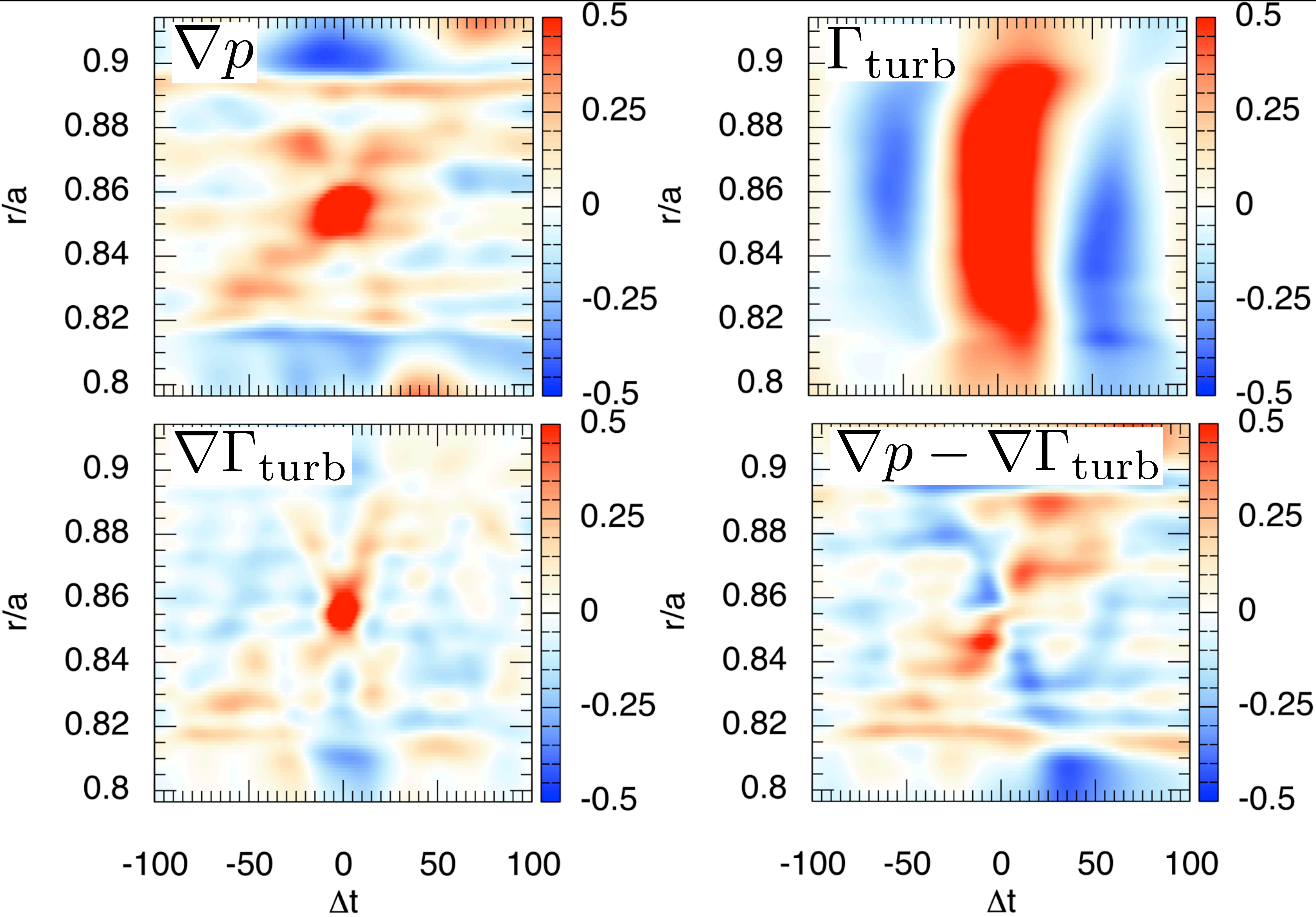
Response of gradient formation and flux.



Dynamic Behaviors in RBM Turbulence



Spatio-temporal Correlations



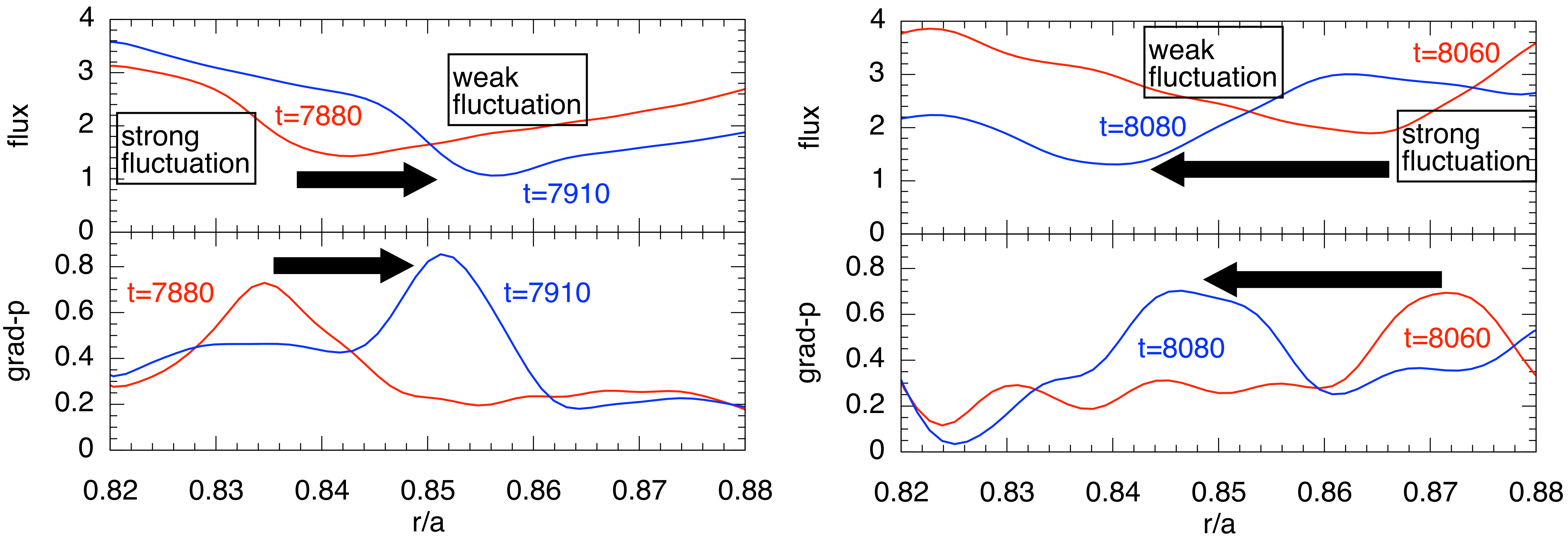
Ballistic Front Propagation

Gradient pulse and turbulent flux front propagate radially outward/inward simultaneously.

Rear of the propagation front: strong fluctuation.

Front of the propagation front: weak fluctuation.

→ Analogy with “turbulence spreading” theory



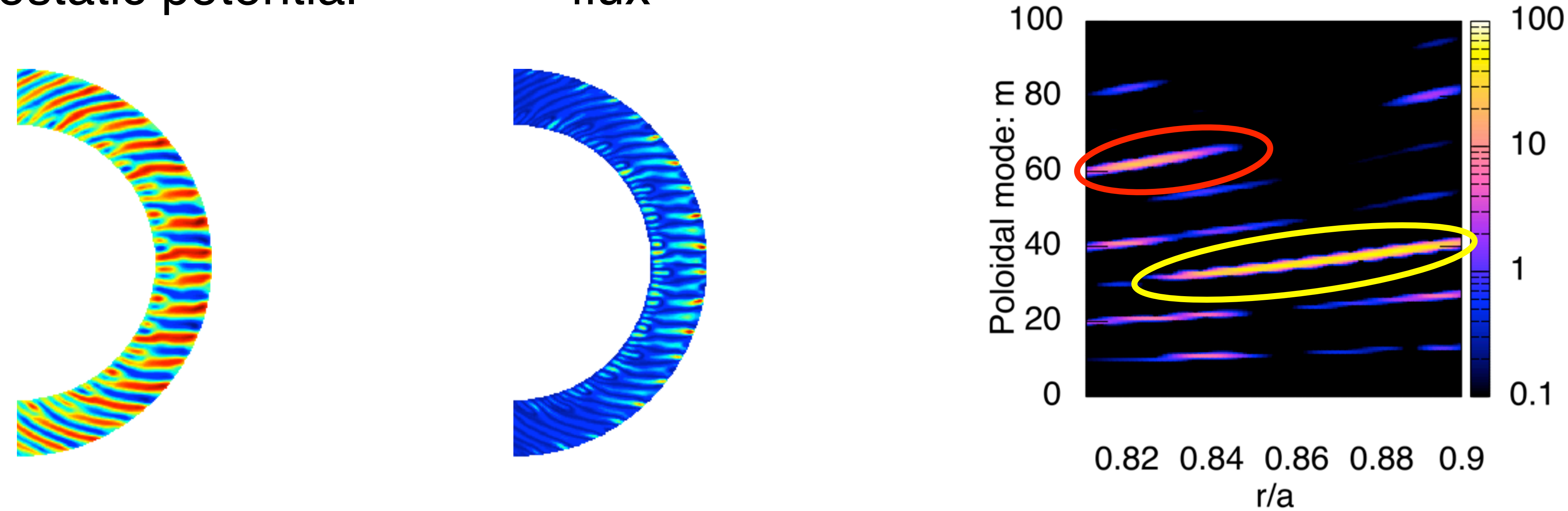
Property of Front Propagation

Unstable mode changes in front and rear of the propagation front (not only the intensity).

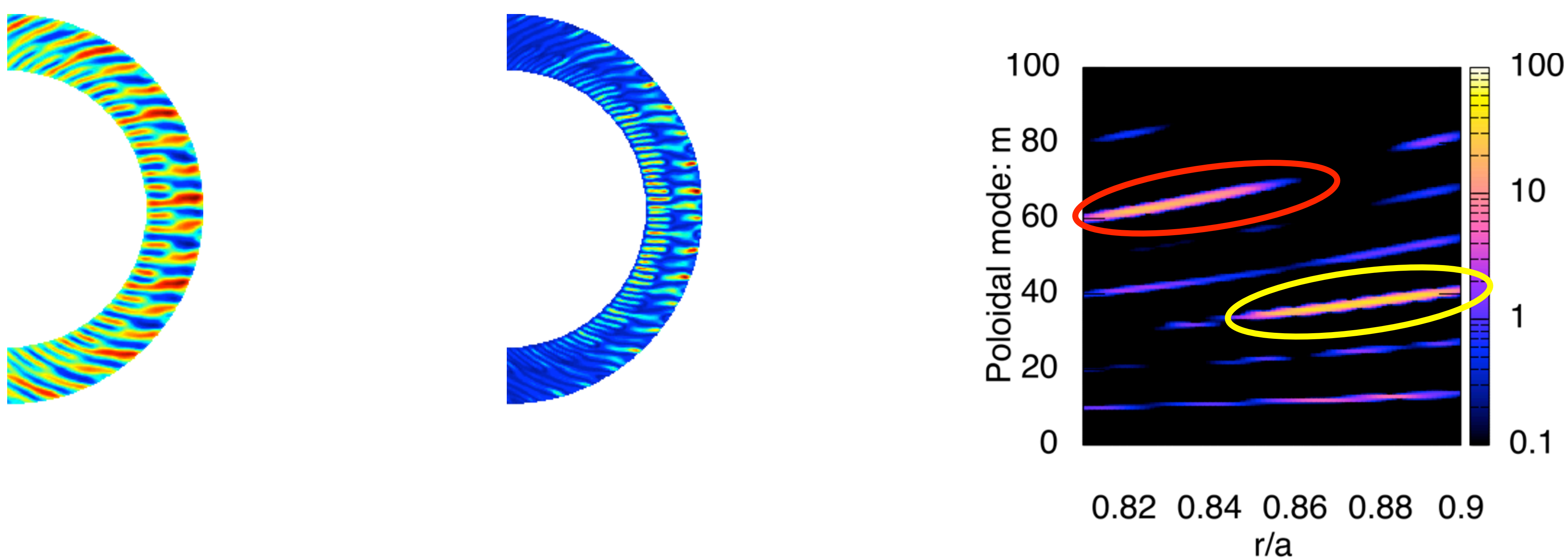
electrostatic potential

flux

t = 7880

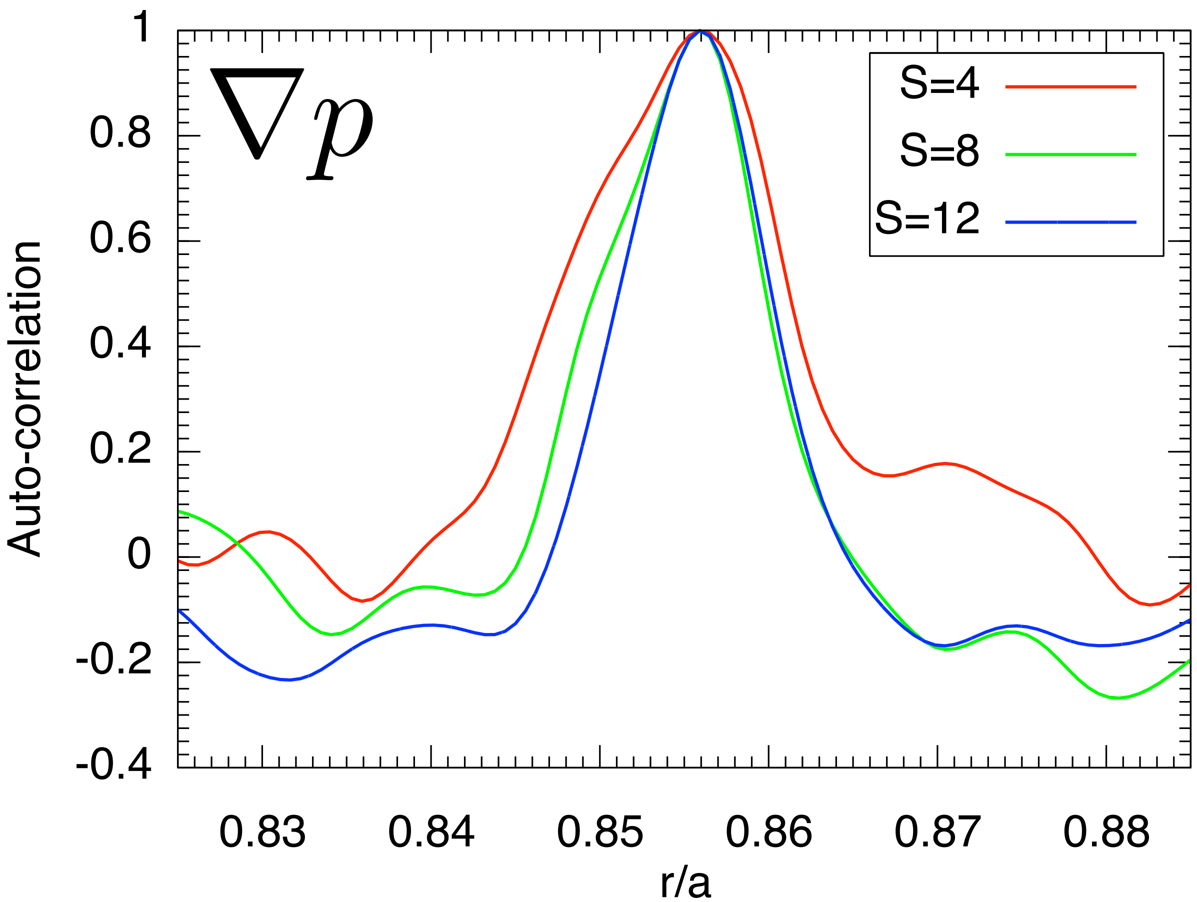


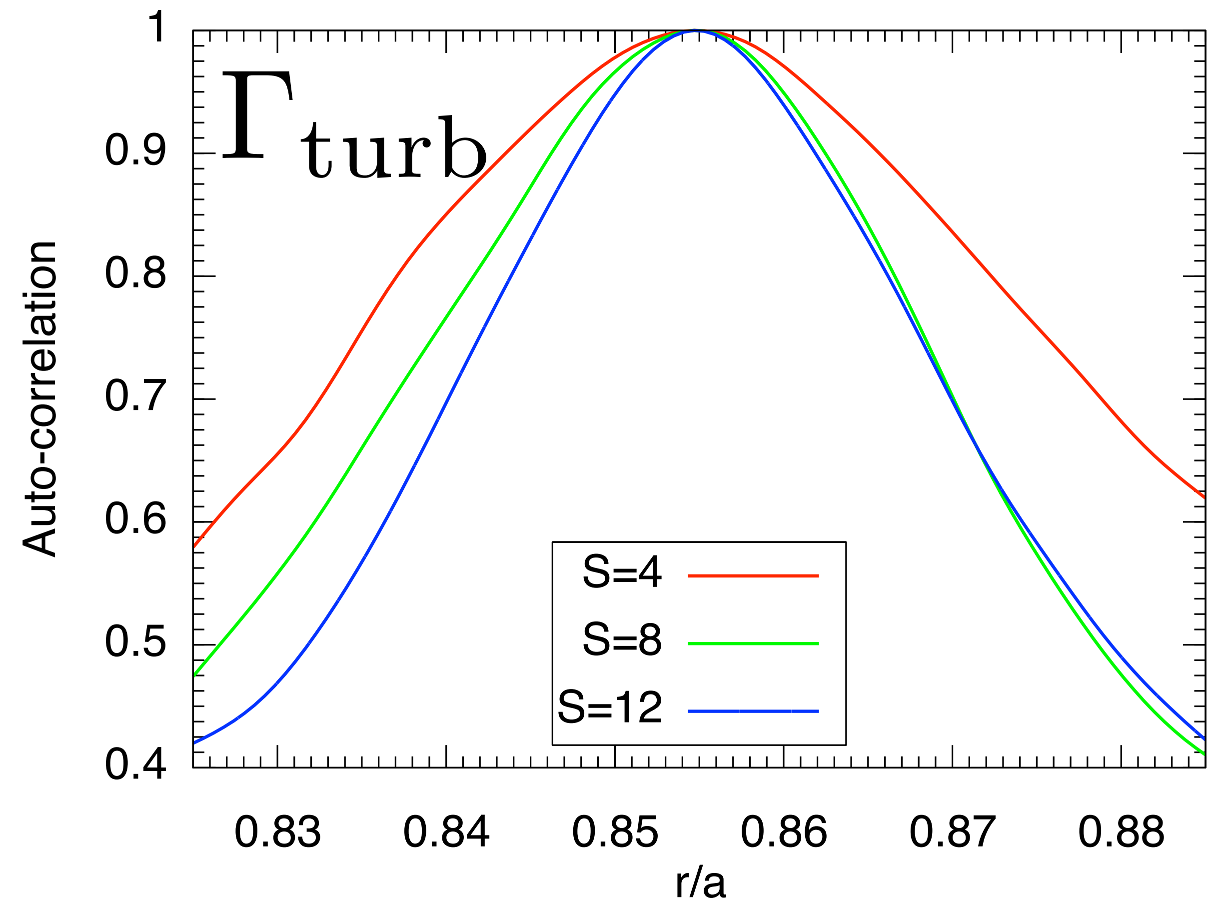
t = 7910

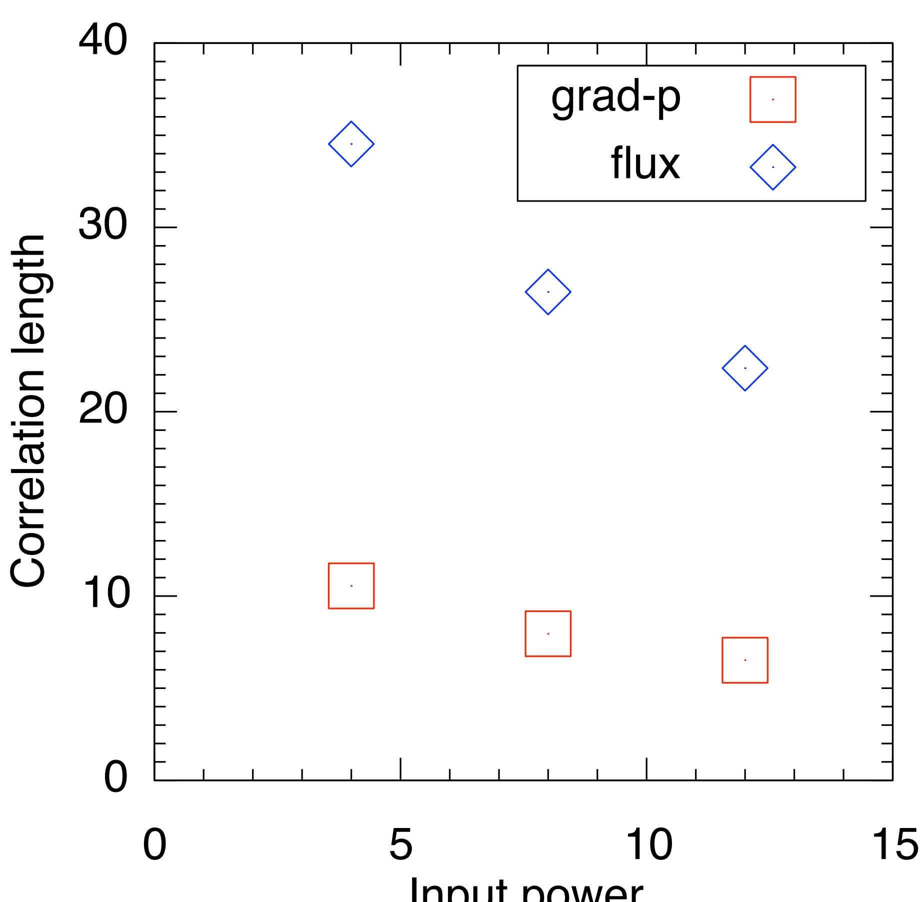


Input power dependence

Input Power dependence of Correlation Length



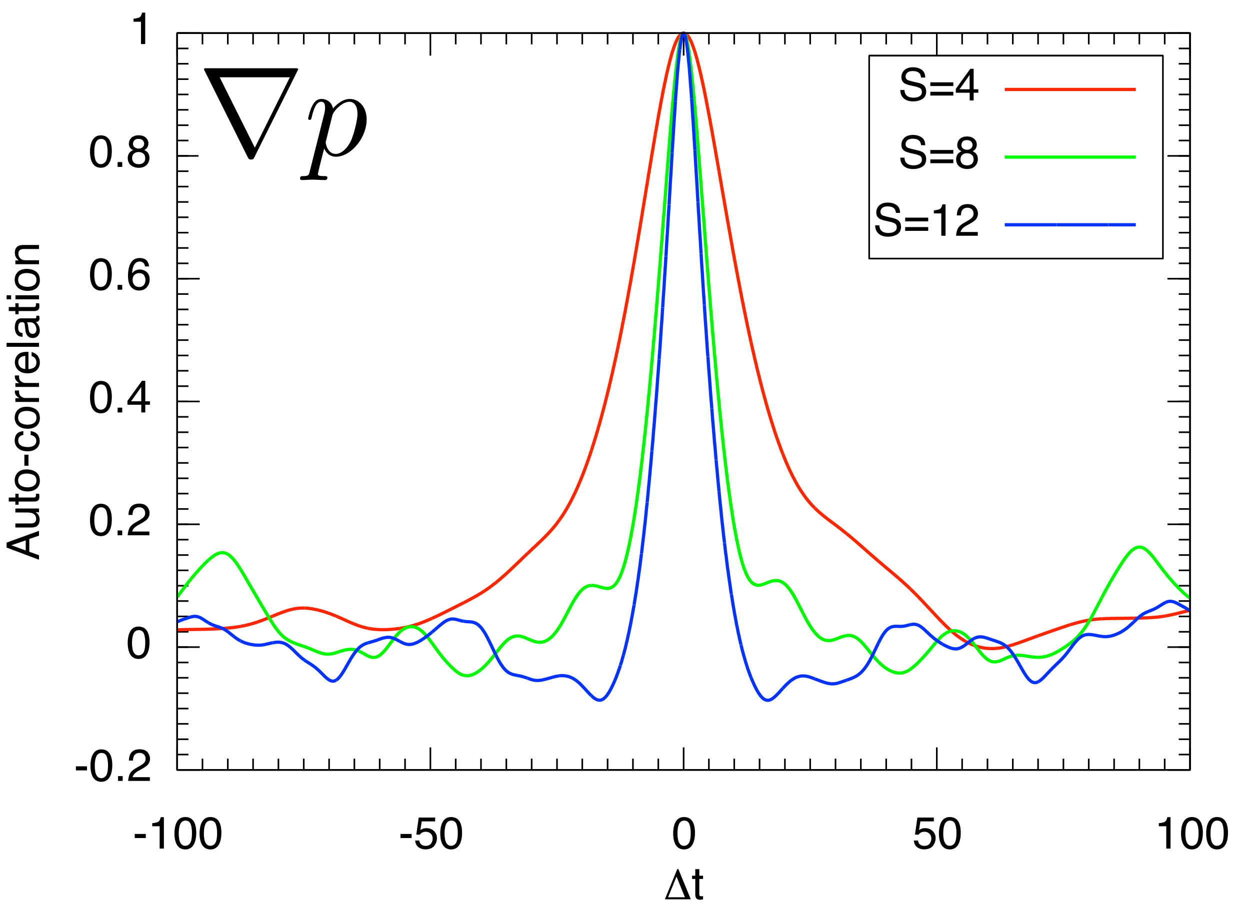


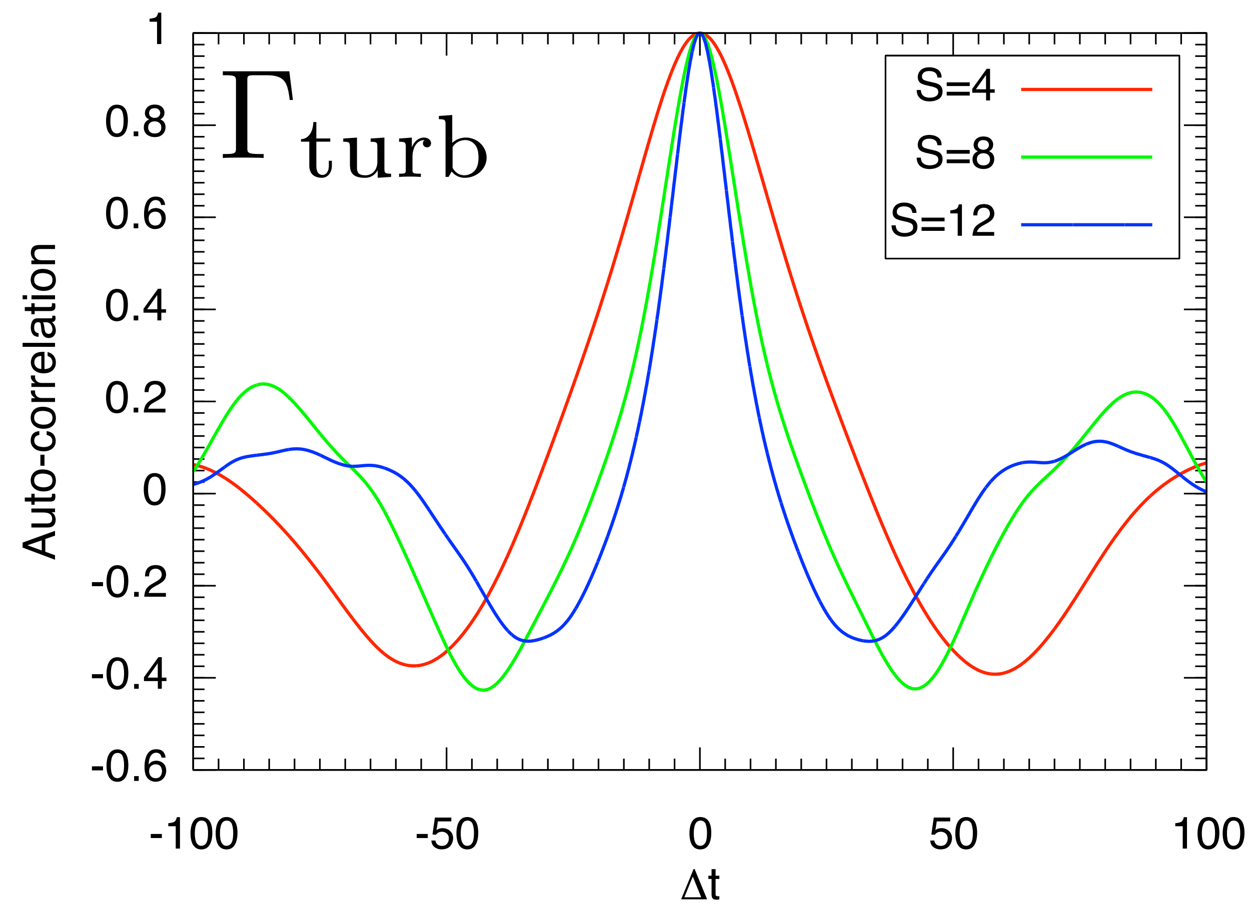


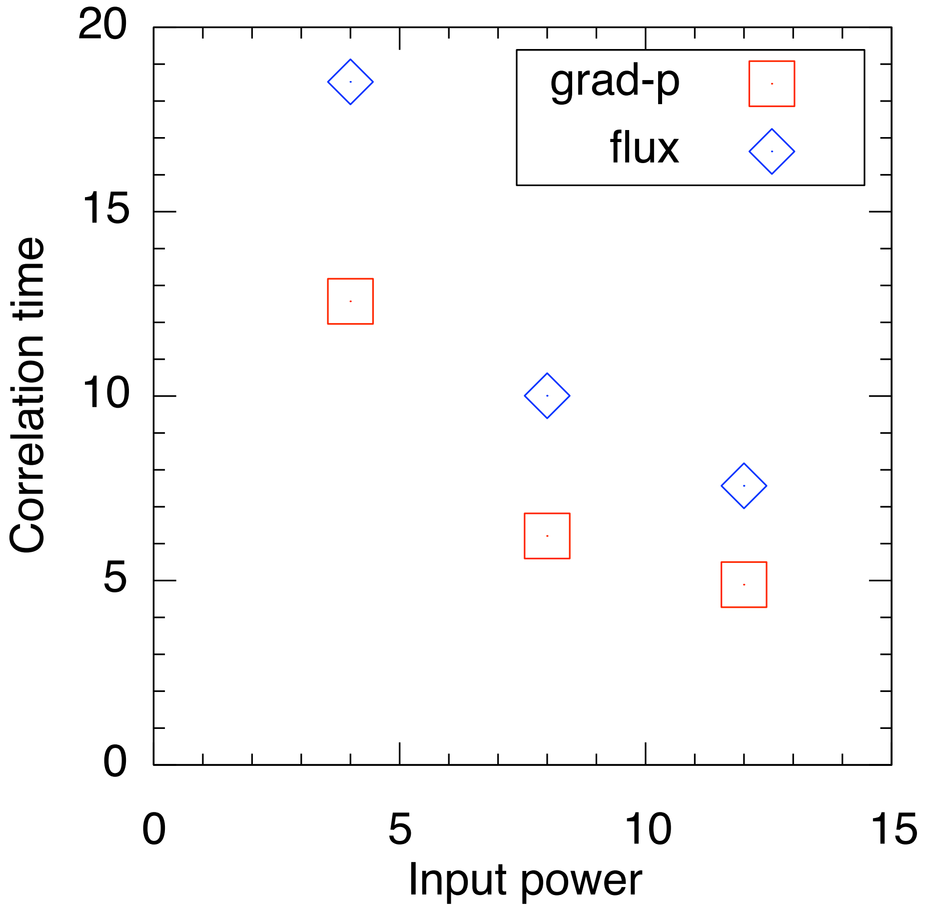
Correlation length decreases with input power increase.

Correlation length of flux and that of grad-p are quite different

Input Power dependence of Correlation Time







Correlation time decreases with input power increase.

Statistical properties of propagation front

and

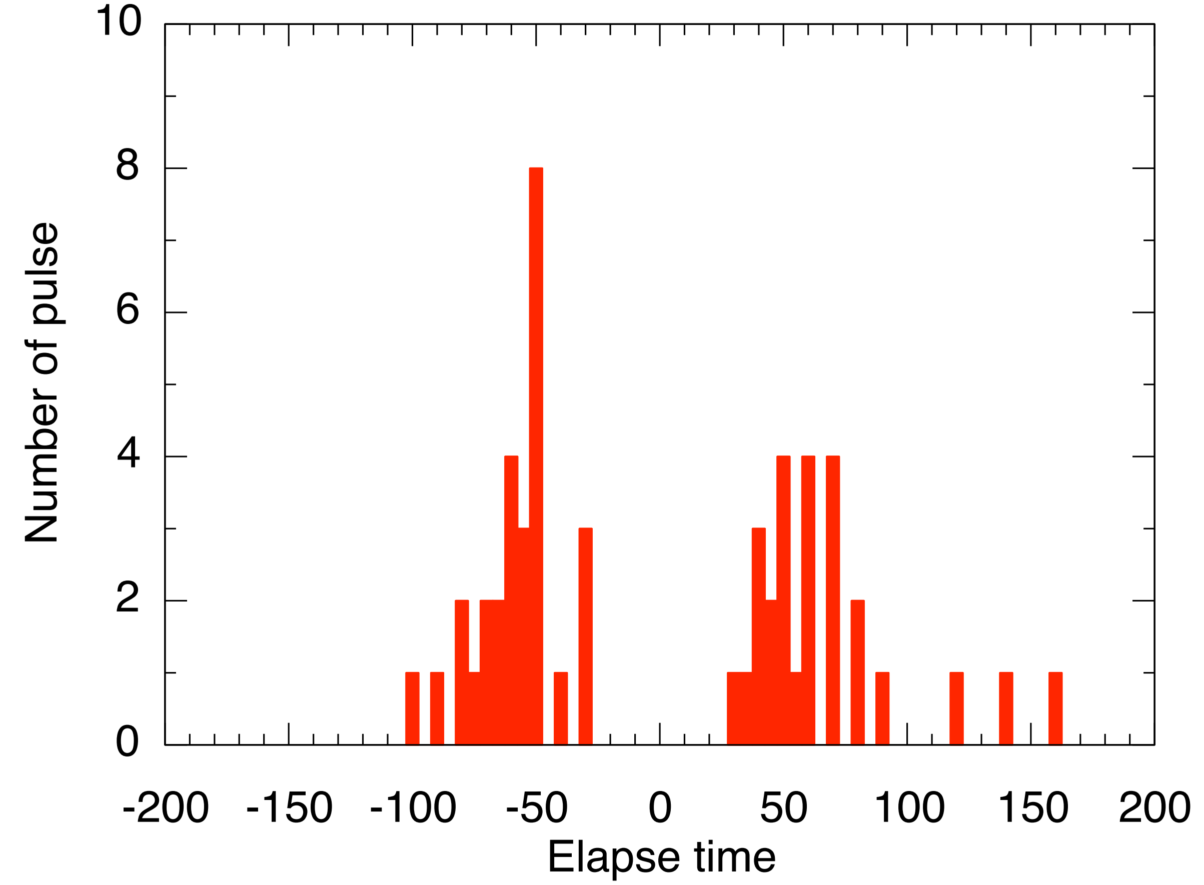
Comparisons with scaling laws

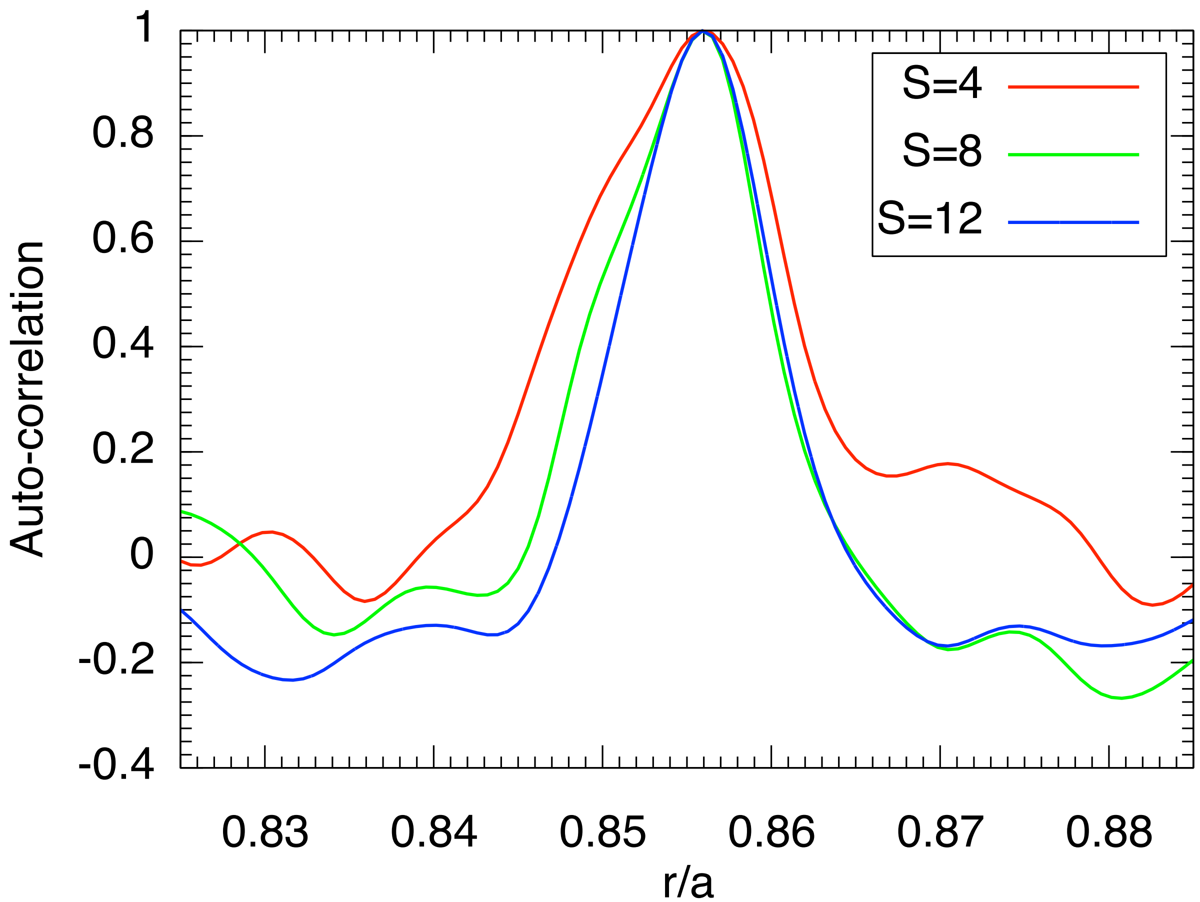
Statistical Characteristics of Gradient Pulse

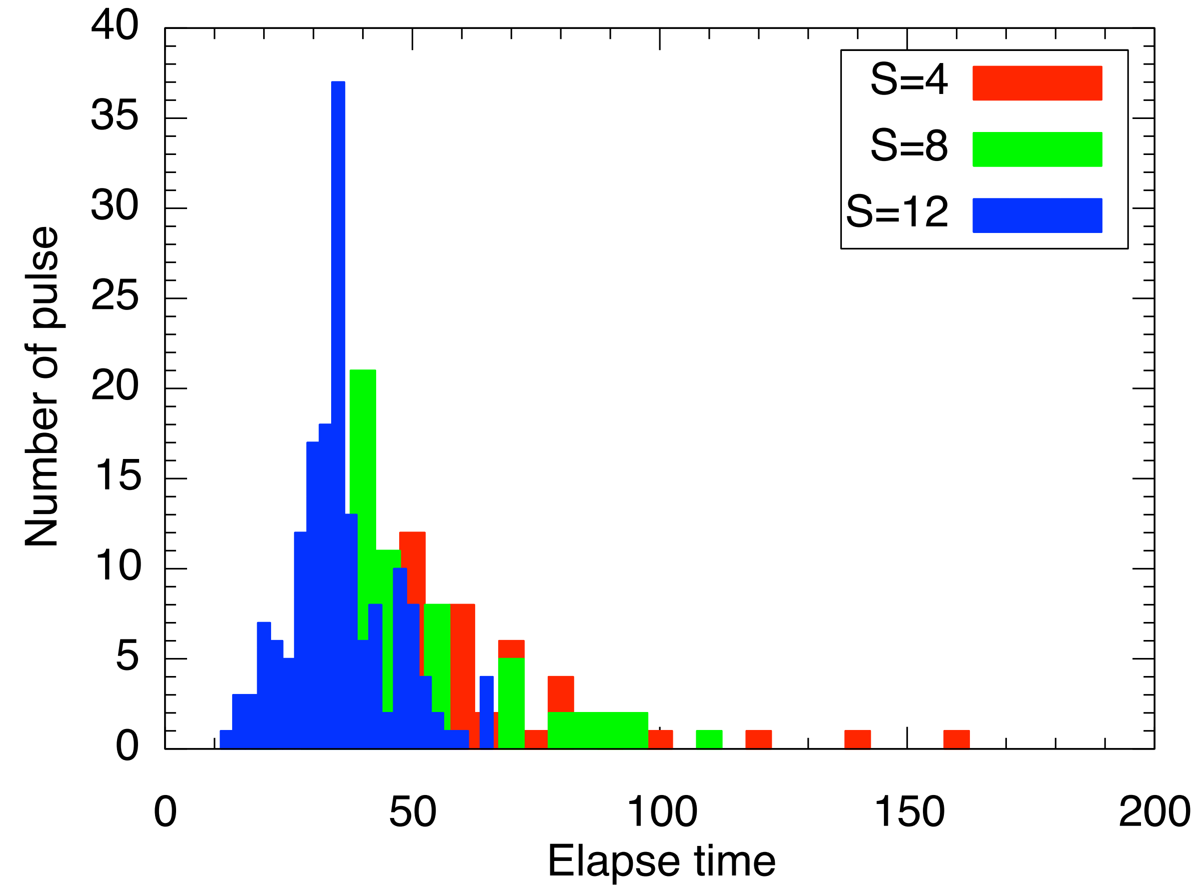
Pulses outward/inward are quasi-symmetric.

Pulses velocity and correlation length depend on input power.

$$S \sim \langle \Gamma_{\mathrm{turb}} \rangle_t + \langle \Gamma_{\mathrm{coll}} \rangle_t$$



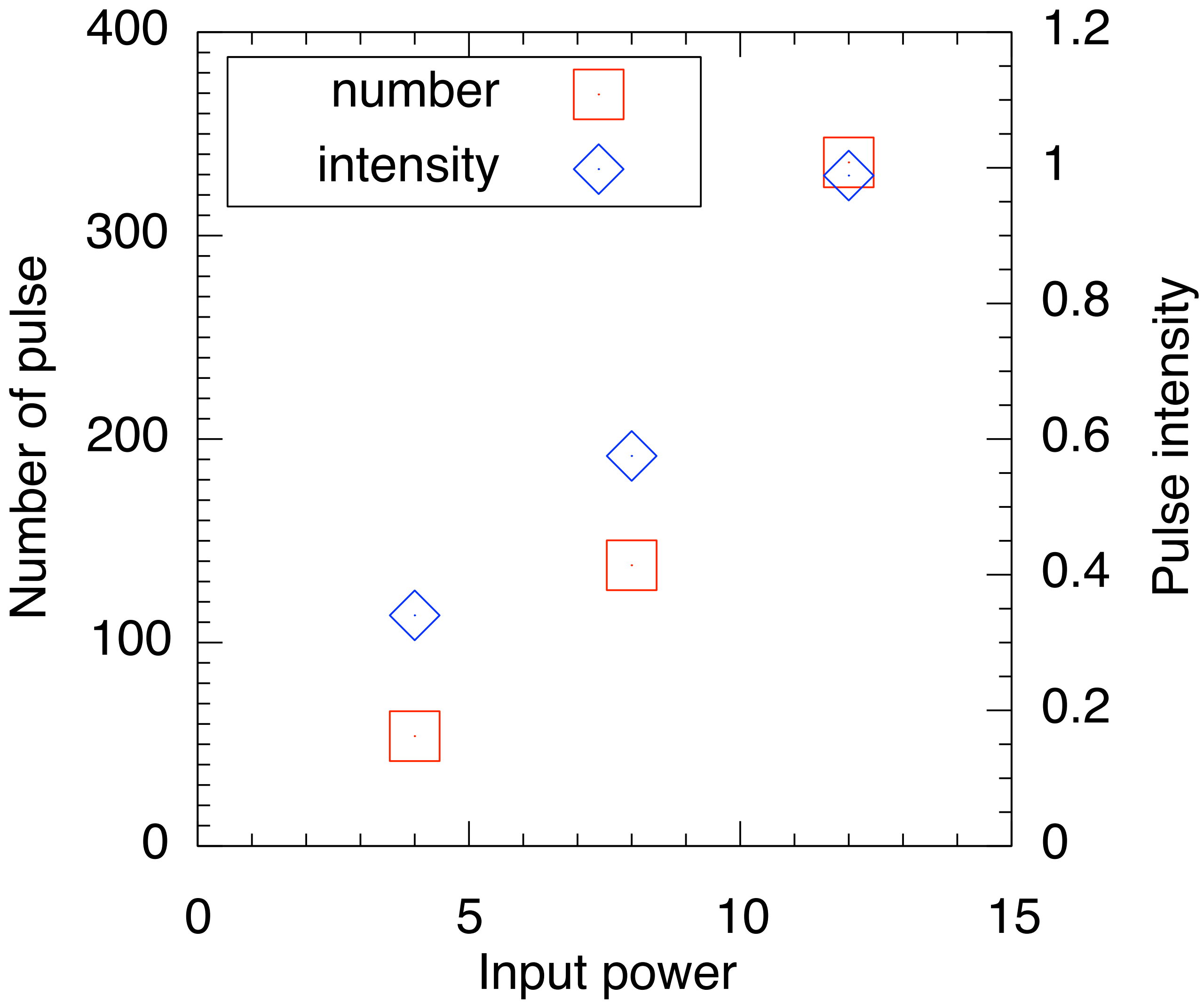


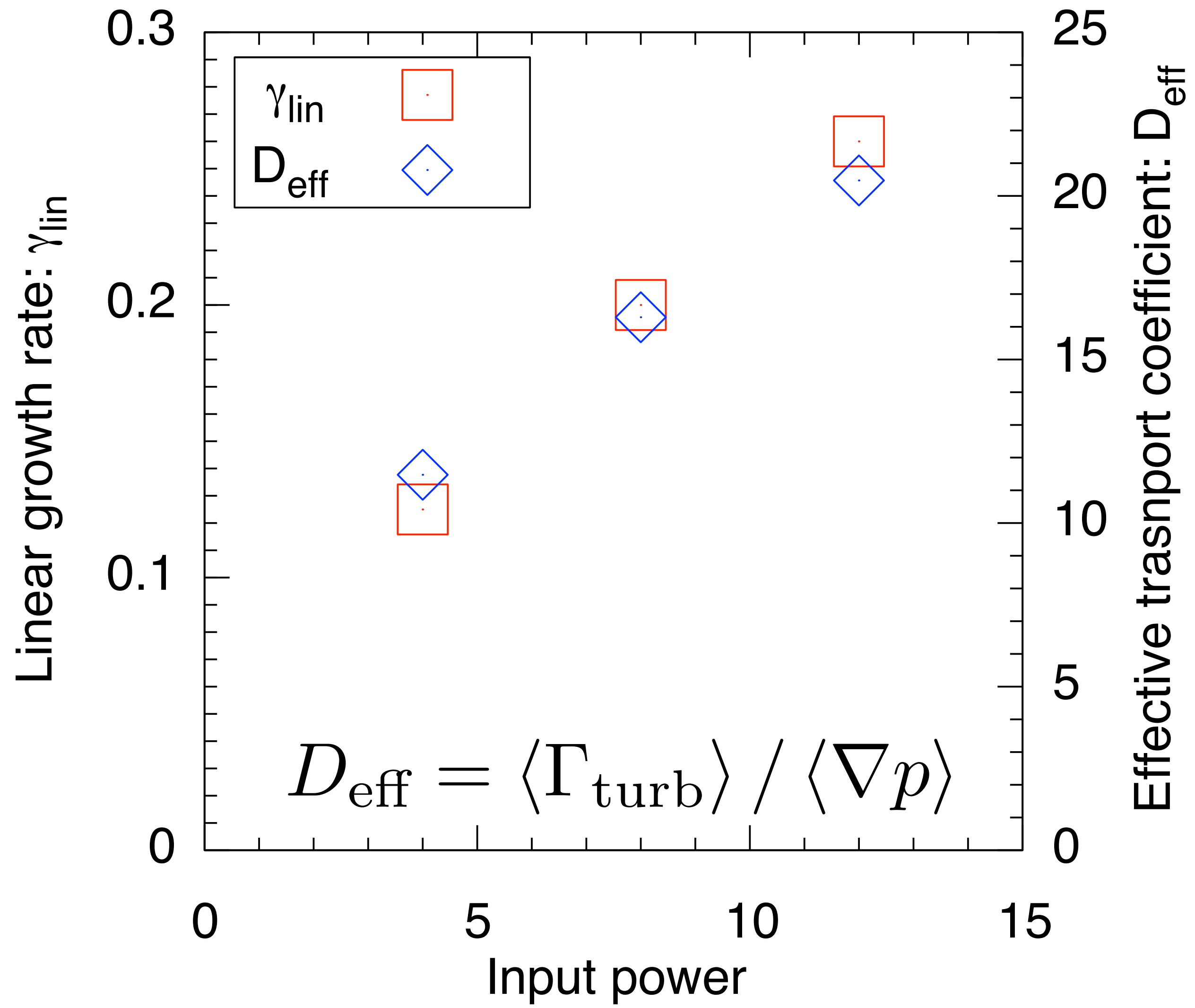


Input Power Dependence

Statistical properties of propagating pulses (number, intensity) are positively depend on the intensity of input power.

Effective transport coefficient is also positively depend on the intensity of input power.

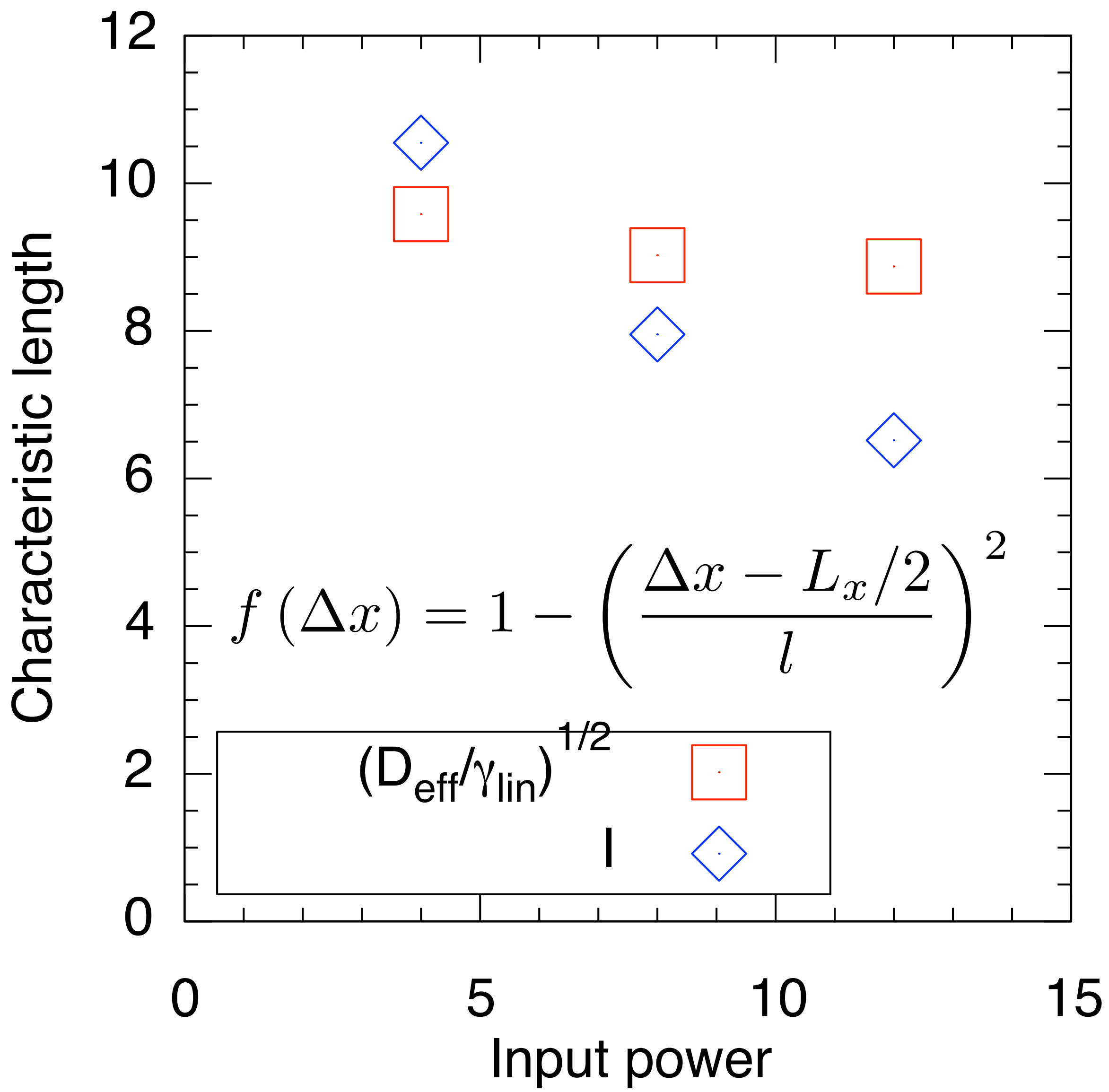


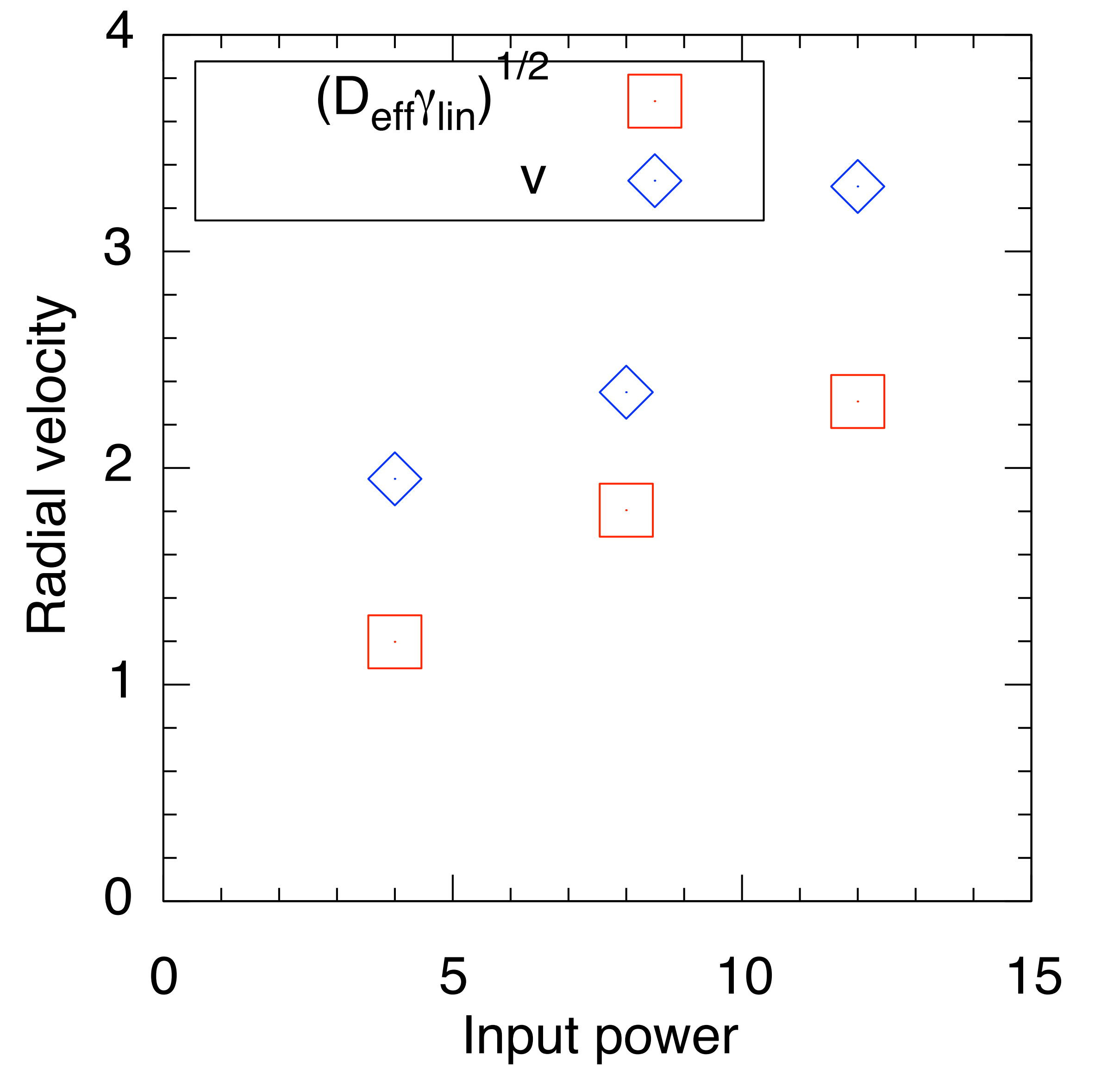


Comparisons with Scaling Law

Order of spatial scale length agrees with scaling law of turbulence spreading theory.

Order and tendency of velocity agree.





Ö.D. Gürcan *et al.*, PoP **12** 032303 (2005)

Summary

- Nonlinear simulations of resistive ballooning mode with tokamak edge geometry are performed.
- Two types of dynamics are observed.
  - Radial propagating pulse of pressure gradient.
  - Appearance/disappearance of global mode of flux.
- Properties of turbulence front propagation are analyzed.
- Statistical values of ballistic propagation are analyzed and compared with scaling law that is given by turbulence spreading theory.