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How fast do exact localized states relaminarize in plane Couette flow?

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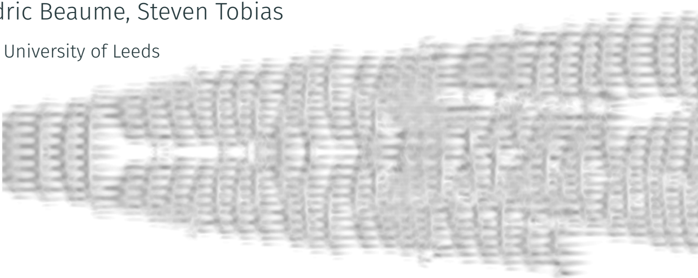
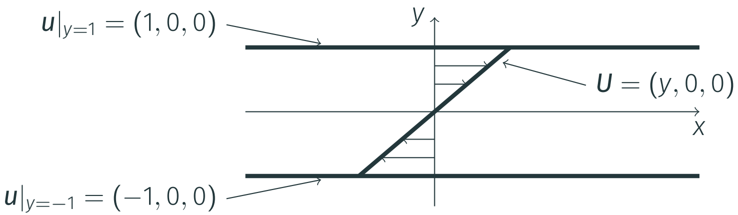


Plane Couette flow

Incompressible Navier–Stokes equation:

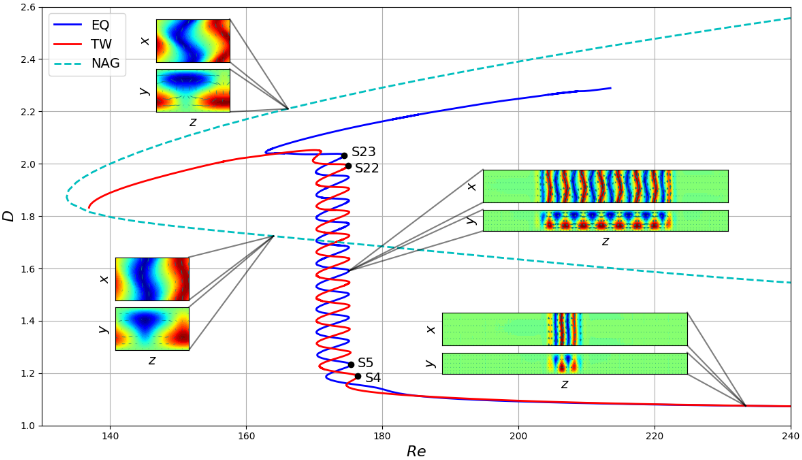
$$\partial_t \boldsymbol{u} + (\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = -\nabla p + \frac{1}{Re}\nabla^2 \boldsymbol{u}$$

$$\nabla \cdot \boldsymbol{u} = 0.$$



	Linearly stable laminar state	Sustained turbulence
Plane Couette flow	all Re	$Re \gtrsim 325$
Pipe flow	all Re	$Re \gtrsim 2040$
Plane Poiseuille flow	$Re \lesssim 5772$	$Re \gtrsim 840$

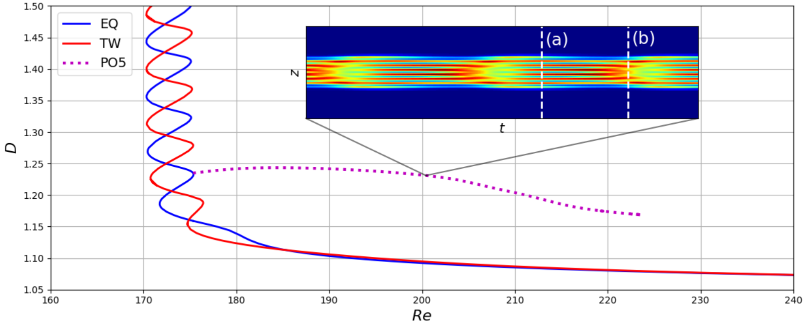
Snaking in plane Couette flow ($4\pi \times 2 \times 32\pi$)

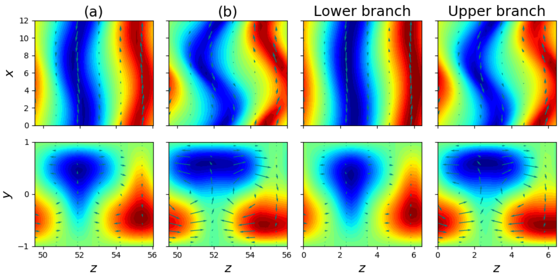


First observed by Schneider *et al.*, Phys. Rev. Lett., 104 (2010).

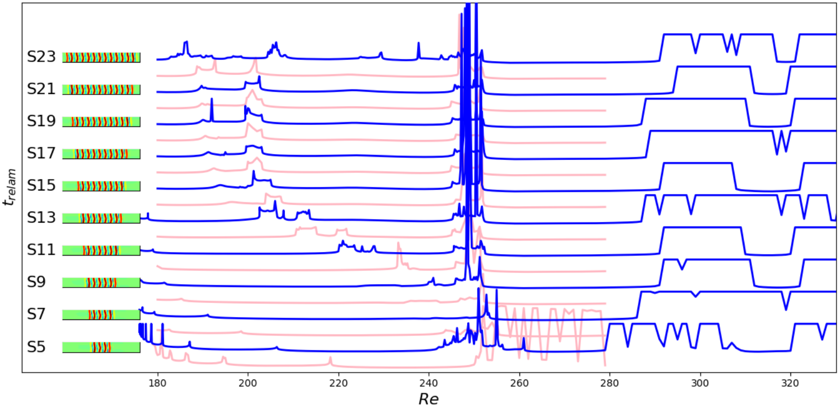
Model of homoclinic snaking is provided by Swift–Hohenberg equation (Knobloch, Annu. Rev. Condens. Matter Phys., 6 (2015))

Oscillatory dynamics ($Re \approx 200$)



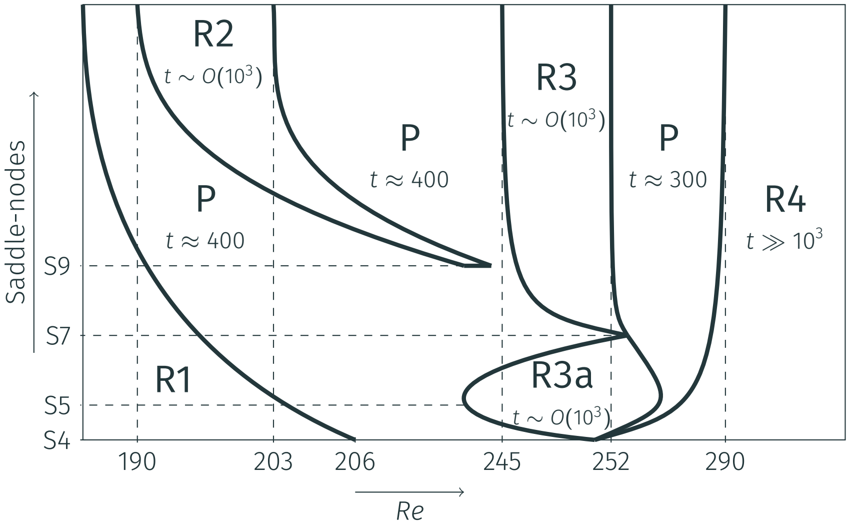


Relaminarisation times for localised states



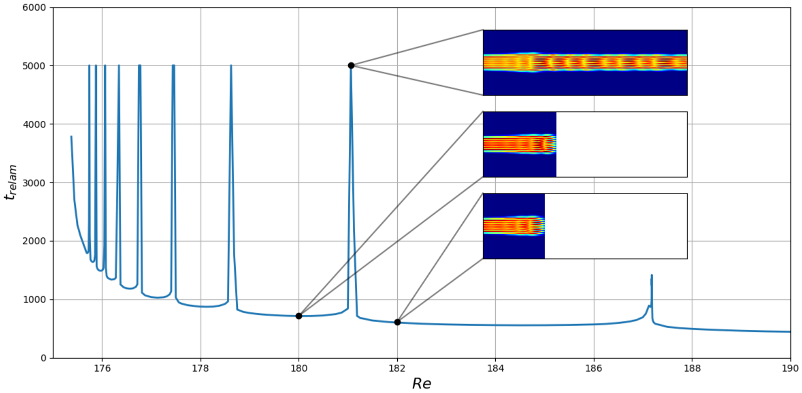
Relaminarisation times for EQ and TW saddle-nodes states (blue and red curves resp.). Midplane of streamwise velocity of EQ saddle-nodes is shown on the left.

No principal difference between the dynamics of EQ and TW



- R1 peaks accumulating at Re_s are present for all initial states.
- Only wide enough states contain R2 and R3.

Region R1 – peaks (S5)

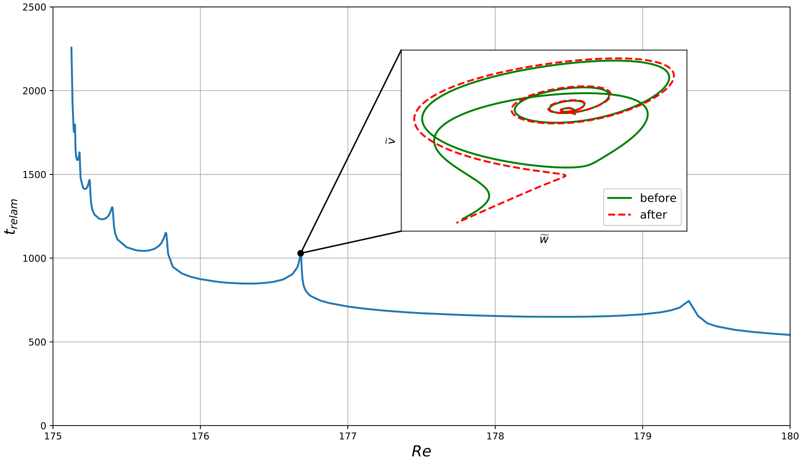


- Peaks: $Re_{n+1} - Re_s = \alpha\,(Re_n - Re_s)$
- Local minima: $t_n = t_0 + \beta n$

$$\Longrightarrow \quad t_{relam} = \frac{\beta}{\ln \alpha} \ln\left[\frac{2\,(Re - Re_s)}{(1+\alpha)\,(Re_0 - Re_s)}\right] + t_0$$

Region R1 – peaks (S7)

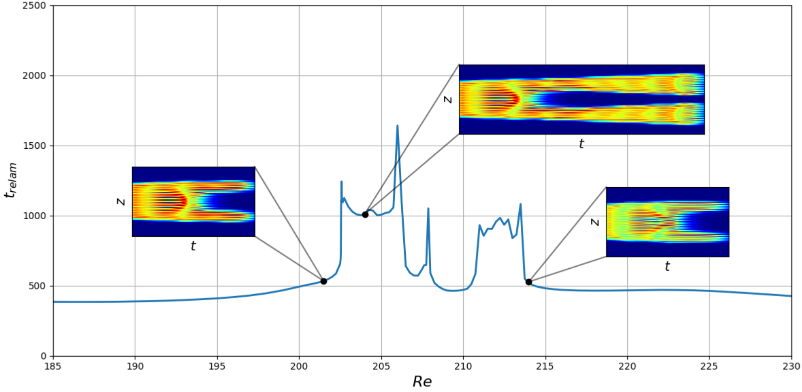
For wider initial conditions, peaks are smoothed.



Crossing a peak corresponds to the gain of the cycle.

Region R2 – splitting

Region R2 appears due to the creation of the spots and their activation.



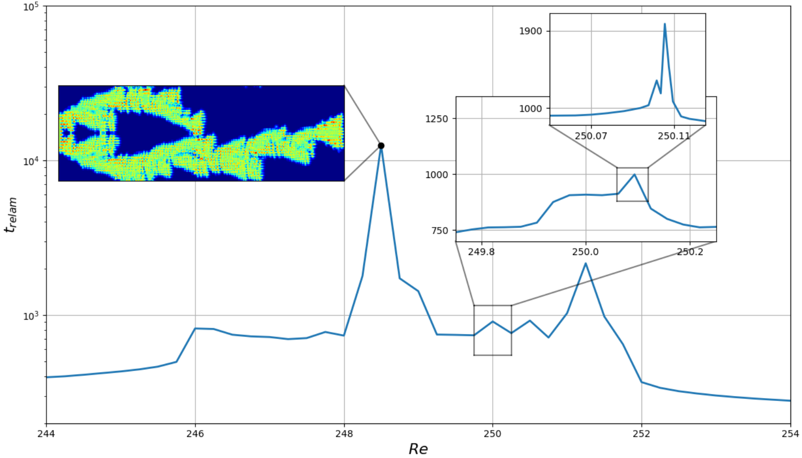
Relaminarisation times for S13 integrated for $Re \in [185; 230]$.

The size of spots is the same for all considered initial conditions.

Region R3 – chaotic transients

Like R2, R3 originates from the splitting of the initial spot.

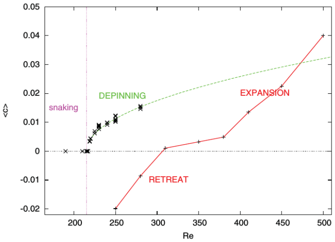
Unlike R2, R3 contains long-lasting chaotic transients ($T > 4000$).



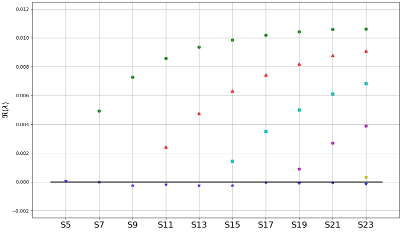
Relaminarisation times for S9 integrated for $Re \in [244; 254]$.

Conclusion

(a) **Depinning?**
comparison with Duguet *et al.*, Phys. Rev. E, 84 (2011)



(b) **Stability analysis of the snakes?**
comparison with Beaume, *et al.*, J. Fluid Mech., 840 (2018)



(c) **Control of relaminarisation times and front growth?**