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Exact Theory of Material Spike Formation in Flow Separation MATTIA SERRA, GEORGE HALLER, ETH - Zurich — We develop a frame-invariant theory of material spike formation during flow separation over a no-slip boundary in two-dimensional flows with arbitrary time dependence. This theory identifies both fixed and moving separation, is effective also over short-time intervals, and admits a rigorous instantaneous limit. Our theory is based on topological properties of material lines, combining objectively stretching- and rotation-based kinematic quantities. The separation profile identified here serves as the theoretical backbone for the material spike from its birth to its fully developed shape, and remains hidden to existing approaches. Finally, our theory can be used to rigorously explain the perception of off-wall separation in unsteady flows, and more importantly, provide the conditions under which such a perception is justified. We illustrate our results in several examples including steady, time-periodic and unsteady analytic velocity fields with flat and curved boundaries, and an experimental dataset.

Mattia Serra
ETH - Zurich

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