Edge states and puff-like turbulent regimes

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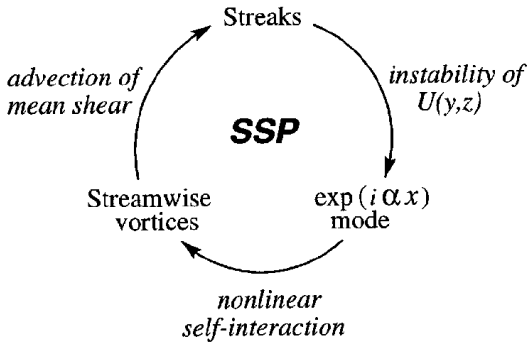
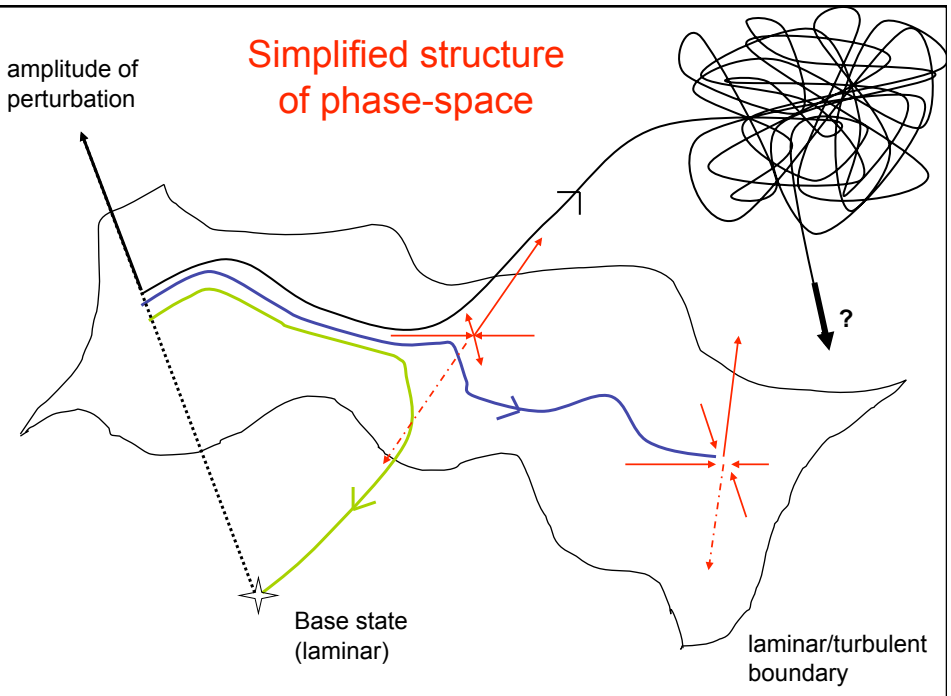
Background

- Simple shear flows display turbulent dynamics even in the absence of linear stability of the base flow
- In the case of small (minimal) computational domains, a dynamical system picture of transition is emerging, based on the knowledge of exact recurrent solutions governed by a self-sustaining process (Waleffe 1997)



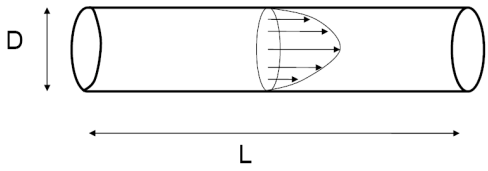
Simplified structure of phase-space



Simple shear flows under consideration

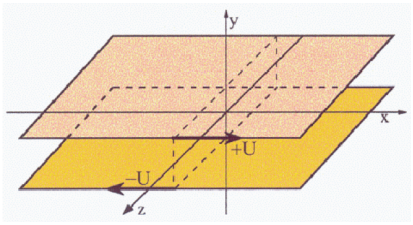
Pipe flow

U : bulk velocity



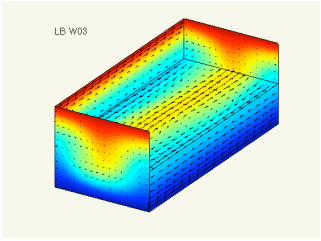
Driving force : fixed mass flux

plane Couette flow

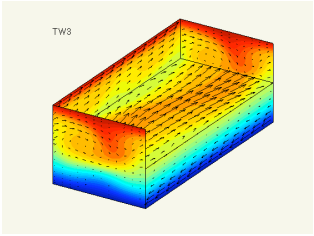


Driving force : wall drag

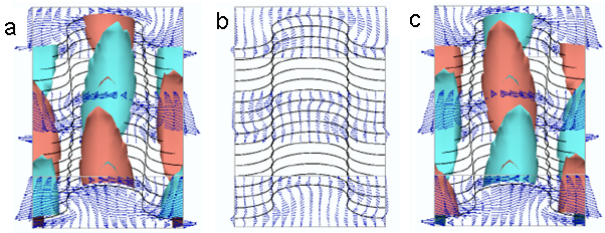
States on the laminar/turbulent boundary : plane Couette flow



Steady states



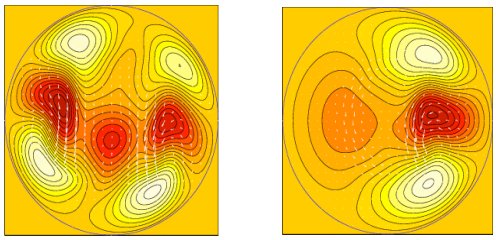
Travelling waves



Periodic Orbits

(Nagata 1990, Schmiegel 1999, Kawahara & Kida 2001, Viswanath 2007, Gibson et. al. 2008,…)

Pipe flow



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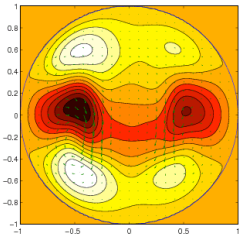
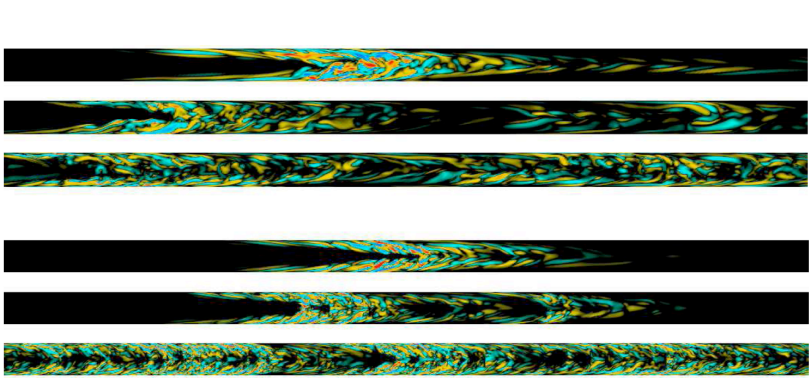


Relative periodic orbits

(Faisst & Eckhardt 2003, Wedin & Kerswell 2004, Duguet, Pringle & Kerswell 2008)

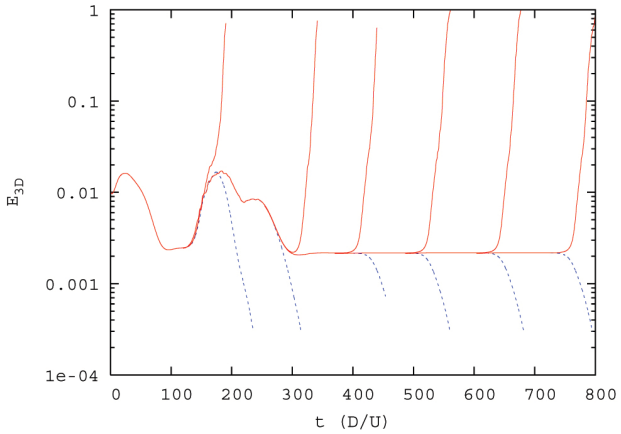
long pipes : full DNS vs. (2+ε) model

(all m up to ± 24) ($m = -3, 0, 3$)

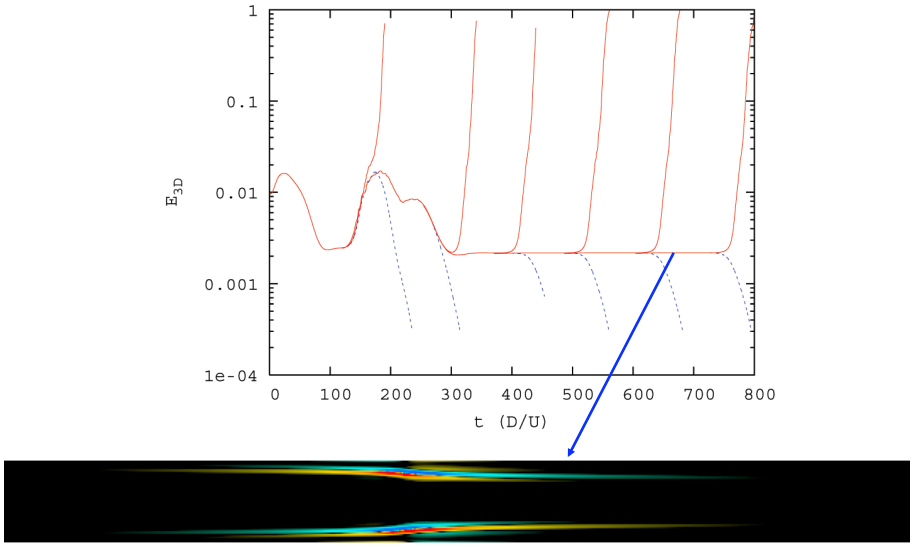


(Willis & Kerswell, 2009)

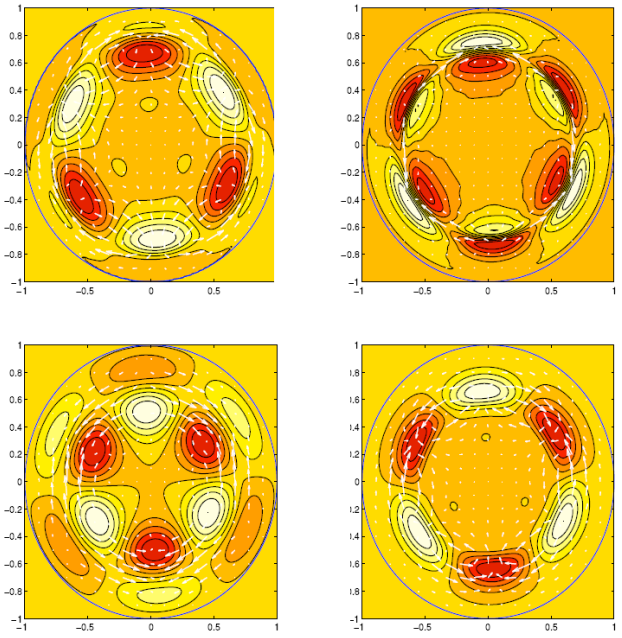
Edge trajectory for Re=10,000 (2+ε-model)



Localised travelling wave solution

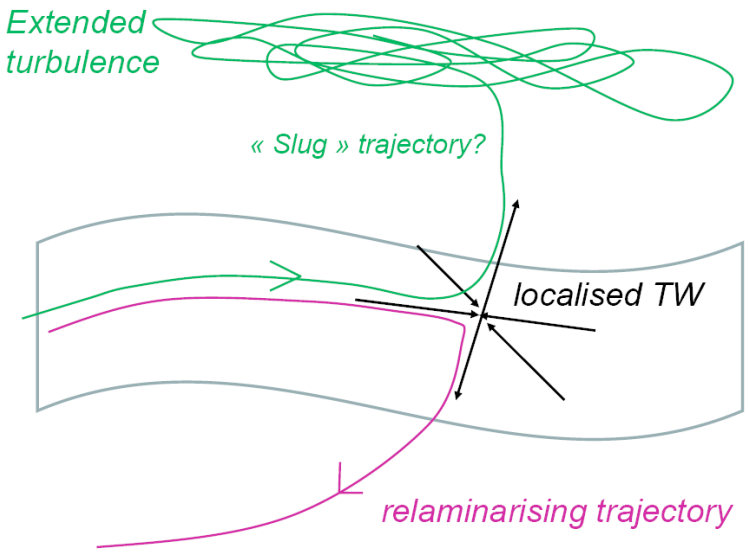


(rear)

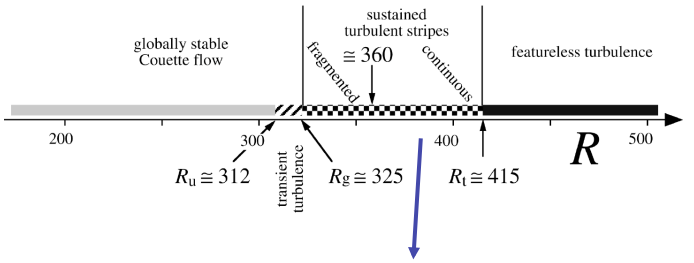


(front)

Dynamical interpretation of slugs ?

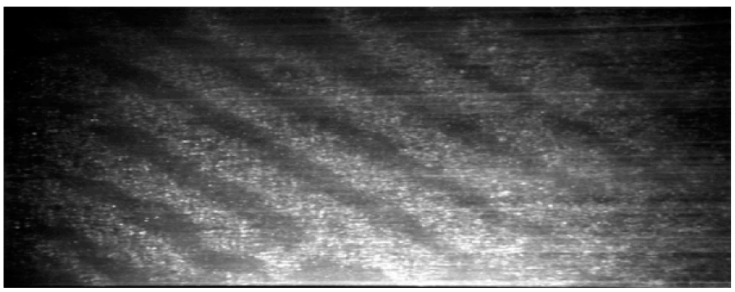


Plane Couette flow



$$R = Uh/\nu$$

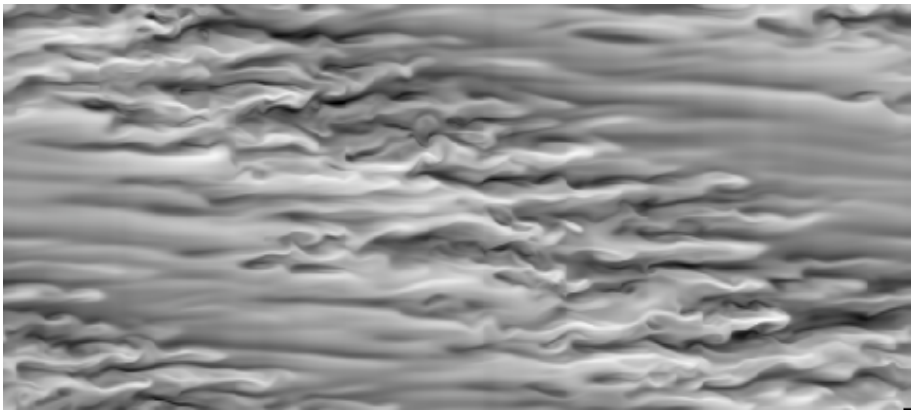
(Manneville, 2003)



flow

(Bottin *et. al.*, 1998)

D.N.S. in a periodic domain



(mid-plane axial velocity, R=370)

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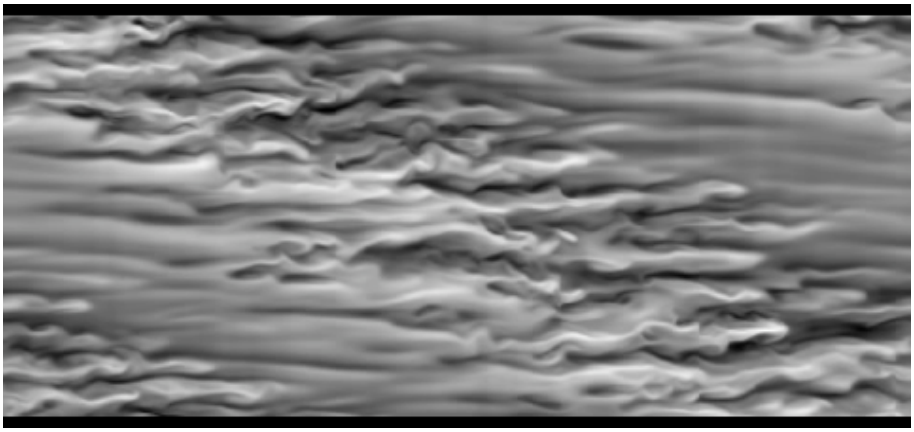
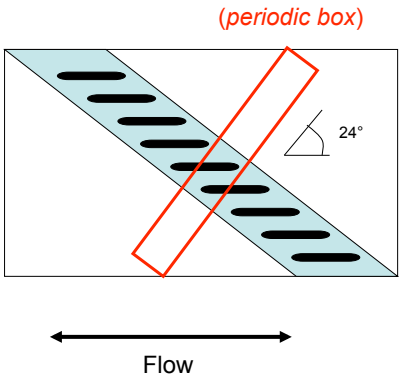


(mid-plane axial velocity, R=370)

Minimal computational domain to capture the dynamics of the stripes

(Tuckerman & Barkley, 2005)



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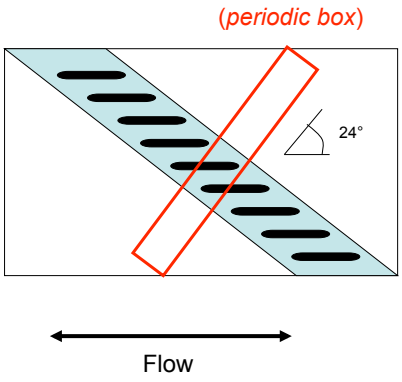

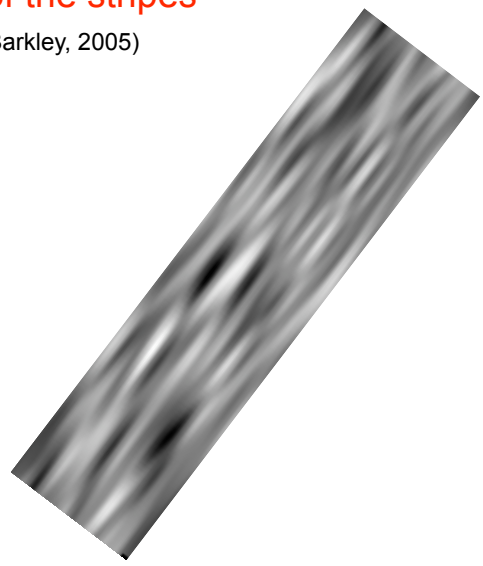

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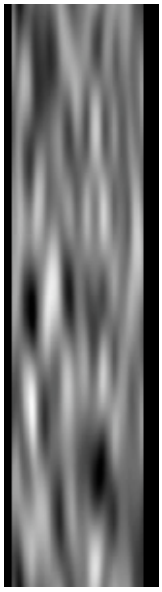
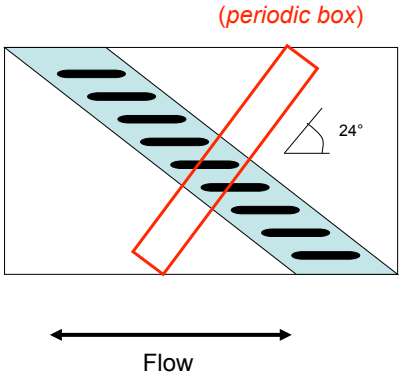
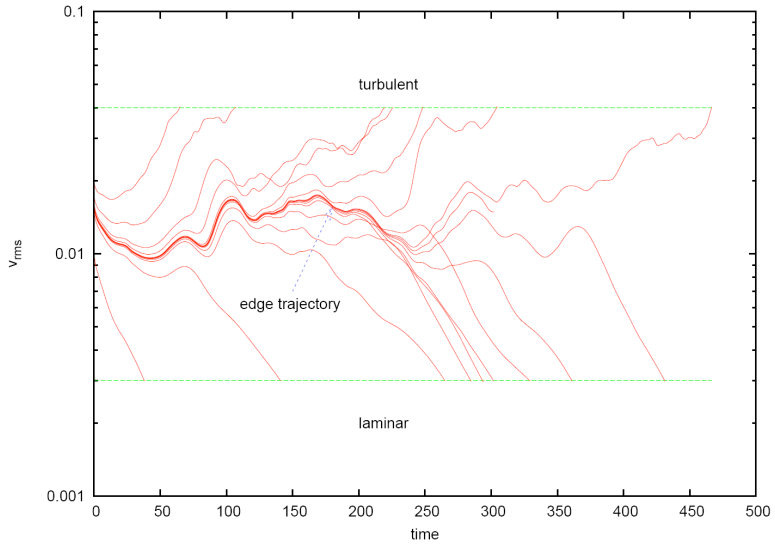
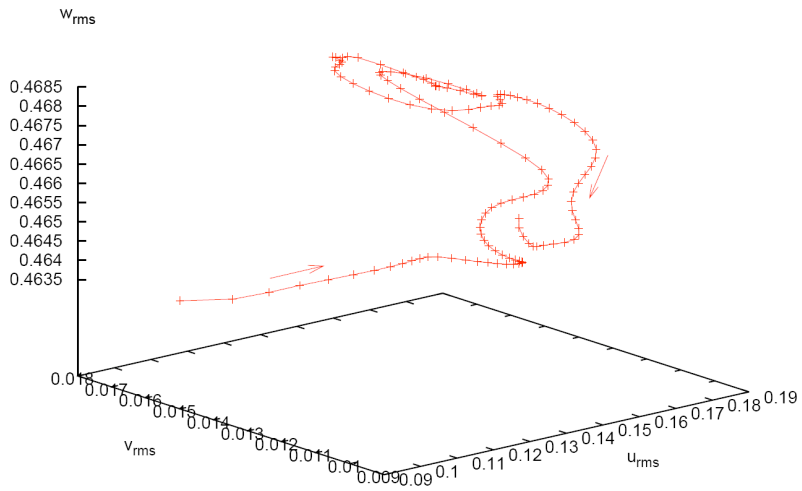




Edge trajectory



Phase-space projection



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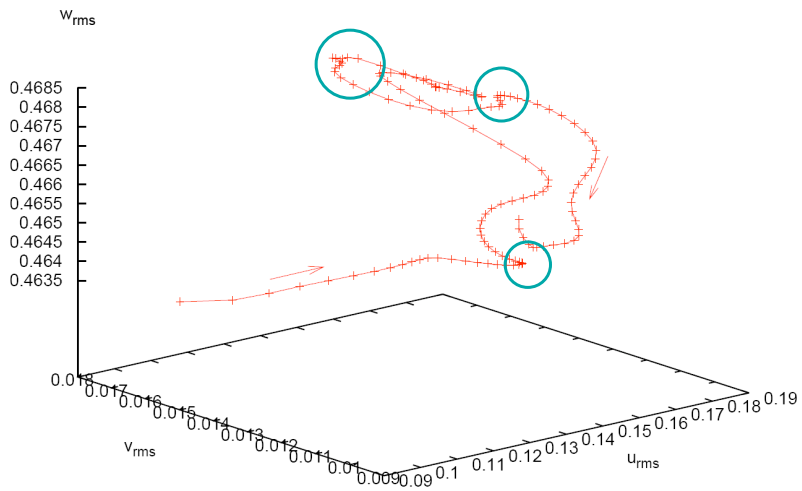
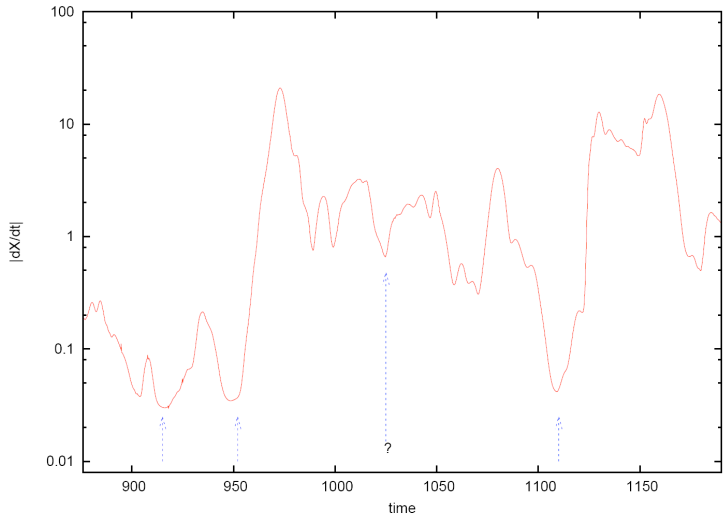


Recurrent approches to steady solutions



Dynamics on the edge

- stays localised wherever the edge trajectory is generated from

- displays less ‘violent’ variations than the corresponding localised regime

- clearly suggests transient visits to steady states solutions

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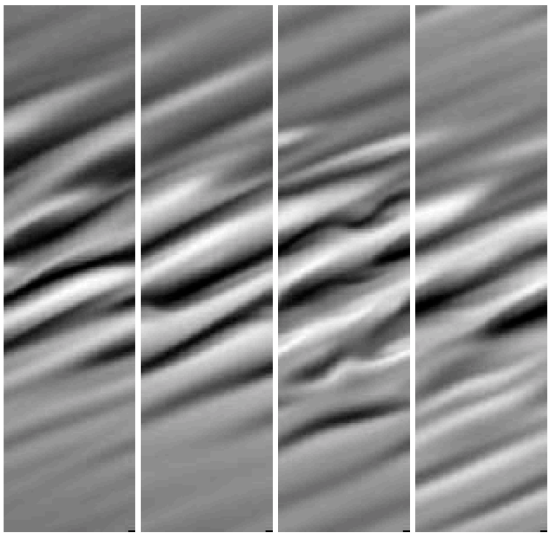
Closest approaches to (localised) steady states



Conclusions

- Spatially localised turbulence → localised edge dynamics
- In both pipe and plane Couette flow, edge trajectories converge or approach transiently exact states (TW/ Steady states)
- Small domains ideas seem extensible to larger computational domains

Open issues

- Influence of the periodic boundary conditions ?

- Increasing numerical complexity to locate non-trivial states