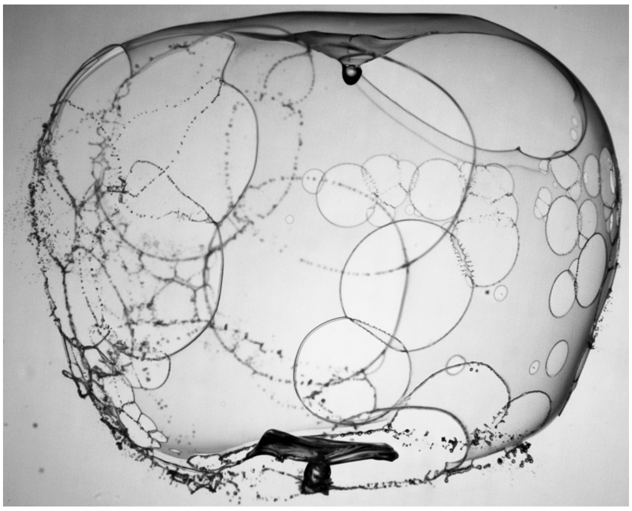
Explosive Fragmentation

Emmanuel Villermaux
IRPHE, Aix-Marseille University



The forced radial expansion of a spherical liquid shell by an exothermic chemical reaction is a prototypical configuration for the explosion of cohesive materials in three dimensions. The shell is formed by the capillary pinch off of a thin liquid annular jet surrounding a jet of reactive gaseous mixture at ambient pressure. The encapsulated gas in the resulting liquid bubble is a mixture of hydrogen and oxygen in controlled relative proportions, which is ignited by a laser plasma aimed at the center of the bubble. The strongly exothermic combustion of the mixture induces the expansion of the hot burnt gas, pushing the shell radially outwards in a violently accelerated motion. That motion triggers the instability of the shell, developing thickness modulations ultimately piercing it in a number of holes. The capillary retraction of the holes concentrates the liquid constitutive of the shell into a web of ligaments, whose breakup leads to stable drops. We offer a comprehensive description of the overall process, from the kinematics of the shell initial expansion, to the final drops size distribution as a function of the composition of the gas mixture, and the initial shell radius and thickness of the bubble.

This problem, in which the fragments distribution is the result of a competition between deformation, breakup and cohesion, is relevant to a collection of phenomena spanning over a broad range of length scales, among which are: Exploding blood cells in the human body, spore dispersal from plants, boiling droplets, underwater explosions, magma eruption in volcanoes, up to the torn patterns of supernovae in the Universe.