Collapse dynamics of non-spherical cavitation bubbles

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Cavitation bubbles in liquids remain a central research topic due to their energetic properties, which can be damaging to e.g. hydraulic turbomachinery or ship propellers or beneficial in applications such as microfluidics, sonochemistry and medicine. The power of cavitation is attributed to the energetic events occurring during the bubble collapse, more specifically during the final collapse stage.

Shock waves are emitted as the bubble interface reaches velocities beyond the speed of sound of the liquid, contributing in stunning the prey of the Mantis shrimp or destroying kidney stones. Micro-jets form as a bubble collapses aspherically and may hit near boundaries at hundreds of meters per second, contributing to erosion on metallic surfaces or penetrating biological tissues. The compression of the imprisoned gases at the bubble collapse is so violent that they get heated up to thousands of degrees, causing light emission, a phenomenon known as luminescence. This extreme heating could serve as a catalyst for unique chemical reactions.

Our research aims to unify the quickly diversifying research field of cavitation and to reach a unified framework for the energy distribution between all these collapse-related phenomena. We describe how pressure anisotropy in the liquid affects the bubble collapse dynamics by introducing an anisotropy parameter ζ, representing a dimensionless measure of the liquid momentum at the collapse point (Kelvin impulse). We probe the limit between highly spherical bubbles and toroidal bubbles by performing delicate measurements in micro-gravity conditions. Furthermore, high-quality visualisations of large and strongly deformed bubbles disclose novel features of the bubble interior. We also perform spectroscopic (UV+visible) measurements of the light emitted by a single collapse of an isolated bubble in order to estimate the temperatures reached inside the bubble. A needle hydrophone is used to measure the single or multiple shock wave emissions from bubbles of varying sphericity. Overall, we uncover details on how gravity and other sources of pressure anisotropy affect the micro-jet properties (such as speed, impact timing and size), shock wave emission (energy, waveform) and luminescence (energy and temperature).