Coherent Structures in Separation Bubbles

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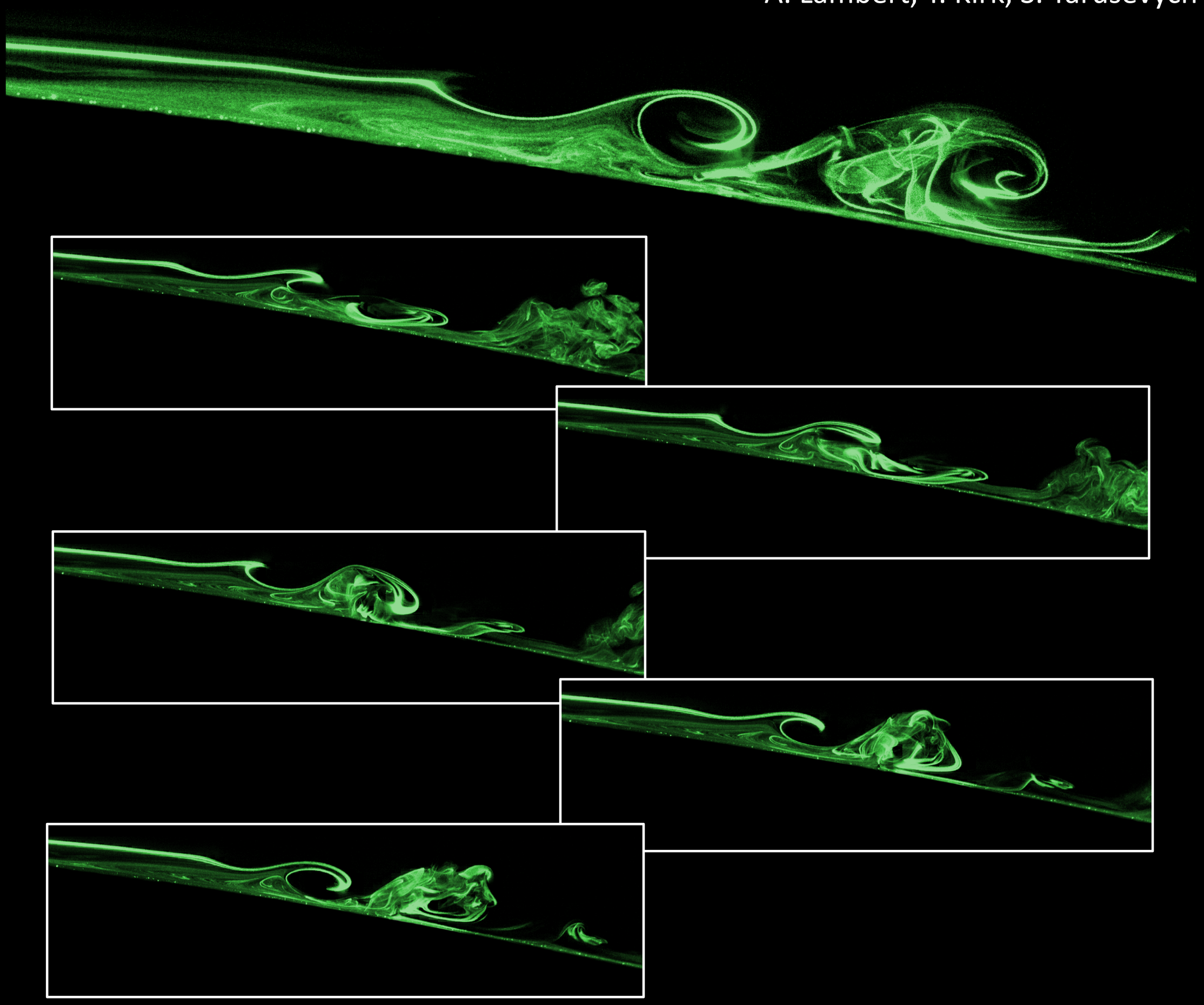
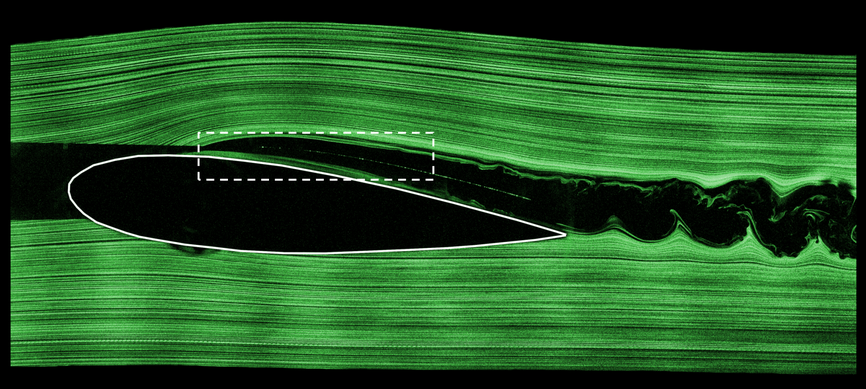
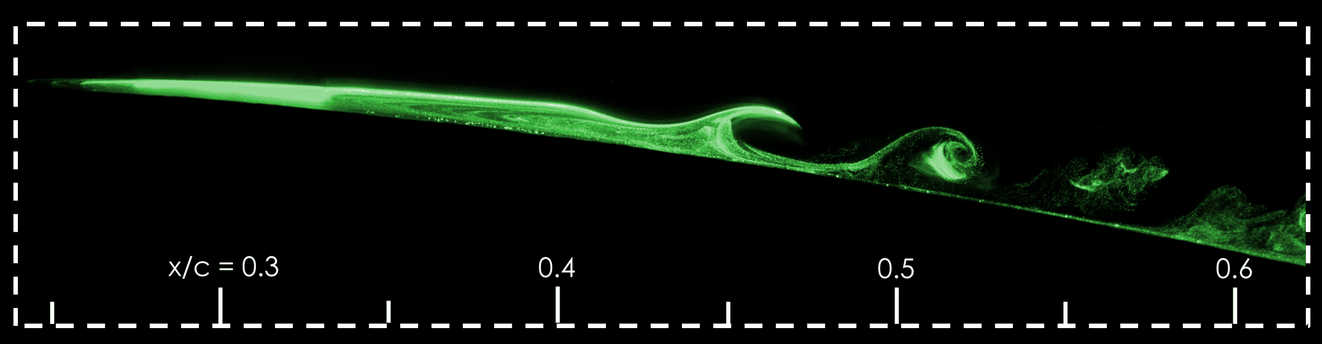


Separation bubbles occur on the suction side of lifting surfaces operating at relatively low Reynolds numbers. Due to their relatively small size, they are difficult to identify via conventional flow visualization techniques in air, as seen in the image below left. To visualize this closed flow region, a flow visualization agent is introduced directly into the separation bubble, which allows capturing the unsteady nature of the flow development (below right). The time-resolved sequence of images presented above shows the formation of vortices within the laminar separation bubble due to the convective amplification of disturbances in the separated flow. The development of these structures enhances the entrainment of higher-momentum fluid, leading to flow reattachment in time-average sense. With the edge velocity of approximately 10 m/s, the visualized structures have a characteristic length scale of 5 mm and are shed at a frequency of about 600 Hz, which makes their visualization challenging. The obtained experimental visualizations provide qualitative insight into the formation and development of coherent structures observed in recent numerical simulations[1,2] of separation bubbles.





[1]O. Marxen, M. Lang, and U. Rist, “Vortex formation and vortex breakup in a laminar separation bubble,” *J. Fluid Mech.*, pp. 58–90, 2013.

[2]L. E. Jones, R. D. Sandberg, and N. D. Sandham, “Stability and receptivity characteristics of a laminar separation bubble on an aerofoil,” *J. Fluid Mech.*, vol. 648 p. 257.,2010.

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