Secondary optimal growth in channel flow

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We compute the linear 'secondary' optimal transient energy growth supported by an unsteady primary optimally growing basic flow in a plane channel at $R = 1500$. The primary flow is generated by giving as initial condition the Poiseuille solution plus 'primary' optimal spanwise periodic vortices of finite amplitude A_v which then evolve into transiently growing streaks. The secondary optimal initial condition is given at $t = 0$, like the primary one, and is computed on the unsteady basic flow by using an adjoint technique. For small amplitudes A_v of the primary initial vortices, the secondary optimal perturbation and energy growth are almost identical to the primary one and respectively consist in $\alpha = 0$ streamwise vortices and streaks. For larger A_v, however, two distinct secondary growth mechanisms set in. The first one is related to the one recently observed on frozen boundary layer streaks[1] and consists in a modified lift-up mechanism leading to a large wavelenght bending of the primary streaks. The second acts on shorter wavelengths and is related to the local (in time) modal secondary instability of the streaks. Sample associated optimal perturbations are shown in figure 1. We conclude that for sufficiently large amplitudes of the primary optimal vortices, the optimal perturbations leading to maximum transient growth in a plane channel flow have $\alpha_{opt} \neq 0$.

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[1]Hoepffner *et al.*, J. Fluid Mech. **537** 2005

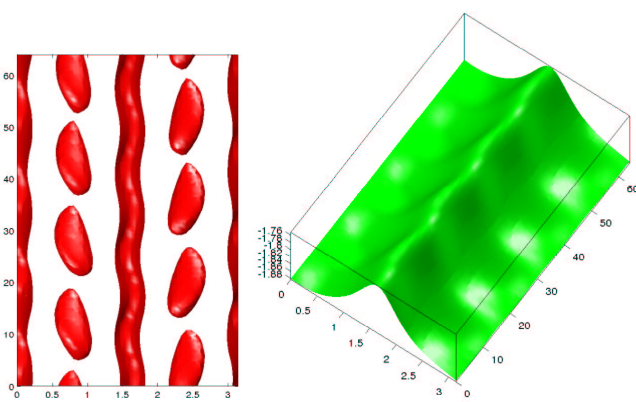

Figure 1: Optimal secondary perturbations added, with an arbitrary constant, to the primary optimal basic flow with $A_v = 0.02$. Left: iso-level surface of $\left[v^2 + w^2\right]^{1/2} = 0.9 \left[v^2 + w^2\right]^{1/2}_{max}$ for the optimal initial condition. Right: iso-level surface of $u = 0.4 u_{max}$ for the optimal response.