Fragmentation of High-Speed Microdrops

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How can a volume of liquid be transformed into a cloud of nanodrops? This is a fundamental question of importance to a number of fields, such as cloud physics through to 3D printing, but is motivated here by a desire to design next-generation mass spectrometers that can rapidly analyse the chemical constituents of sample volumes [1]. Due to the minute spatio-temporal scales of interest in nano-fluidics, experimental analysis is impossible and theoretical predictions are highly sought after to provide new understanding of drop dynamics at these scales.

The development of next generation mass spectrometers are limited by an inability to transform microdrops, that are ripped off a nozzle at $\sim 100\,\mathrm{m/s}$, into nanodrops. Currently, this is achieved by smashing the drops into a solid rod; not only is this crude, but because the physical mechanisms behind this are unknown, it is unclear how to improve the process. It could be that (a) microdrops splash upon impact with the solid, (b) strong gradients in the gas flow around the solid deform and split free drops, or (c) that the liquid film accumulating on the solid emits drops under shear from the gas flow. Which mechanisms are dominant determines the important design parameters — e.g. the solid's properties would play a major role in (a), but an inconsequential role in (b) and (c).

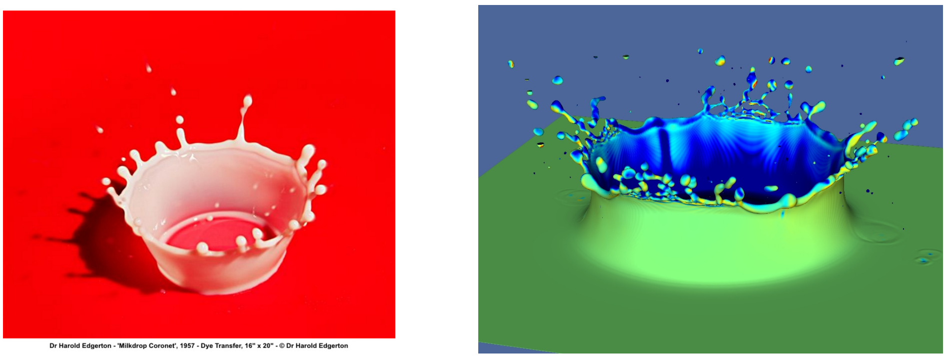

Figure 1: A drop splashing experiment (left) and simulation results from open-source software Gerris (right).

The multitude of physical effects present means attempting to directly simulate 'everything' is both futile and unhelpful. Instead, we propose to build a coherent picture of the overall process piece-by-piece, isolating the influence of each effect to enable experimental findings to be understood. This programme of work will combine traditional tools of industrial mathematics with cutting-edge high performance computational simulations (figure 1) to understand dominant mechanisms of microdrop fragmentation.

Collaborator - The project is motivated by Waters, a multi-national corporation specialising in analytical instruments, and will involve a close interaction with experimentalists based at their UK site in Wilmslow.

Summer Project - Work with Dr Steve Bajic at Waters to understand the industrial challenge, establish key controlling parameters and begin to formulate a mathematical model. The summer project will focus on calculating the high-speed background gas flow, that will allow us to determine the trajectories of microdrops, quantify the likelihood of mechanisms (a)-(c) and compare to qualitative observations from Waters.

PhD Environment - You will be integrated into a team of researchers working on related micro and nano flows, see `www.micronanoflows.ac.uk`, and will have the opportunity to participate in weekly group meetings, focussed workshops/training and international conferences.

Applicant Requirements - The research is rewarding and challenging, so applicants should have a background in fluid dynamics as well as the standard analytic and computational methods of applied mathematics; experience of programming languages would be an advantage.

Interested? - Email J.E.Sprittles@Warwick.ac.uk or E.J.Brambley@Warwick.ac.uk to arrange a chat.

[1] Mass spectrometers are fascinating instruments, whose complex physical workings are described on Wikipedia: `https://en.wikipedia.org/wiki/Mass_spectrometry`