Abstract for an Invited Paper
for the DFD08 Meeting of
The American Physical Society

**Transitions in viscous withdrawal**

WENDY W. ZHANG, University of Chicago

A process analogous to flow-focusing occurs in extended and stably stratified layers of immiscible, viscous liquids. In viscous withdrawal, an axisymmetric converging flow is imposed in the upper layer. When the upper layer flow is weak, the interface forms a hump. No liquid from the lower layer is entrained. When the upper layer flow is strong, liquid from the lower layer is entrained and the interface becomes a spout. Here I summarize recent results on the fundamental mechanisms controlling these regimes. For selective withdrawal, a clear picture has emerged, with good agreement between theory, simulation and experiment. The regime ends when the viscous stress exerted by the upper layer flow overcomes surface tension, creating a saddle-node bifurcation in the hump solution. Less is understood about viscous entrainment. A long-wavelength model including only local information is degenerate, possessing many solutions for the same withdrawal condition. Including information about the global geometry removes this degeneracy but also makes the surprising prediction that global geometry can change the nature of the transition. First-order, weakly first-order or continuous transitions are all possible. How these results relate to the variety of experimental phenomena, such as stable, micron-sized spouts, intricate patterns of hysteresis and multiple stable spout states under the same condition, is at present unclear. (Includes material from joint works with Blanchette, Cohen, Kleine Berkenbusch, and Schmidt.)