The Fluid Mechanics behind the LH Transition

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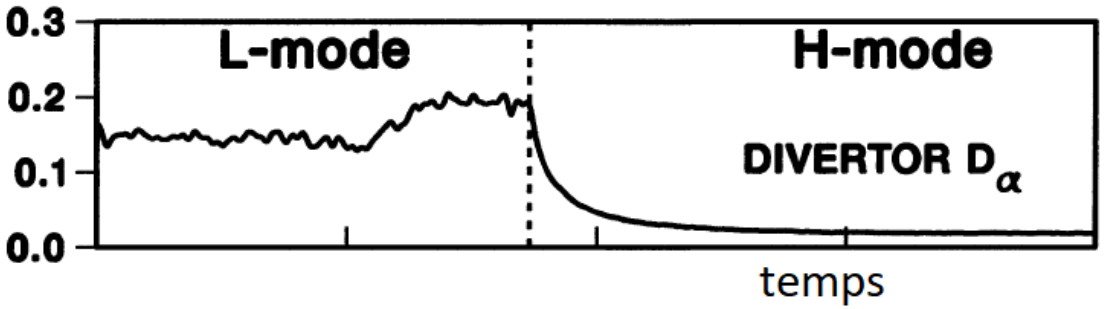
The guy who did the work

Wesley Agoua

Some characteristics of the LH transition[1]



- Self-organization (zonal flows)
- Reduced level of turbulence
- Reduced transport
- Sharp transition (bifurcation)

[1] Wagner et al. ASDEX PRL 1982

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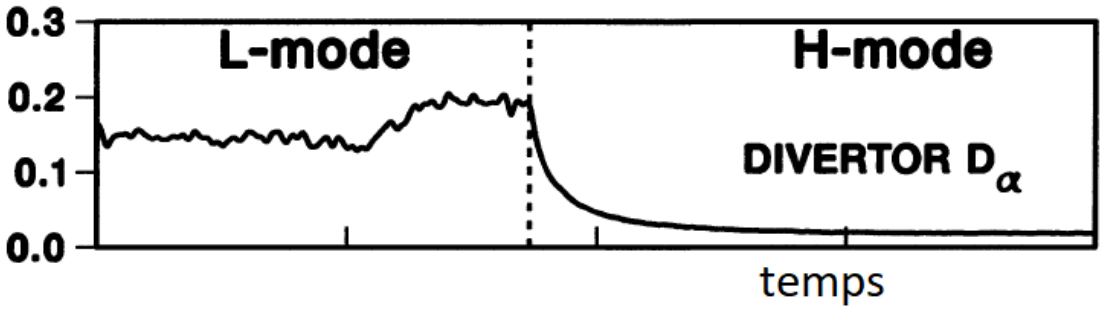

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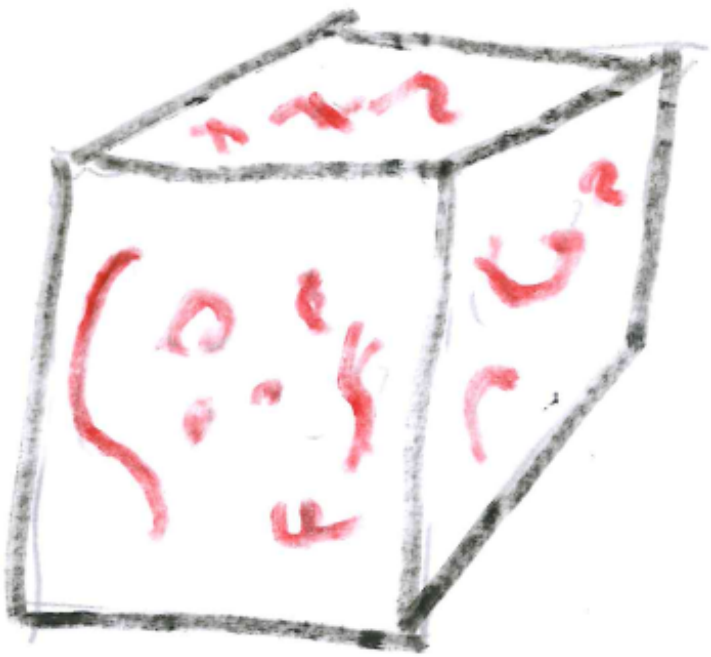
What is the origin?

[1] Wagner et al. ASDEX PRL 1982

Turbulence

3D versus 2D turbulence



Turbulence

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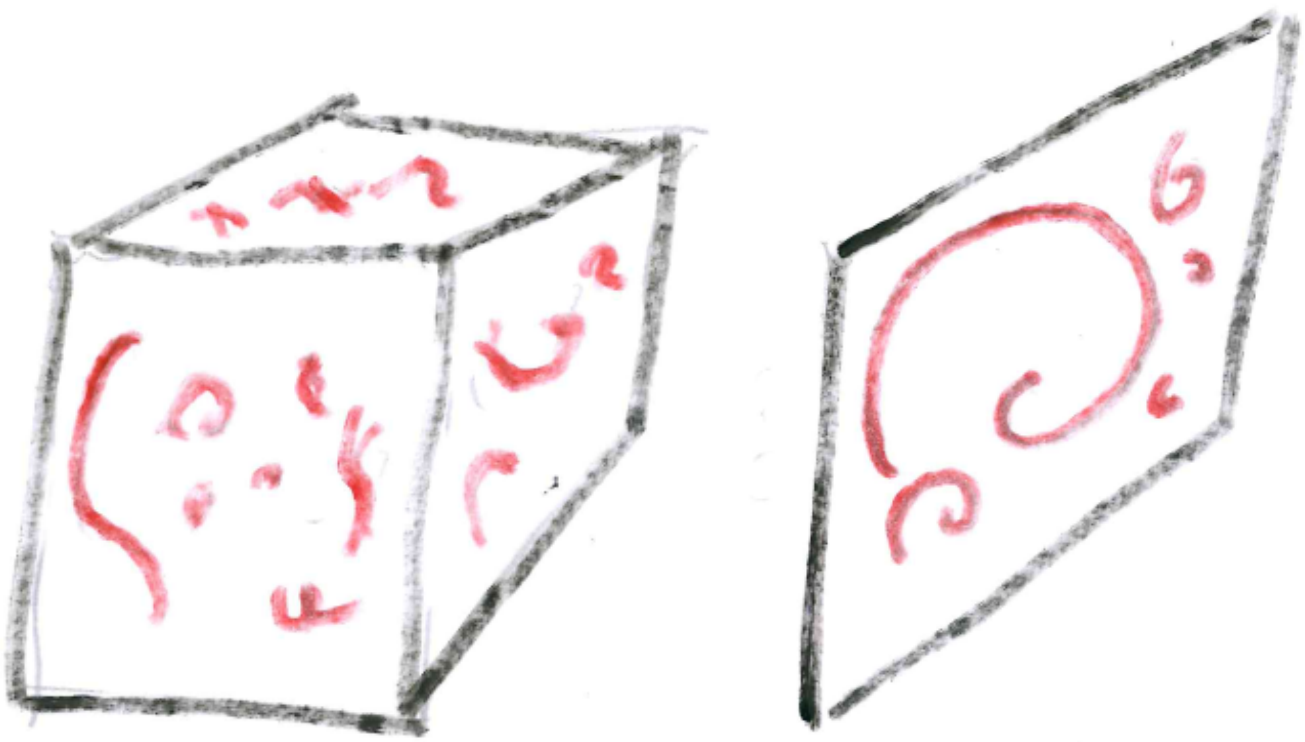
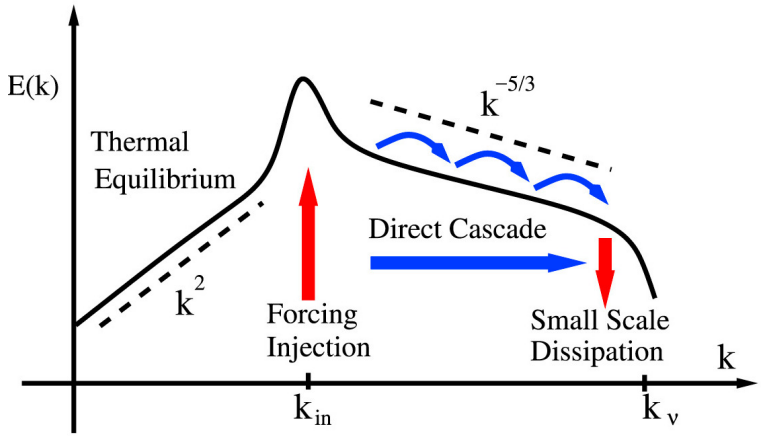


Turbulence

Three- and two-dimensional turbulence[2]

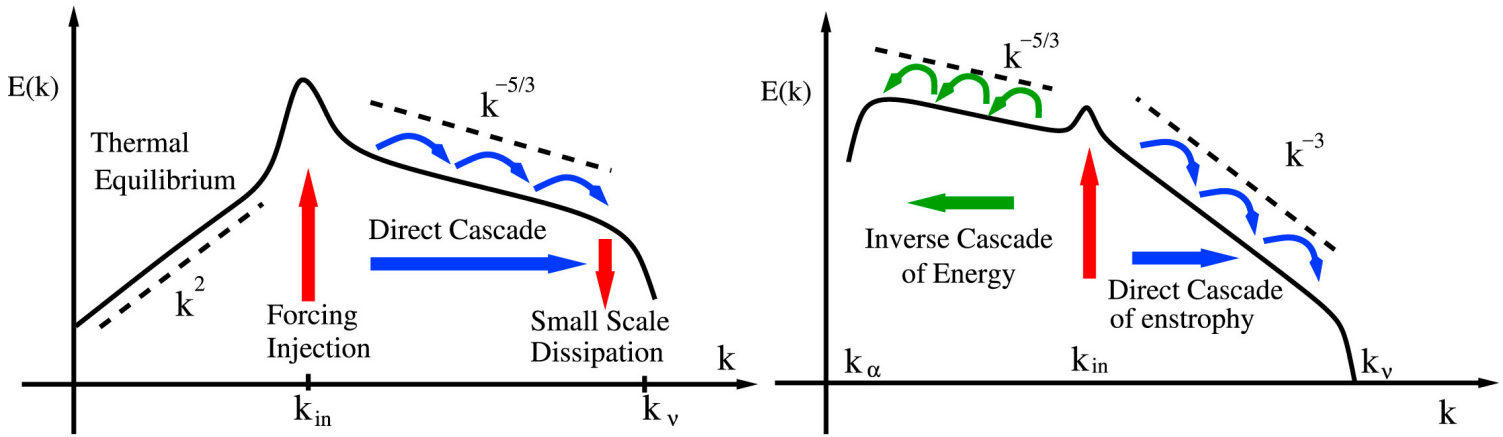


[2]Figures: Alexakis & Biferale 2018

[3]e.g. Shats, Xia, Punzmann - PRE 2005

Turbulence

Three- and two-dimensional turbulence[2]



Inverse cascade leads to coherent structures of domain size.
Link with H-mode[3].

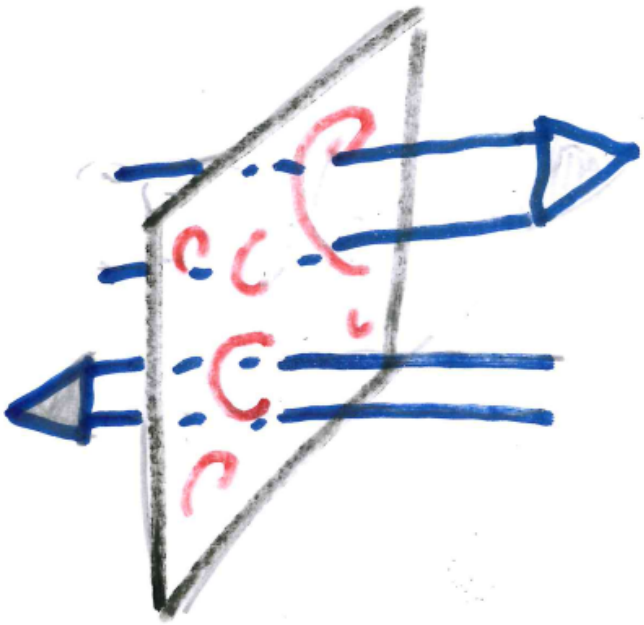
Does not explain the existence of an L-mode.

[2]Figures: Alexakis & Biferale 2018

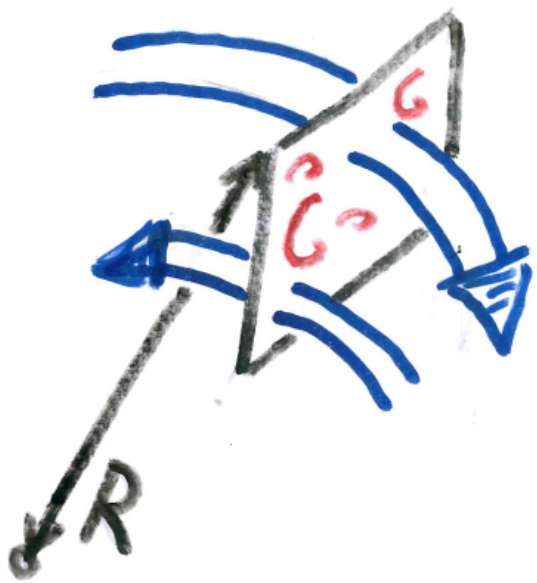
[3]e.g. Shats, Xia, Punzmann - PRE 2005

In between 2 and 3 dimensions

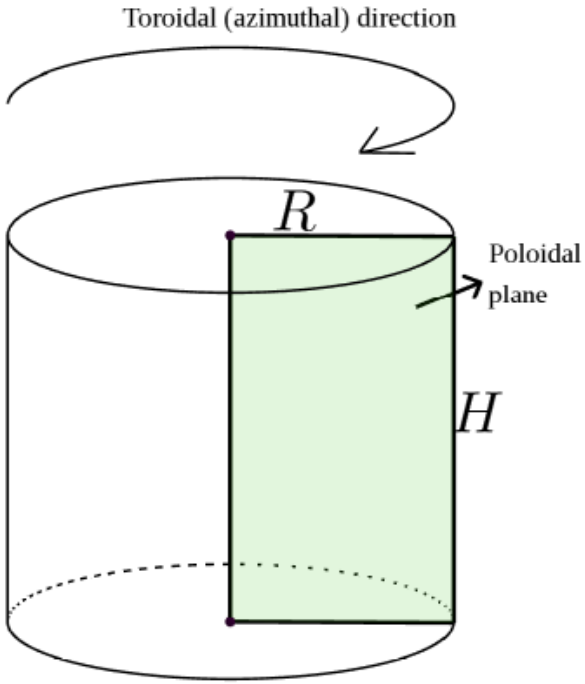
2D3C



2D3C-R (Axisymmetric)



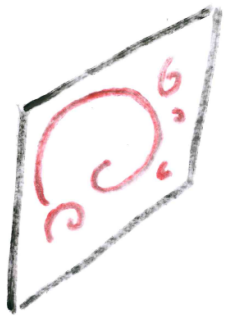
Axisymmetric turbulence in a cylinder

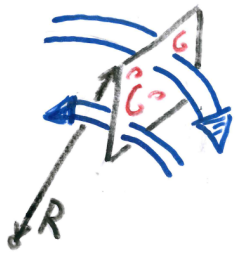


Is there a difference between 2D3C and 2D3C with curvature? Yes[4]

[4] Leprovost, Dubrulle, Chavanis - PRE 2006
Monchaux, Ravelet, Dubrulle, Chiffaudel, Daviaud, 2006 PRL 2006

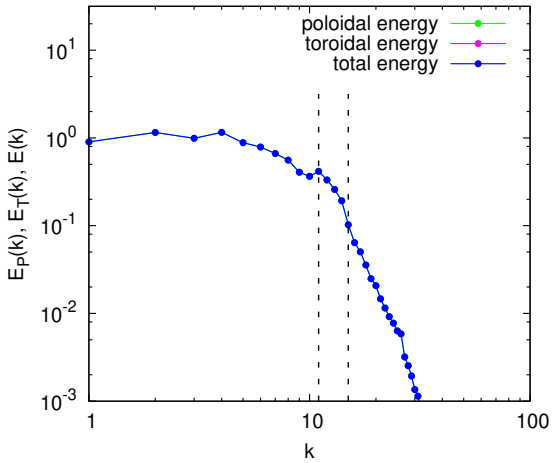
Cascade directions?[5]

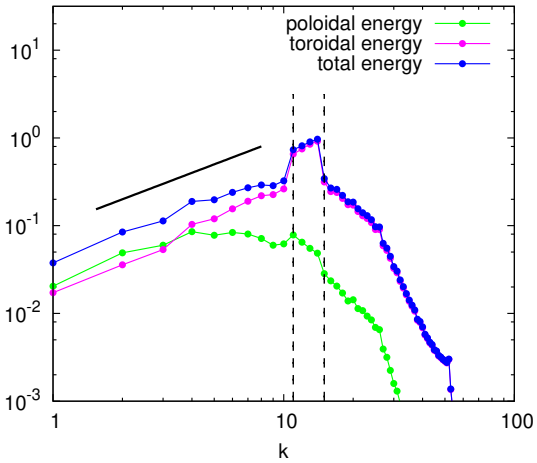




2D2C

2D3C-R (Axisymmetric)

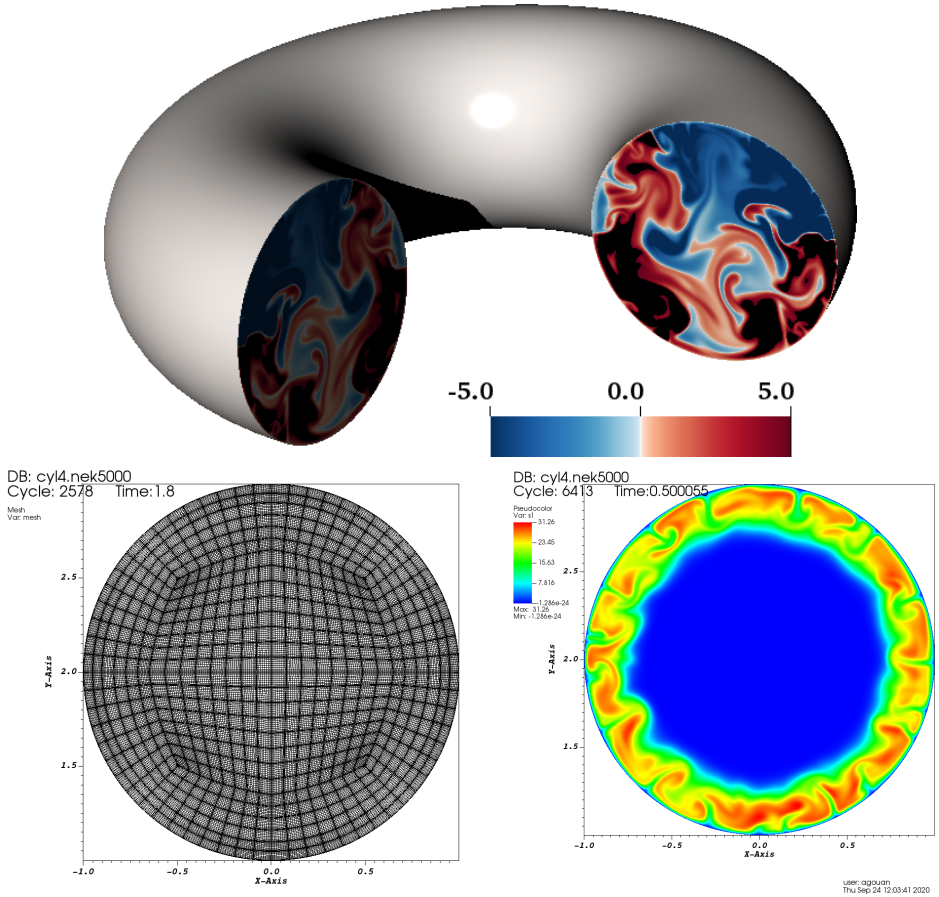




In axisymmetric turbulence (2D3C-R), we observe a direct cascade !

[5] Qu, Naso, Bos, PRF (2017, 1018) Qin, Faller, Dubrulle, Naso, Bos, PRF (2020)

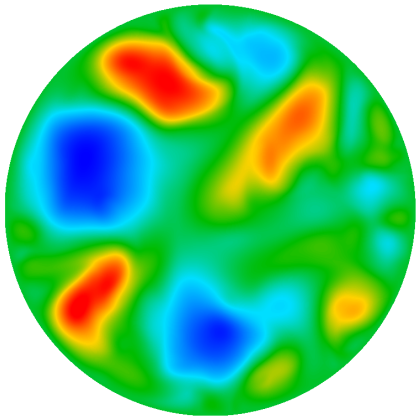
Does this persist in a torus?



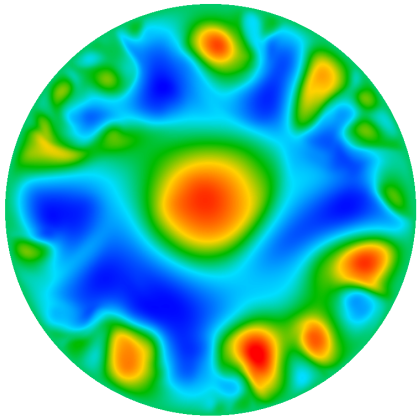
Simulations NEK5000, Axisymmetric Navier-Stokes, linear forcing near edge, Symmetry-axis aligned with toroidal direction.

Control parameter F_T/F_P

2D3C(R)
L-mode



2D2C
H-mode



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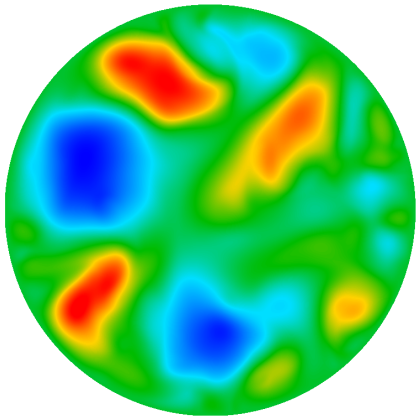

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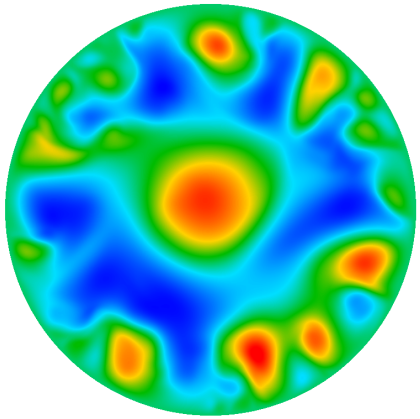
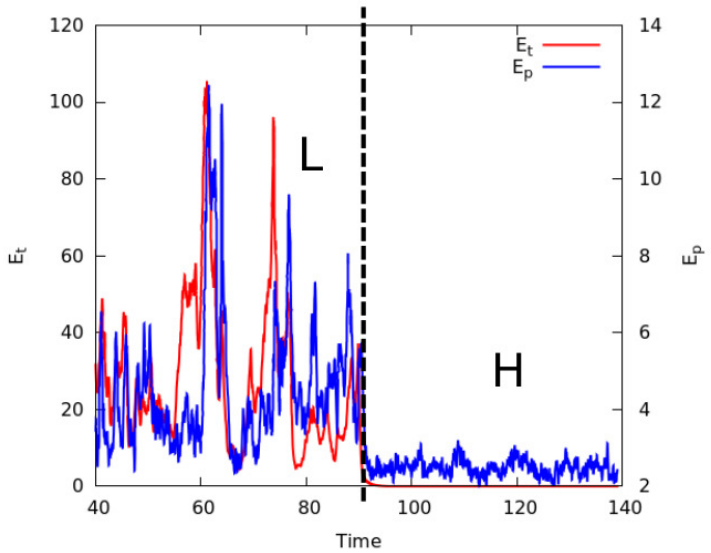
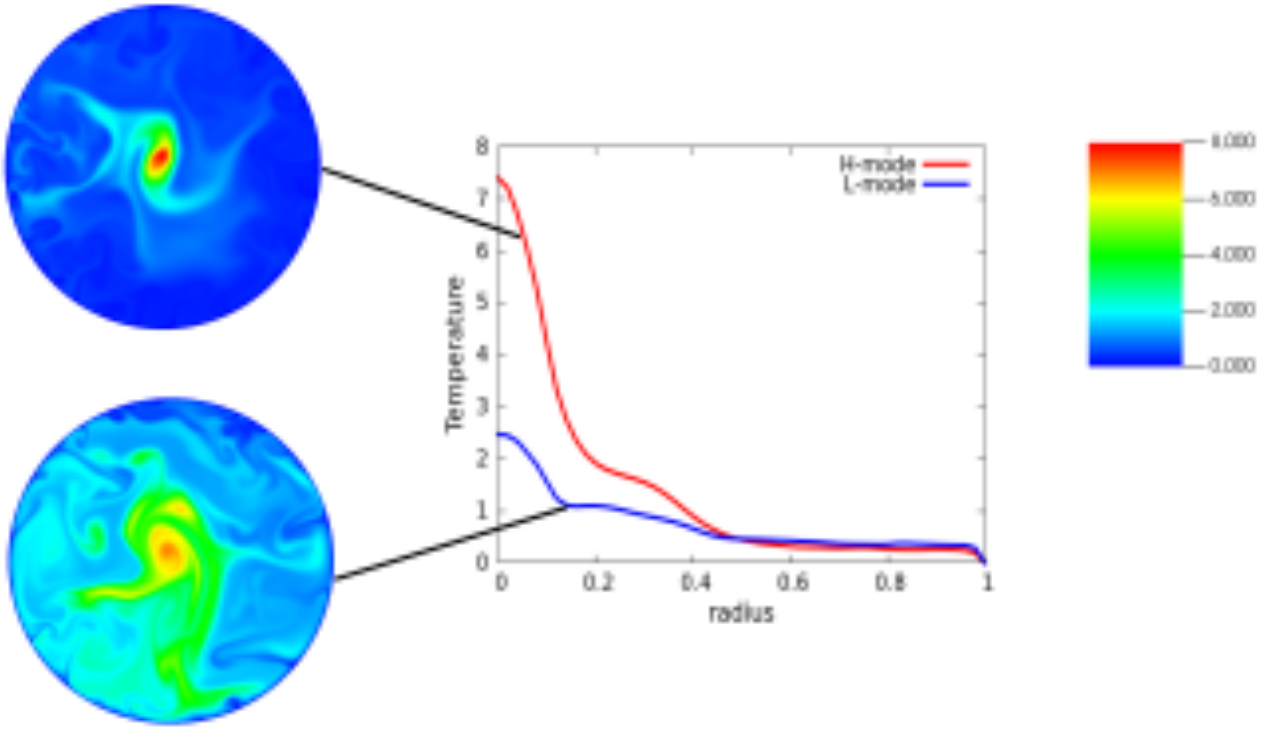




2D3C(R) to 2D transition reduces turbulence intensity, cf. LH transition!

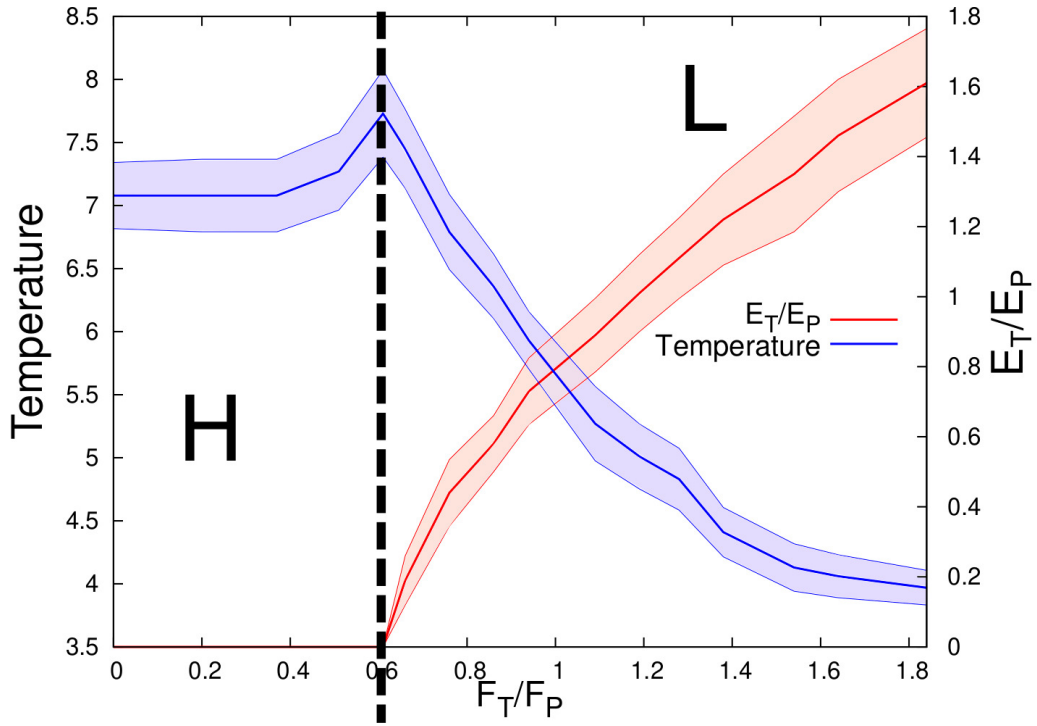
Does this improve the confinement?

Passive tracer injected in center of domain.
Its concentration measures the confinement.



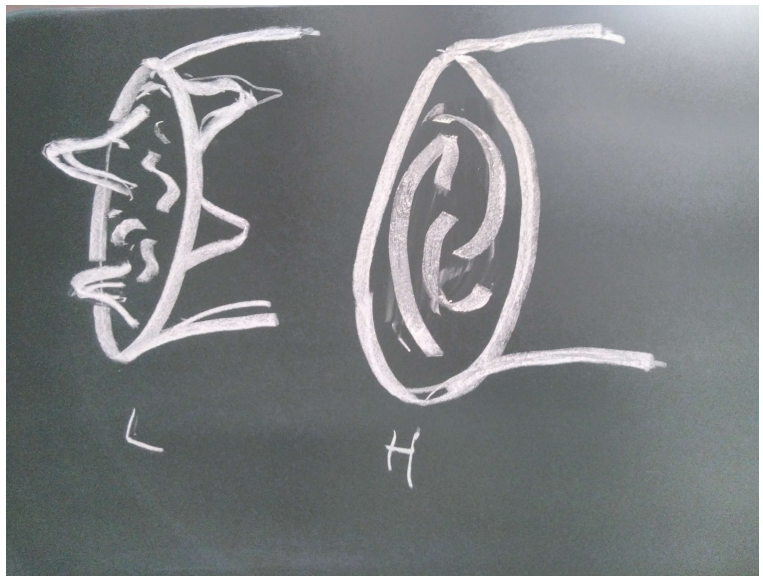
Yes!

Overview of the bifurcation



The anisotropy of the instability/forcing pilots the transition.

Conclusion



Possibly the simplest *generic* explanation for the LH-transition is that it corresponds to a 2D3C(R) $\rightarrow$ 2D2C transition.

Open issues

- connect the forcing mechanism to physical instabilities
- hysteresis (in the torus)
- back-reaction temperature on forcing
- helical shape of the symmetry axis
- How to compare with Experiments/Gyrokinetics