# Transition to (spatio-temporal complexity and) turbulence in thermoconvection & aerodynamics

http://emmanuelplaut.perso.univ-lorraine.fr/t2t

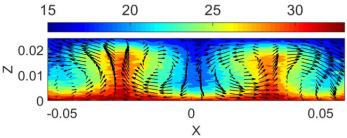
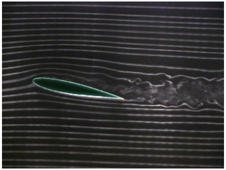
| Session | Date | Content |
|---|---|---|
| 1 - | 29/09 | Thermoconvection: phenomena, equations, differentially heated cavity, cavity heated from below = **RB** cavity, linear stability analysis |
| 2 - | 06/10 | **RB** Thermoconvection: linear stability analysis |
| 3 - | 13/10 | **RB** Thermoconvection: (weakly) nonlinear phenomena |
| → 4 - | 20/10 | Aerodynamics of **OSF**: linear stability analysis |
| 5 - | 27/10 | Aerodynamics of **OSF**: linear & weakly nonlinear stability analyses |
| 6 - | 10/11 | Aerodynamics of **OSF**: nonlinear phenomena |
| | 24/11 | **Examination** |

**RB*** = Rayleigh-Bénard    **OSF*** = Open Shear Flows

## Today: session 4: transition in open shear flows:

- Introduction: OSF, instabilities of OSF, Rayleigh criterion
- Numerical linear stability analysis of plane Poiseuille flow: towards TS waves

# Introduction: open shear flows, a new family of systems, quite different from Rayleigh-Bénard thermoconvection systems

| | RB Thermoconvection | Open shear flows (OSF) |
|---|---|---|
| |  |  |
| | [ Leclerc & Métivier ] | [ Homsy et al. ] |
| Fields | $\mathbf{v}$<br>$T$ | $\mathbf{v}$<br>$T = constant$ |
| Base state | $\mathbf{v} = \mathbf{0}$ trivial<br>$T = T(z)$ | $\mathbf{v} \neq \mathbf{0}$ complex<br>$T = constant$ |
| Eqs and nonlinearities | Navier-Stokes contains $(\mathbf{v} \cdot \boldsymbol{\nabla})\mathbf{v}$<br>Heat equation contains $\mathbf{v} \cdot \boldsymbol{\nabla} T$ | Navier-Stokes contains $(\mathbf{v} \cdot \boldsymbol{\nabla})\mathbf{v}$<br>Heat equation trivially fulfilled |

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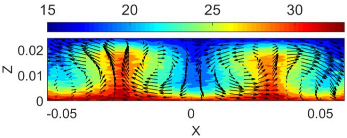
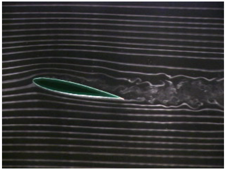
| |   |  |
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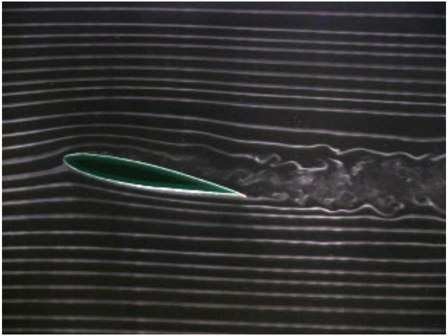
| | $T = T(z)$ | $T =$ *constant* |
| Eqs and nonlinearities | Navier-Stokes contains $(\mathbf{v}\cdot\nabla)\mathbf{v}$ | Navier-Stokes contains $(\mathbf{v}\cdot\nabla)\mathbf{v}$ |
| | Heat equation contains $\mathbf{v}\cdot\nabla T$ | Heat equation trivially fulfilled |

**OSF quite interesting but also quite challenging:**

**easier to understand $\mathbf{v}\cdot\nabla T$ than $(\mathbf{v}\cdot\nabla)\mathbf{v}$ !**

# Open shear flows are often encountered in aerodynamics

**Turbulent** (?) **flow** around an obstacle, an airfoil, at an angle of attack $\alpha = 15^{\mathrm{o}}$, observed with smoke in a wind tunnel at U. Stanford:



[ Homsy et al. 2019 *Multimedia Fluid Mechanics Online*. Cambridge University Press ]

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**Laminar flow** around an obstacle, an airfoil, also exists, and may be computed, for the external flow, with potential flow theory - complex analysis techniques:

[ Plaut 2018 *Mécanique des fluides : des bases à la turbulence*. Cours Mines Nancy 2A ]

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When and how **laminar open shear flows** get **unstable** and go to **turbulence ?**