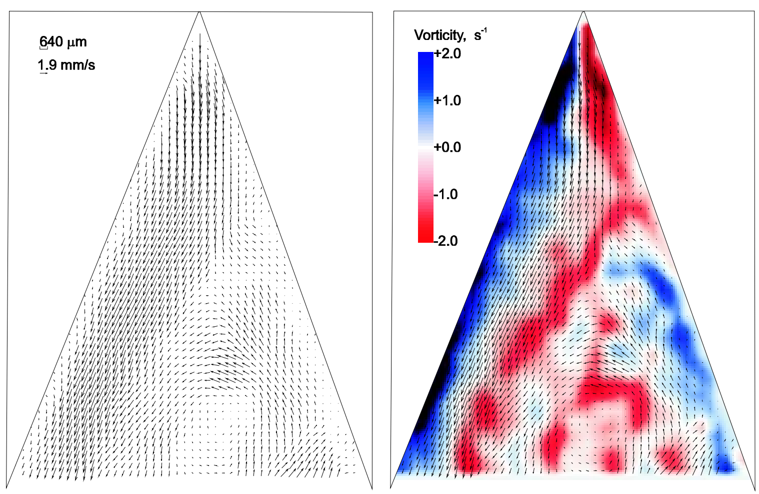
Experimental and theoretical investigation of bifurcations in Jeffery-Hamel flows

P. Vorobieff, V. Putkaradze
The University of New Mexico

Flows in expanding and contracting channels are a common feature of a variety of applications of fluid dynamics. An idealized version of these flows can be described by the classical Jeffery-Hamel solutions of the Navier-Stokes equations. These analytical solutions exhibit a rich bifurcation structure and, their apparent simplicity notwithstanding, are still subject of active research.

In the light of the importance of expanding/contracting flows, it is rather surprising that a thorough experimental investigation of Jeffery-Hamel flows had been missing until now. In our work, we produce a detailed quantitative study of a number of nearly-two-dimensional flows in expanding/contracting channels within a range of opening angles and flow rates. The flows are characterized in terms of instantaneous and ensemble-averaged velocity fields. It is noteworthy that the experimental realizations reveal a hysteretic bifurcation structure different from that predicted by the classical theory. The symmetry breaking bifurcation manifests itself in the appearance of large-scale vortical structures asymmetrically blocking the flow. We explain this bifurcation structure by the feedback mechanism between the downstream and upstream flow. We also show that the disturbances grow due to the appearance of the Kelvin-Helmholtz instability in the region of high shear adjacent to the vortex.



Instantaneous velocity field (left) and velocity overlayed with vorticity (right). Experimental data taken inside an expanding channel. Note the large-scale vortex (top half visible) with smaller vortices due to secondary instabilities.