Whale Fluke Instability
in Viscoelastic Fluids

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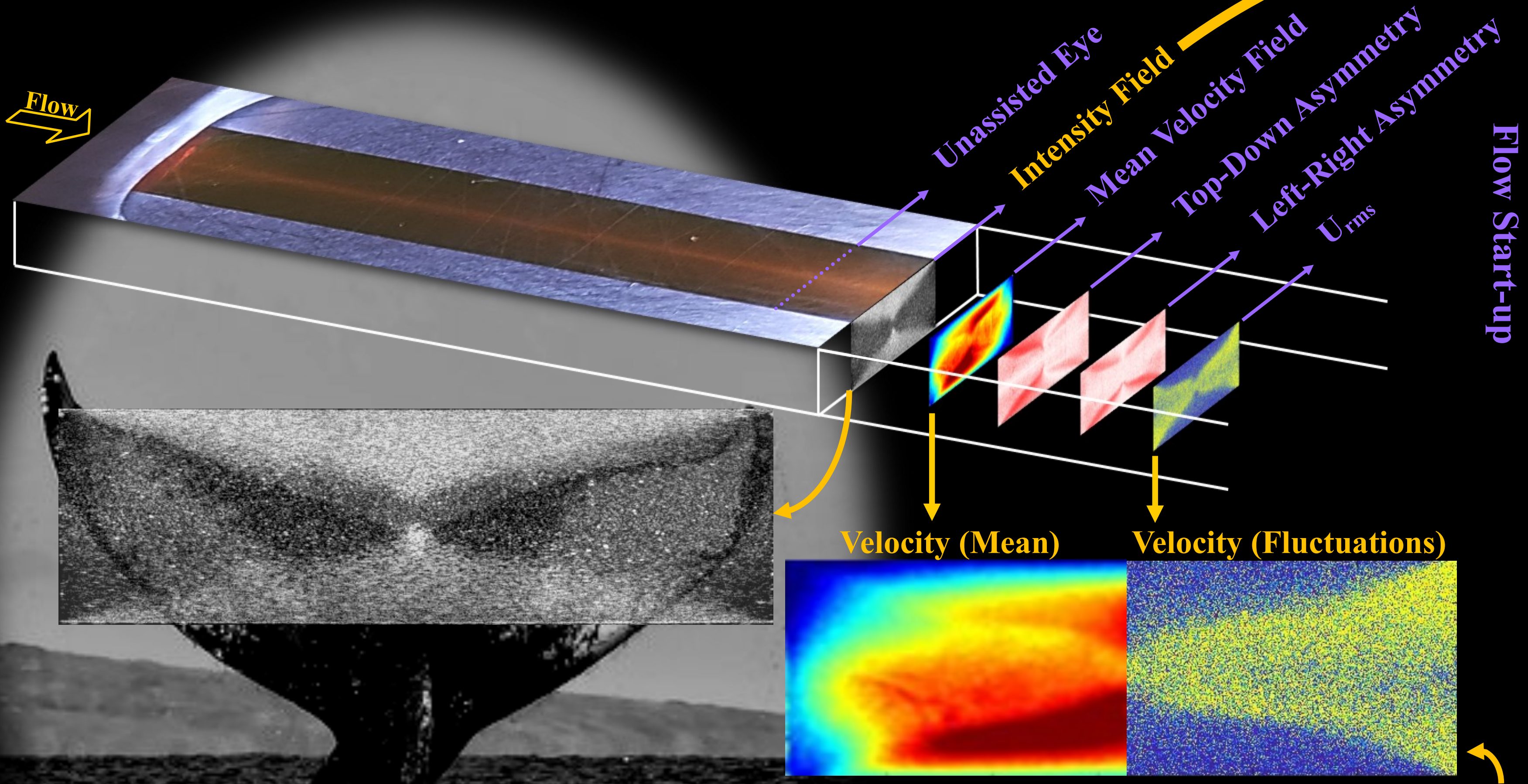
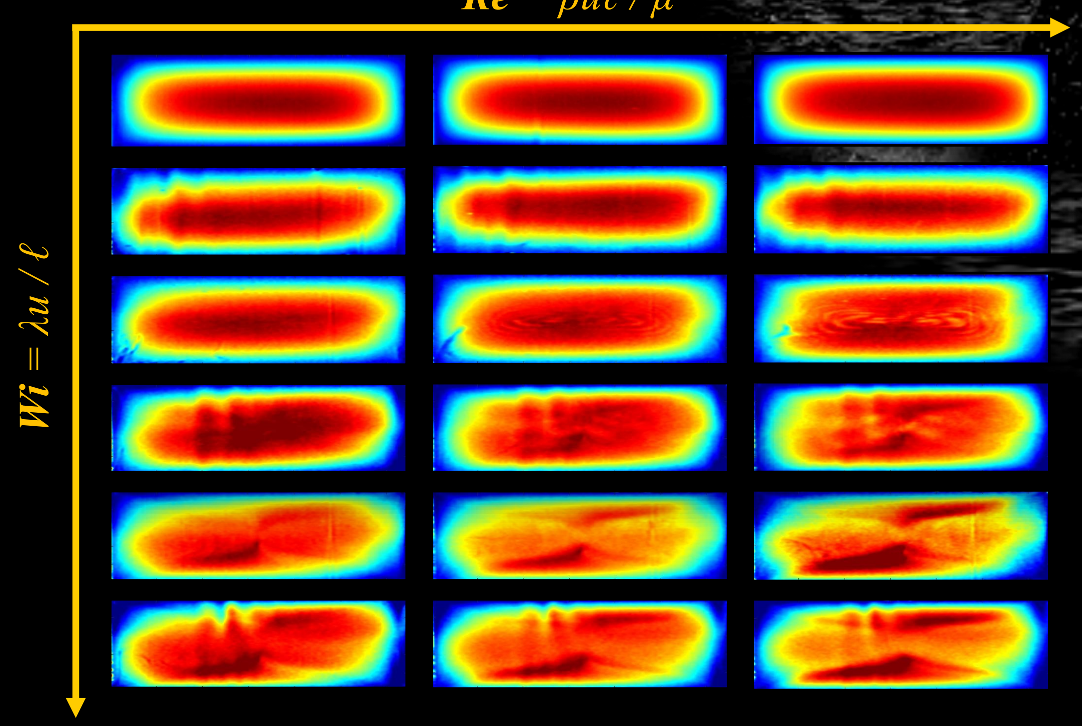
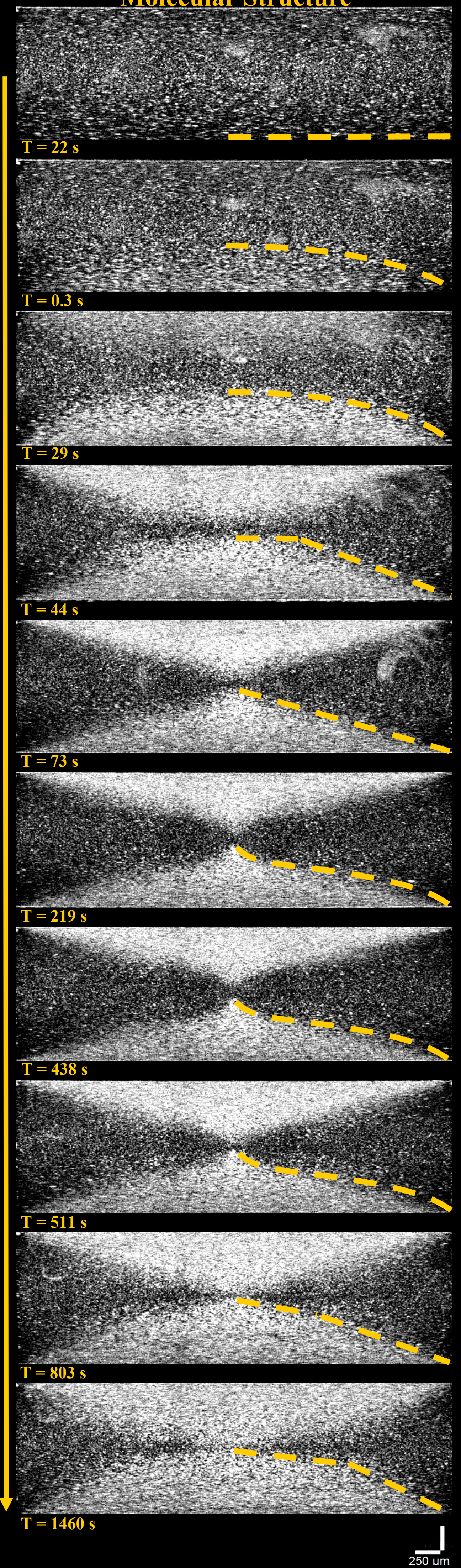


Phenomenology:

Existence of micro-structures in the fluids lead to nonlinearities in the shear stress versus shear rate response of the complex fluids. Coiling and entanglement of the polymer chains, for instance, result in the emergence of elastic stresses in addition to the already existing viscous dissipations, hence the term Viscoelastic Fluids (VEFs). The interplay of the *inertial*, *viscous*, and *elastic* forces renders the flow susceptible to instabilities.



Aqueous solution of polyacrylamide (molecular weight > 15×10^6) in non-dilute state (here 5000 ppm) exhibits high elasticity caused by the entanglement of its long linear chains. Capturing the intensity field of the cross-section of a rectangular microchannel using Doppler Optical Coherence Tomography (D-OCT), the heterogeneously imposed shear field leads to the segmentation of the domain. In the vicinity of the longer sides of the cross-section, higher shear rates reduce the viscosity of the highly shear-thinning fluid, leading to an increased velocity, which enhances the partial orientation of the polymer chains in the flow direction. The change in the optical refractive index of this segment of the flow field is captured by the OCT interferometer, as well as the unassisted eye, when looking at regions with different proportions of the oriented and entangled segments. By starting the flow from a quiescent state, the mentioned regions start developing from the near-wall areas. The arced peripheries of these regions get closer to the center, and through interaction with the lower shear rate regions forming from the shorter sides of the duct, morph through trapezoid and then triangular shapes. By reaching a bulk flow steady state, the interface of the oriented and entangled zones forms a complex curvature resembling that of a whale fluke. The complex interplay between the inertia, shear-thinning, and elasticity within the segments in- and outside of the whale fluke regions lead to an elasticity-driven highly fluctuating instability with local velocity minima in the central regions, while two asymmetrically positioned maximum points emerge inside the whale fluke regions; hence the naming ***Whale Fluke Instability (WFI)***. Upon cessation of the flow, diffusion will embark on decaying the sharp boundaries between the high and low refractive index regions. However the time-scales required for the full homogeneity reaches beyond 24 hours.



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