Flow past a compressor blade

Gabriele Rocco
Hugh M. Blackburn, Xuerui Mao, ,Spencer J. Sherwin, Tamer Zaki

Imperial College London

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Imperial College London

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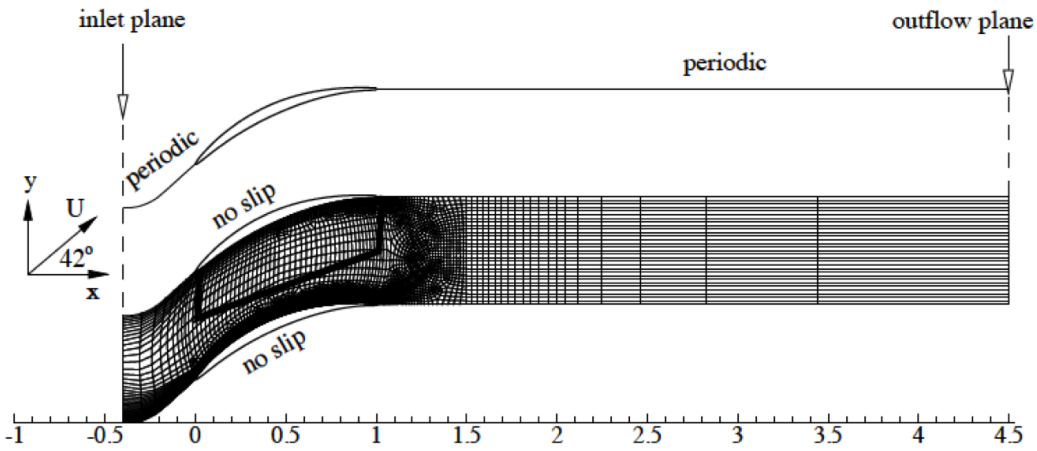

Case study

1. NACA 65 profile.

What we are interested in

1. Well resolved D.N.S.
2. Direct/adjoint stability analysis
3. Transient growth

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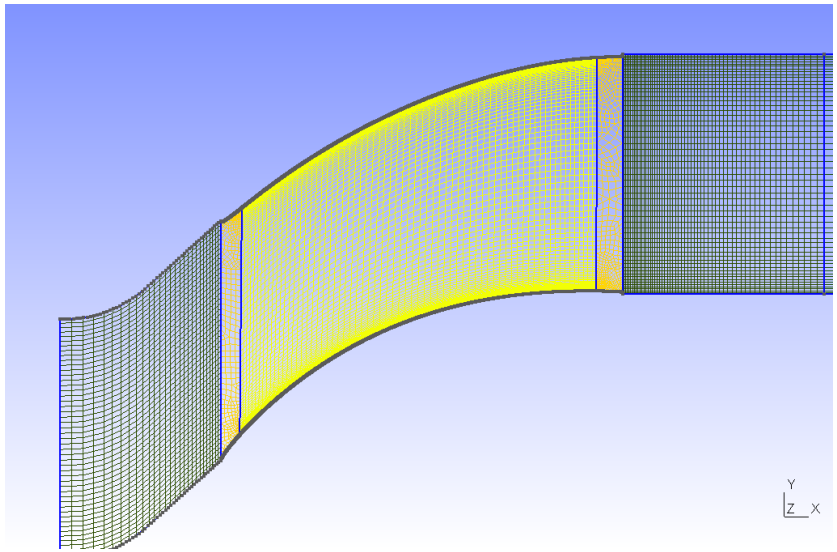
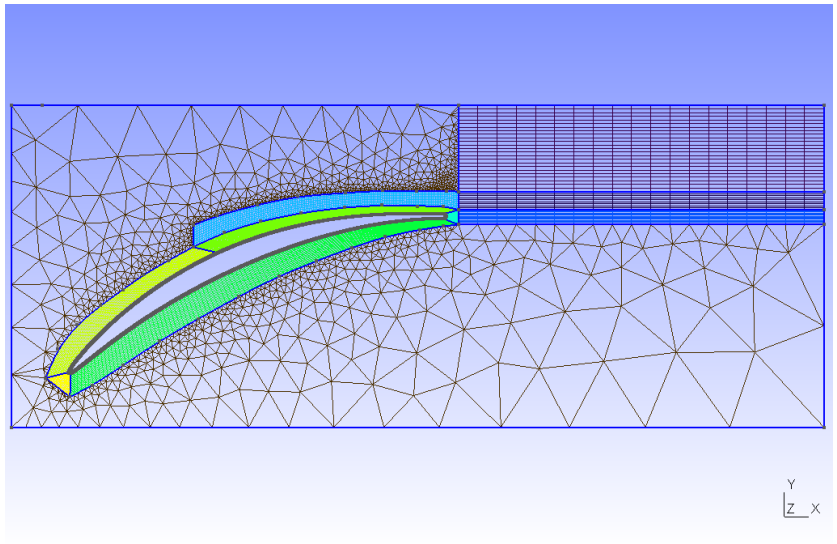
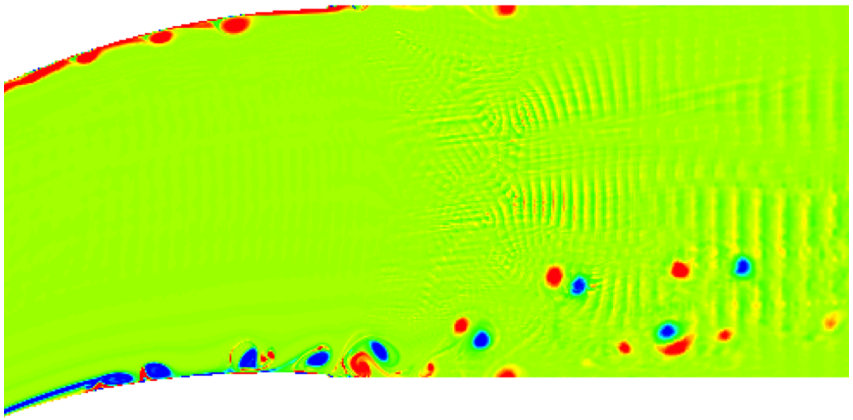


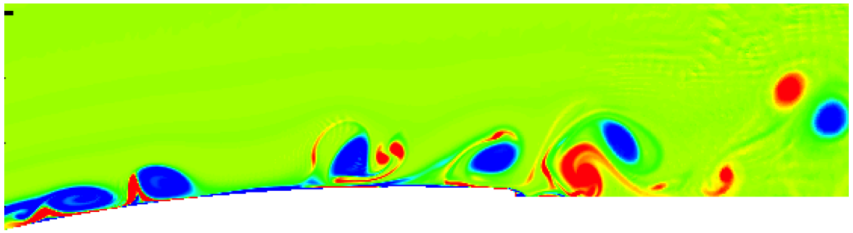


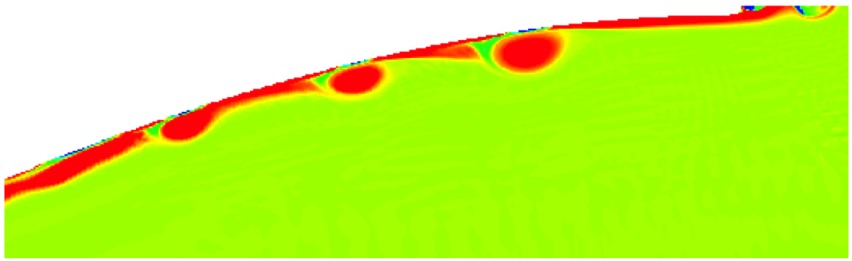
DNS simulation

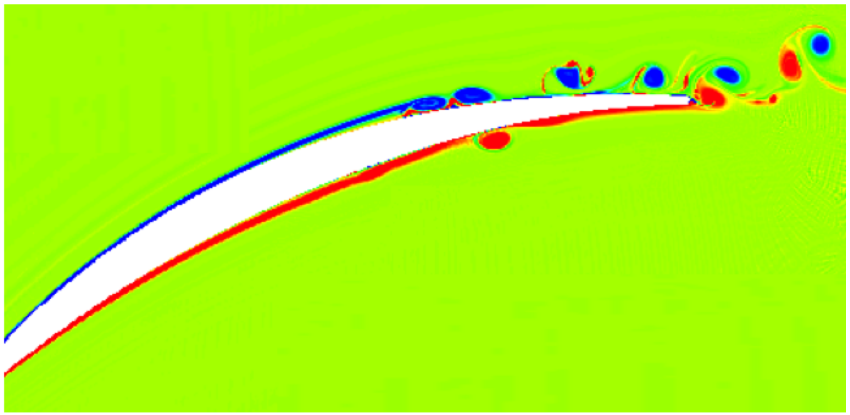
1. $Re = 138500$
2. 10400 elements
3. 7^{th} order GLL-Lagrange/modified polynomial
4. Spectral/hp dealiasing
5. $\Delta t = 10^{-6}$

Profile of the vorticity









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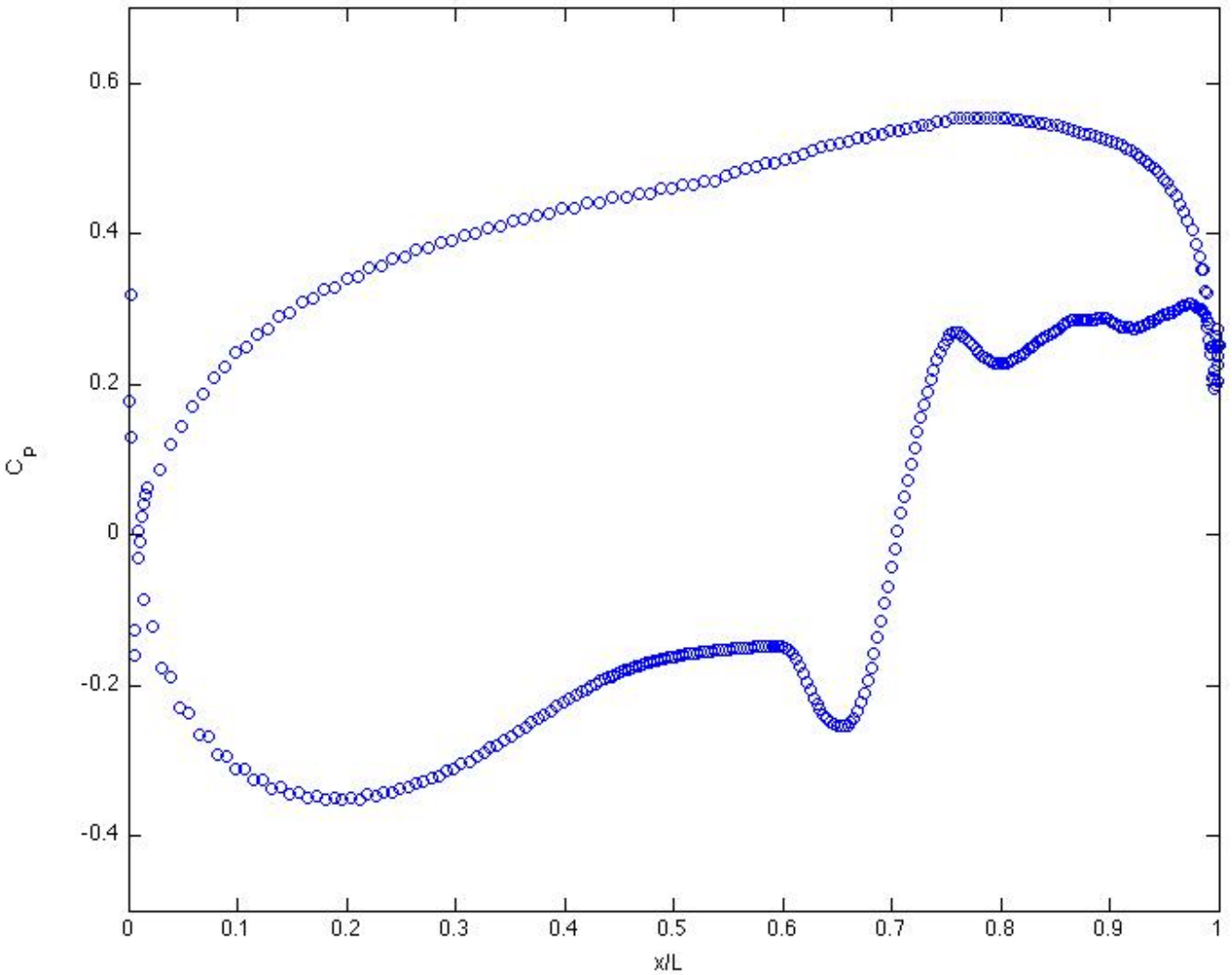
$$C_p = (p - p_\infty)/(\tfrac{1}{2}\rho U^2)$$



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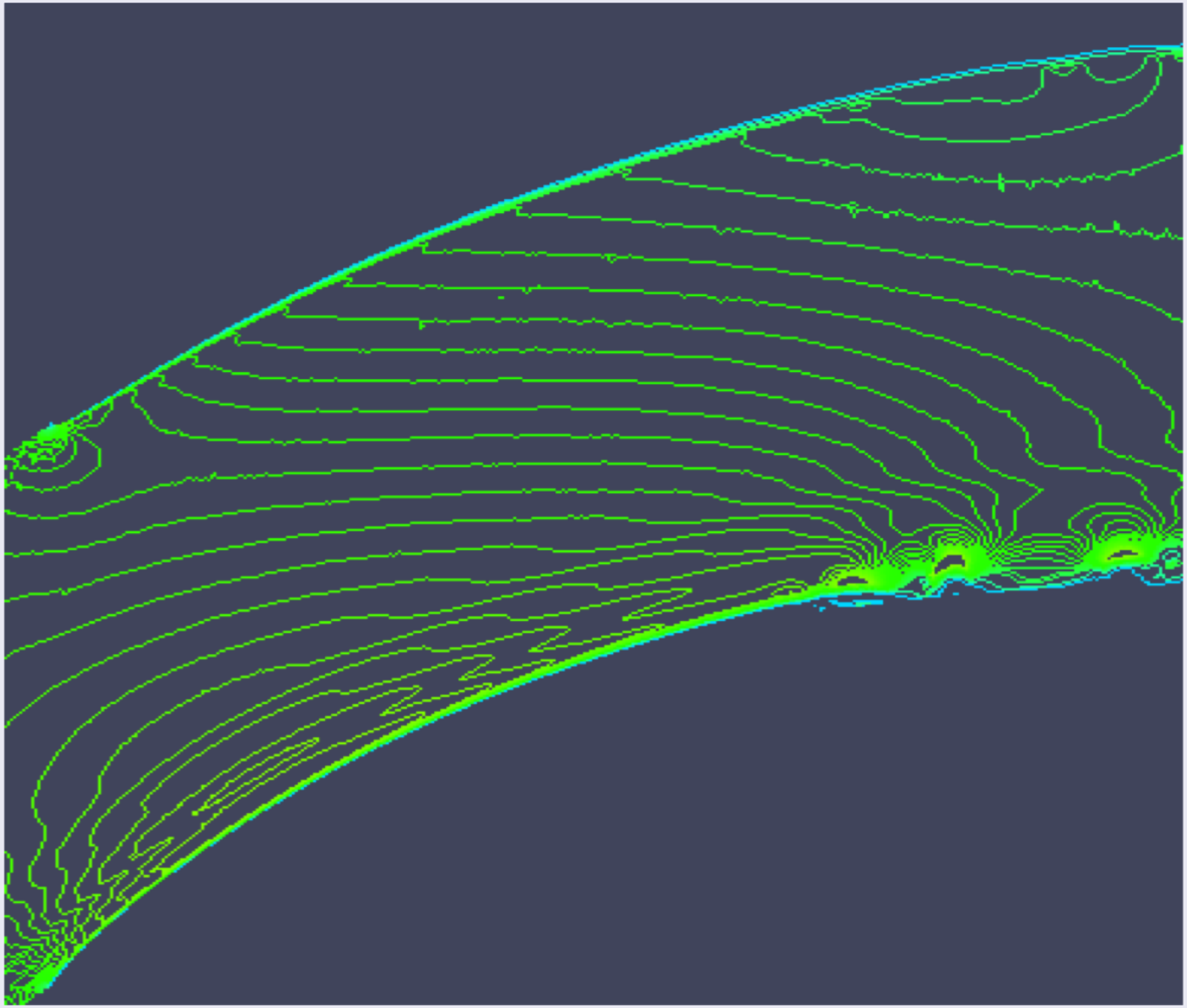
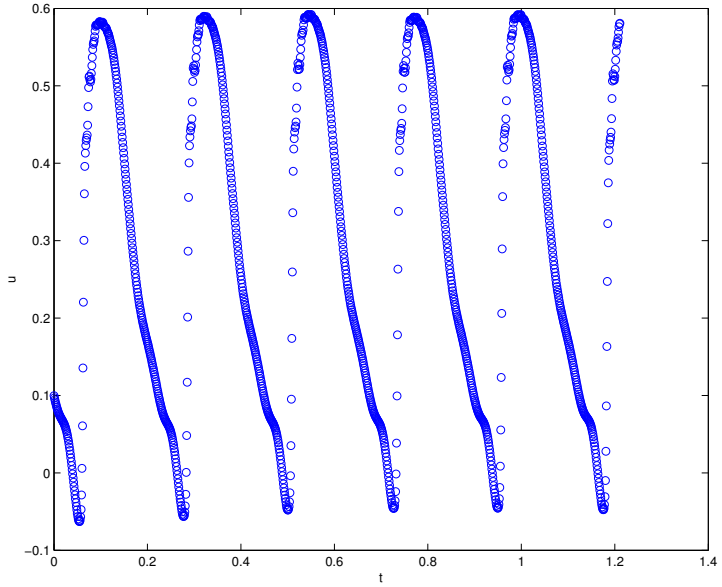
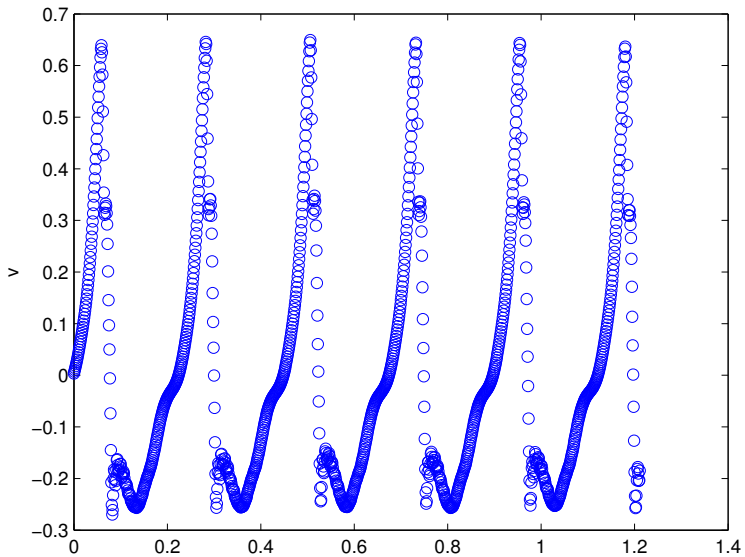
Esemble averaged fields $\bar{U} = \sum_N U_i$

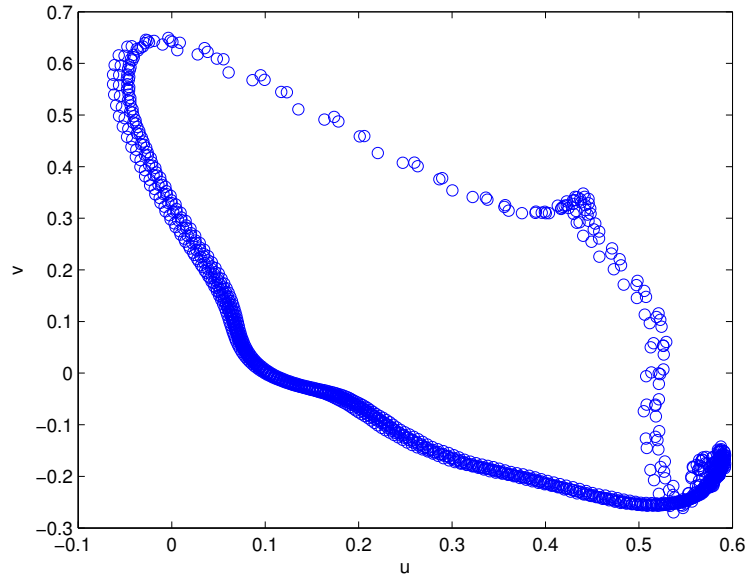


Flow past a compressor blade

Flow is periodic on the suction side close to the trailing edge







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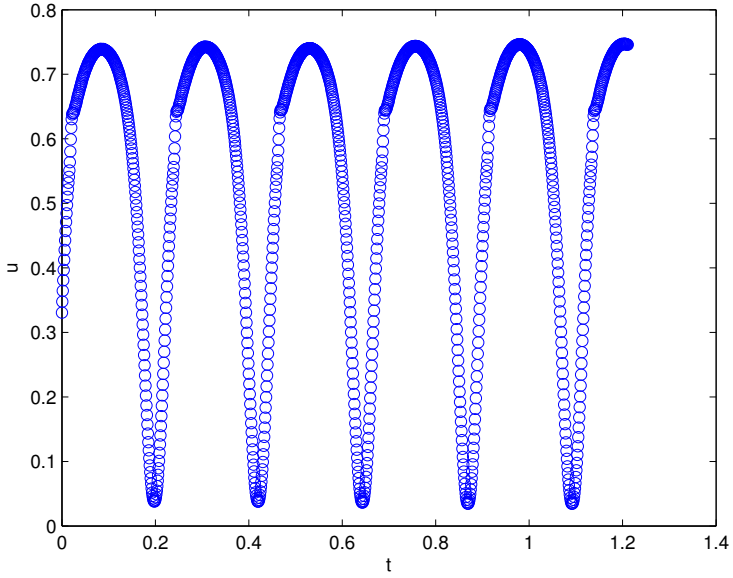

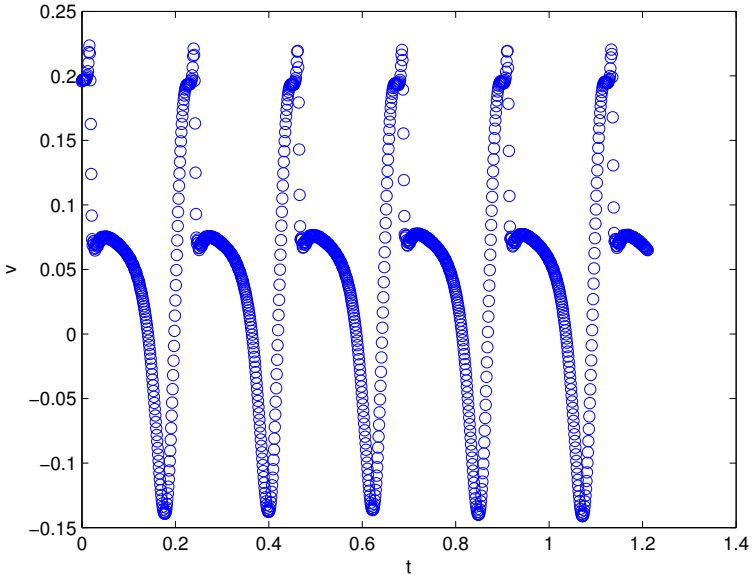

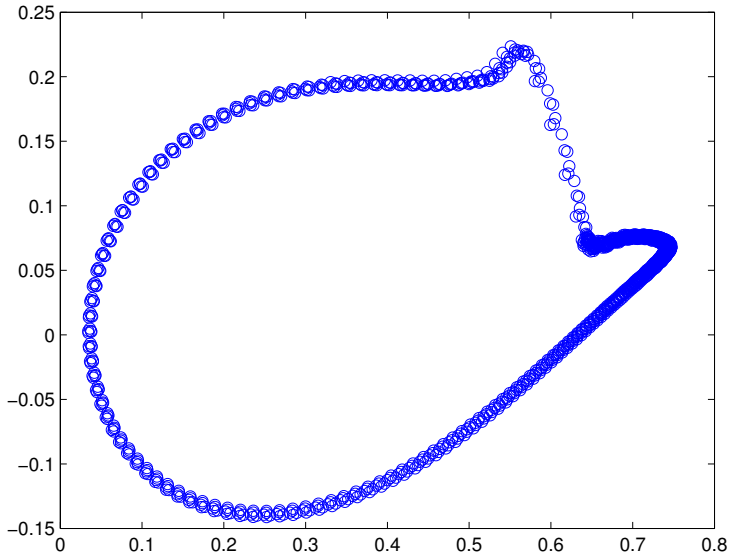

Central frequency

$$\omega = \frac{2\pi}{T} \simeq 28.5$$

Phase-averaging (Cantwell, Coles-J.F.M., 1983)

$$s = \bar{s} + s' + \tilde{s}$$

- s' random component
- Global mean $N\bar{s} = \sum_{n=1}^{N} s_n$
- mean at constant phase $N_i < s >= \sum_{\nu=1}^{N_i} s_\nu \quad (\nu = 1, \ldots, 50)$
- periodic component $\tilde{s} =< s > -\bar{s}$
- $\bar{\tilde{s}} = 0$ the periodic motion has zero mean when averaged over one cycle
- $< s' >= 0$ random fluctuations at constant phase have zero average
- $\overline{\tilde{s}s'} = 0$ periodic and random motions are uncorrelated

It is possible to derive the momentum equation for the mean flow at constant phase, noticing $\tilde{s} =< s > -\bar{s}$.

$$\frac{\partial < \mathbf{u} >}{\partial t} + < \mathbf{u} > \cdot \nabla < \mathbf{u} >= -\nabla < p > +\nu \nabla^2 < \mathbf{u} > -\nabla \cdot < \mathbf{u}'\mathbf{u}' >$$

$\mathbf{u}'$ is much smaller than $\mathbf{u}$ so the last term can be neglected

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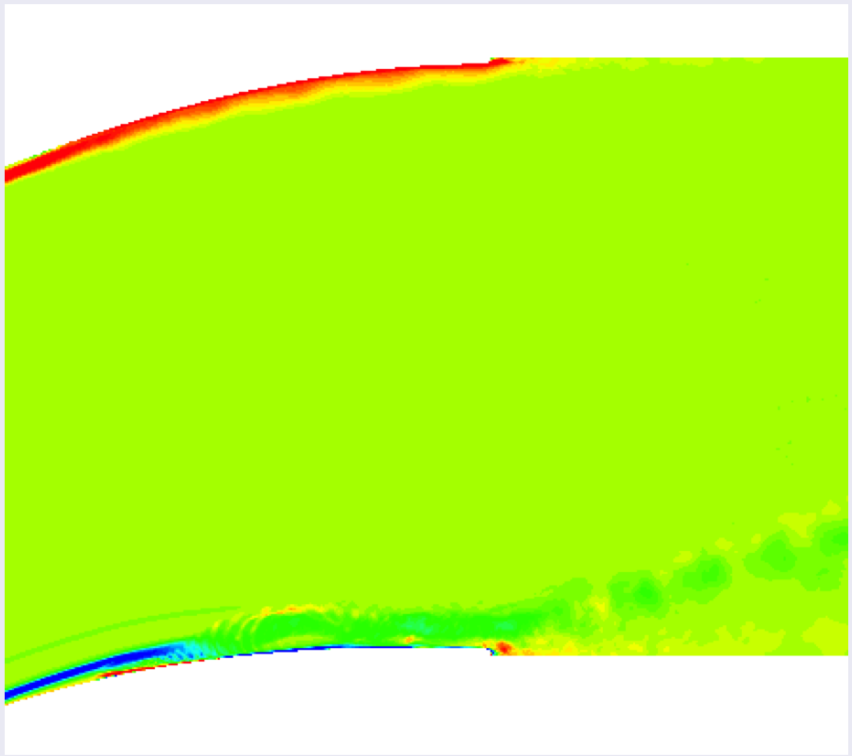
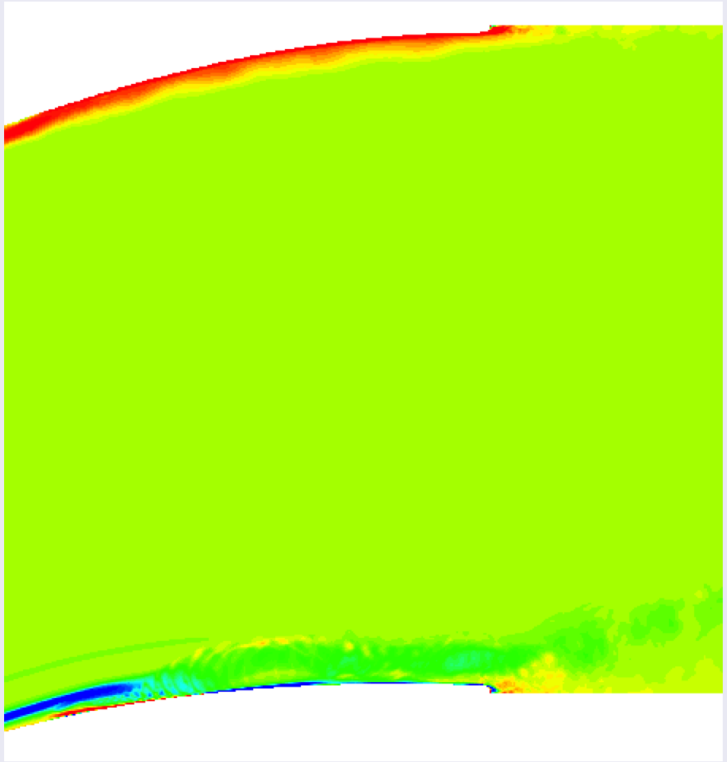
Phase averaging over 80 periods

ϕ_0: $t = 0$



ϕ_{25}: $t = T/2$



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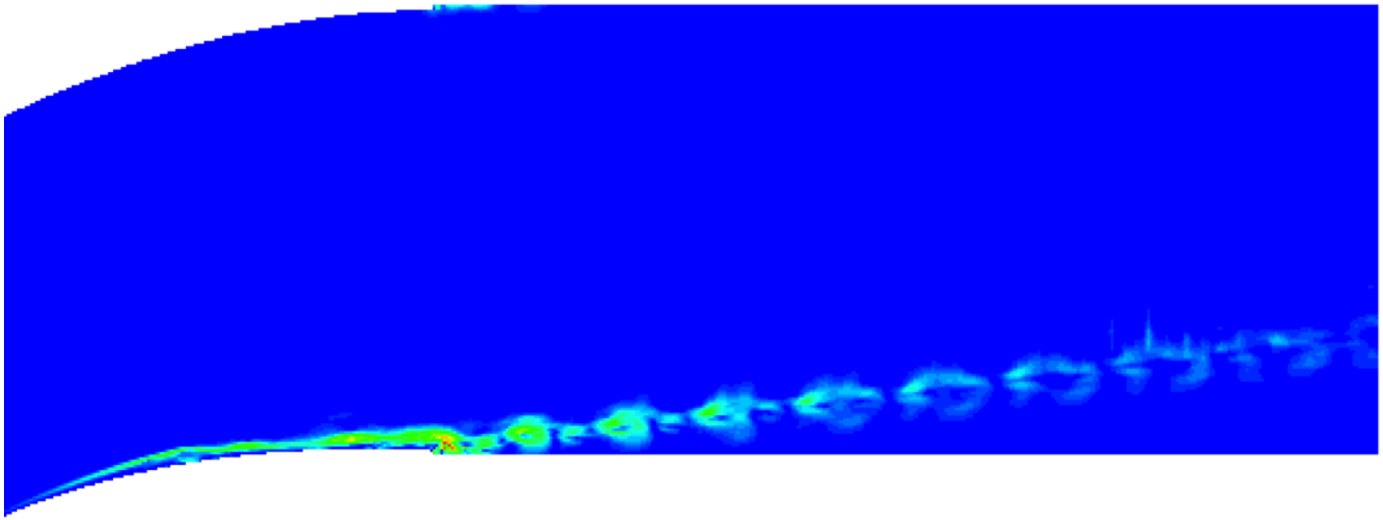
Task

Direct Floquet analysis of the phase-averaged flow

- Simulations still going.
- Results seem to point out an unstable mode with $\sigma \simeq 3 \times 10^{-1}$.



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Current and future simulations:

- Adjoint stability analysis
- Transient growth analysis
- "Localised" stability analysis