Theoretical modelling of rotating respiratory saliva dumbbells

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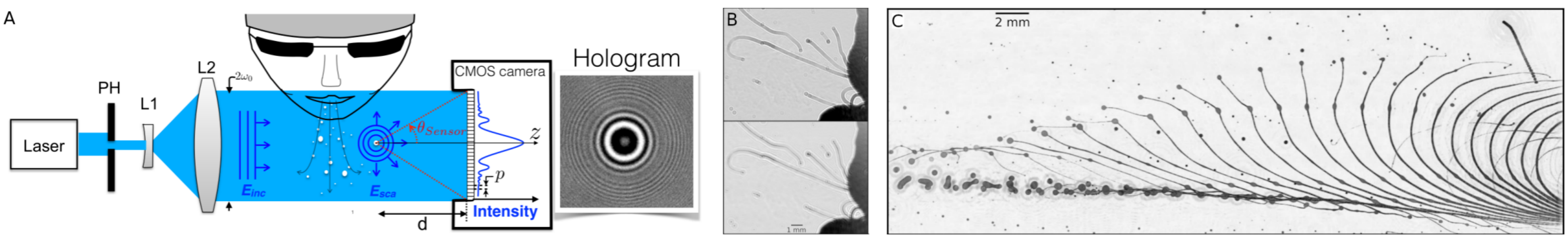
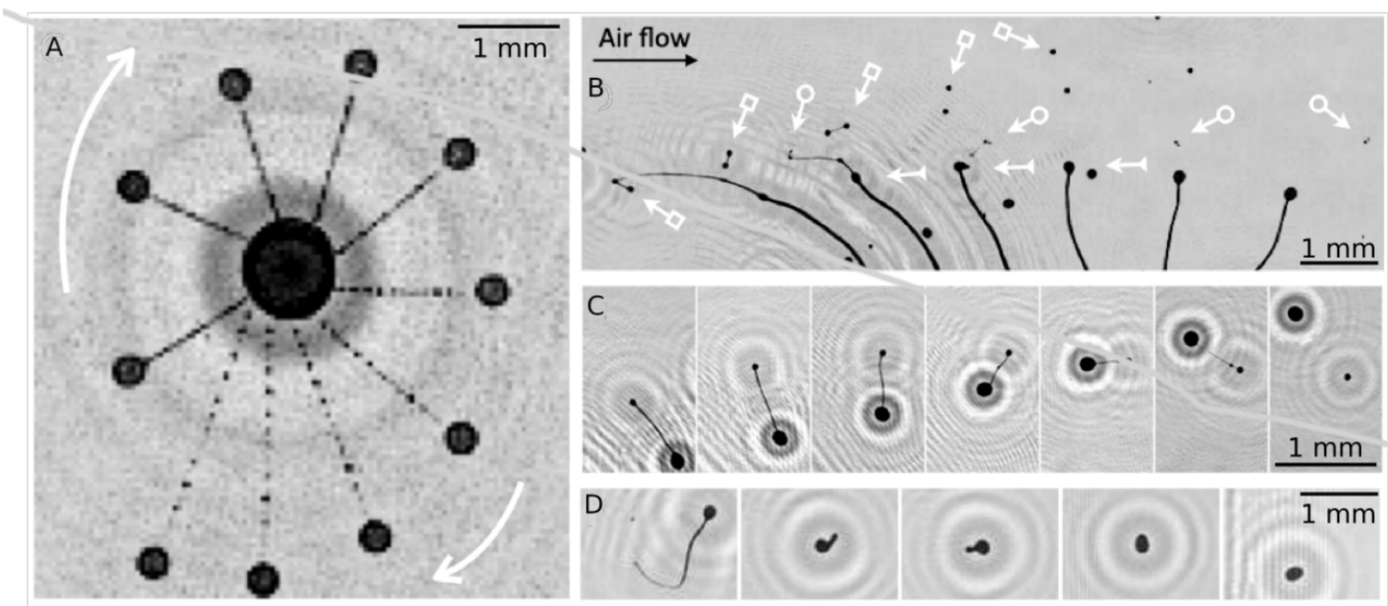
Airborne aerosols, produced while coughing, sneezing, or speaking, are a significant transmission route of biological pathogens. While quantitatively imaging aerosol droplet production directly at the mouth has historically proven challenging, we have recently demonstrated that digital in-line holography (DIH) is a powerful tool that overcomes many previous limitations. We use DIH to image the rapid formation, elongation, and deformation of saliva filaments at the mouth, followed by their fragmentation and aerosolization. The full morphology, three-dimensional position, and size of filaments and droplets is accessible over a large field of view, allowing us to probe the physical mechanisms of aerodynamic fluid fragmentation.



A) A schematic of the digital inline holography (DIH) setup B) A single raw hologram (top) and its projected reconstruction (bottom) of filaments forming at the lips and breaking during the pronunciation of `pa'. C) An overlaid sequence in time of multiple projected reconstruction frames of a filament as it leaves the mouth (on the right, not shown).

Propelled by expelled air, saliva filaments often whip outward upon breaking from the lips, shedding fast rotating (> 100 Hz) "dumbells," i.e. two saliva droplets connected by a slender saliva filament. Depending on the initial distance between the two lobes, we observe either breakup of the adjoining filament, or a coalescence into a single larger droplet.



Rich dynamics of `dumbbells' or orbiting droplets. A) Ten sequential projected reconstructions, each 0.42 ms apart, aligned by the center of mass of the central droplet and superimposed, showing orbiting droplets as the filament which connects them elongates and demonstrates the `beads on a string' phenomenon B-D) Projected reconstructions showing examples of the different dynamics of orbitting dumbells.

While similar dynamics have been described for Newtonian fluids [1, 2], we would like to understand how the observed dynamics are affected by visco-elastic stabilization of the filament against a Rayleigh–Plateau instability. Starting from and extending upon a recent model of filament retraction in a viscoelastic fluid [3], this project aims to draw the theoretical phase diagram that describes the dynamics of translating and rotating saliva dumbells and understand under which initial conditions the system coalesces versus ruptures and fragments. These results will be compared to future DIH measurements; the student may participate in this process as well.

[1] Elkins-Tanton, L., Aussillous, P., Bico, J., Qu´er´e, D. & Bush, J. A laboratory model of splash-form tektites. Meteorit. Planet. Sci. 38, 1331–1340 (2003.
[2] Brown, R. & Scriven, L. The shape and stability of rotating liquid drops. Proc. R. Soc. Lond. Math. Phys. Sci. 371, 331–357 (1997).
[3] Sen, U., Datt, C., Segers, T., Wijshoff, H., Snoeijer, J. H., Versluis, M., and Lohse, D. The Retraction of Jetted Slender Viscoelastic Liquid Filaments. Journal of Fluid Mechanics. 929, (2021).