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Sonic bloom: how flowers may arise from acoustic streaming jets

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As it propagates within a fluid, a sound wave is attenuated due to viscous and thermal effects. This, in turn, drives a nearly steady flow called *acoustic streaming*. Thanks to its weakly-intrusive nature, acoustic streaming represents an attractive solution for industrial systems, such as solidification processes of melted metals and semiconductors. We are particularly interested in controlling the flows that may occur in the melts using jets driven by beam-shaped fields of progressive ultrasounds. For an efficient use of acoustic streaming in this context, it is necessary to first gain a deep understanding of the stability of the streaming jet itself.

We studied numerically the stability of an acoustic streaming jet flowing in a closed cylindrical cavity. The latter is entirely filled with a newtonian fluid and is fitted with a plane circular transducer at one end, continuously emitting a beam of ultrasonic waves propagating towards the opposite sound-absorbing wall. The beam yields a body force driving the flow, with a magnitude defined by the acoustic Grashof number Gr_{ac}. Besides of seeking the instability onset in terms of a critical Gr_{ac}, we consider different jet confinements, which are obtained by modifying the size of the cavity with respect to the size of the beam. In each case, the streaming jet is axisymmetric, and features a strong acceleration close to the transducer followed by a smooth velocity decay. The jet finally impinges the wall facing the transducer, creating vortices near that wall.

Besides its stabilising effect, confining the streaming flow significantly affects the nature of the leading unstable perturbations: whilst these are non-oscillatory for the largest aspect ratios, narrowing the cavity causes the destabilising mode to become oscillatory. Furthermore, we show that different bifurcation criticalities are achieved simply by changing the cavity size. Nevertheless, the mechanism responsible for the flow destabilisation is the extra shear caused by the jet impingement at the end wall, whatever the aspect ratio of the cavity. On the impinged surface, the unstable friction perturbations display floral patterns we called *sonic bloom* (figure 1). We explained the change of unstable mode shape as the cavity size is varied using critical point analysis.

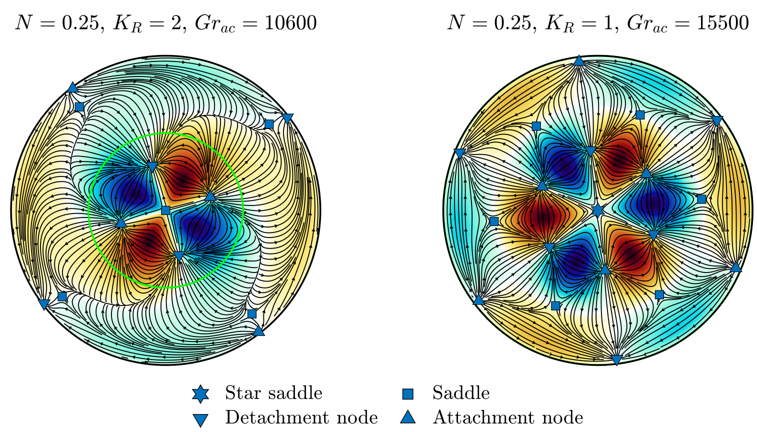

Figure 1: Skin friction lines exerted by the leading unstable perturbation on the downstream wall for two cavity sizes. The background colour is related to the azimuthal friction (red is positive, blue is negative). Critical points, i.e., points of zero friction perturbation, are also reported (blue symbols). The ratio between the sound attenuation distance and cavity length is defined by N, and K_R is the ratio between the cavity and beam (green circle) diameters. Both modes are oscillatory.

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