THE IDENTIFICATION OF THE INSTABILITY CORE OF INSTABILITIES UNDERPINNED BY AN ACOUSTIC-HYDRODYNAMIC FEEDBACK.

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Acoustic-hydrodynamic feedbacks are a common theme in jet noise. Strong sound emissions are supported by fluid instabilities, whose core is not necessarily localized in space. A common example is the feedback-loop instability of cavity flows, impinging jets or the flow past airfoils. The feedback-loop is composed of a convective instability, which is usually an instability of the shear layer, and an acoustic pressure wave or a hydrodynamic non-local effect. Despite the fact that such a mechanism is widely accepted, a precise identification of the most sensitive spatial regions underpinning the instability is missing. Herein, we propose a non-local decomposition of the *structural sensitivity* [1] and the *endogeneity* [2] concepts. These notions allow us to precisely identify the most sensitive regions of the flow responsible for the closure of the feedback-loop. The systematic use of these techniques could be applied in the design of passive flow control devices.
First, we decompose the direct global mode, respectively the adjoint; the velocity field follows the Helmholtz-Hodge decomposition,

$$\hat{\mathbf{u}} = \hat{\mathbf{u}}_{ac} + \hat{\mathbf{u}}_{hyd} = \nabla\phi_c + \nabla\times\mathbf{\Psi}, \qquad \hat{\mathbf{u}}^\dagger = \hat{\mathbf{u}}^\dagger_{hyd} + \hat{\mathbf{u}}^\dagger_{ac} = \nabla\phi^\dagger_c + \nabla\times\mathbf{\Psi}^\dagger. \tag{1}$$

In a second step, we analyse the effect of a localised harmonic forcing $\mathbf{H}(\hat{\mathbf{q}}) \equiv \delta(\mathbf{x}-\mathbf{x}_0)\mathbf{P_H}\mathbf{C}_0\mathbf{P}_{\hat{\mathbf{q}}}\hat{\mathbf{q}}$ on

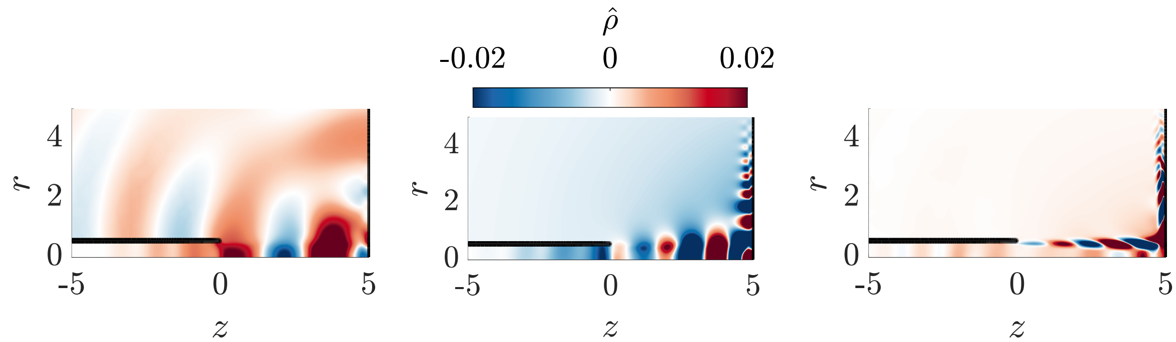

Figure 1: Decomposed density field of a mode ($Re = 900$, $M_J \approx 0.9$). (left) $\hat{\rho}_{ac}$, (centre) $\hat{\rho}_{hyd}$, (right) $\hat{\rho}_s$.

the linearised dynamics $\Big(-\mathrm{i}\omega\mathbf{B}|_{\mathbf{q}_0} + \mathbf{DF}|_{\mathbf{q}_0}\Big)\hat{\mathbf{q}} = \mathbf{H}(\hat{\mathbf{q}})$ by means of a *decomposed* structural sensitivity

$$\begin{aligned} \mathrm{i}\delta\omega^k_j &= \langle \hat{\mathbf{u}}^\dagger_k, \delta(\mathbf{x}-\mathbf{x}_0)\mathbf{C}_0\hat{\mathbf{u}}_j\rangle &&\leq ||\mathbf{C}_0||||\hat{\mathbf{u}}^\dagger_k(\mathbf{x}_0)||||\hat{\mathbf{u}}_j(\mathbf{x}_0)|| = ||\mathbf{C}_0||\mathbf{S}^{(j,k)}_{\mathbf{u},s}(\mathbf{x}_0), \\ \mathbf{S}^{(j,k)}_{\mathbf{u},s}(\mathbf{x}_0) &&&= ||\hat{\mathbf{u}}^\dagger_k(\mathbf{x}_0)||||\hat{\mathbf{u}}_j(\mathbf{x}_0)|| \text{ with } j,k = \text{ac, hyd, s.} \end{aligned} \tag{2}$$

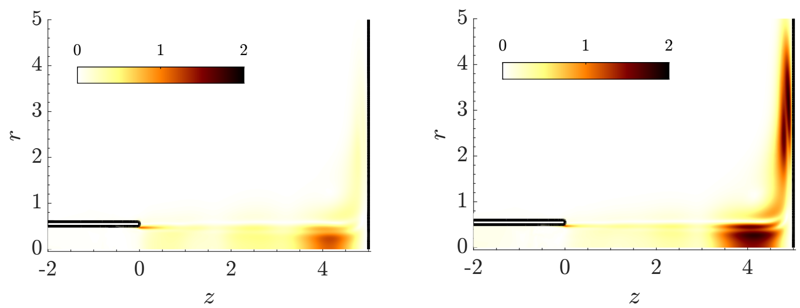

Figure 2: (left) $\mathbf{S}^{(hyd,ac)}_{\mathbf{u},s}$, (right) $\mathbf{S}^{(ac,hyd)}_{\mathbf{u},s}$ for the same global mode as Fig. 1.

References

[1] Giannetti, Flavio, and P. Luchini (2007). *Structural sensitivity of the first instability of the cylinder wake.* Journal of Fluid Mechanics, 581, 167-197.
[2] Marquet, Olivier, and L. Lesshafft. *Identifying the active flow regions that drive linear and nonlinear instabilities* arXiv preprint arXiv:1508.07620 (2015).