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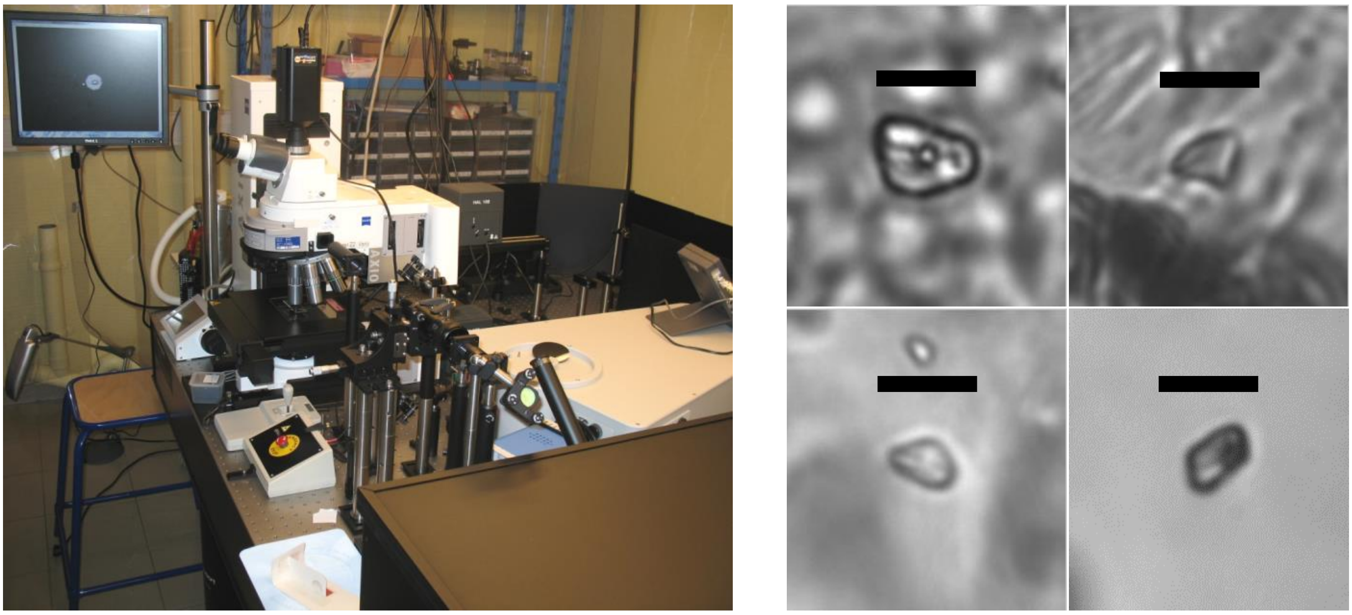
Heavy water at negative pressure as a new route to explain water anomalies

An hypothesis proposed for water more than 20 years ago [1] is still highly debated [2]. Water might exist in two liquid states, which would differ by the local arrangement of the molecules. However, the two liquids would separate only at very low temperature, and thus, up to now, experiments were not able to detect this transition, despite record-low temperatures reached with liquid water (-43°C [3,4]).

In order to decide between the available theoretical scenarios, we investigate water at negative pressure, generated by cooling water at constant volume. The samples are a few µm droplets trapped into a quartz crystal, synthesized by the group of Max Wilke in Potsdam. We measure the sound velocity in the liquid with Brillouin spectroscopy, from which we reconstruct the equation of state. Recently [5], we have reached -140 MPa in water, and discovered a new anomaly: a maximum in isothermal compressibility along isobars. This anomaly is a necessary condition for the validity of two scenarios for water. These two theories also predict that the famous line of density maxima (at 4 °C at ambient pressure) should reach a turning point at P<0 (maximum temperature). In our experiment, we see the line becoming more vertical but, unfortunately, we cannot reach the putative turning point because of unavoidable nucleation of the vapor (cavitation).

Our project is to repeat the same study on heavy water. Because water and heavy water have nearly equal surface tensions, we expect cavitation to occur at similar pressures. In contrast, extrapolations from the equation of state at positive pressure suggest that the turning point of the line of density maxima occurs at less negative pressure. The long-sought turning point might thus become observable in our experiment.

This work can be extended during a PhD by investigating other phenomena in metastable liquids (at negative pressure, supercooled or supersaturated), in our lab and with our partners abroad.



Experimental setup and examples of inclusions studied (scale bar = 7 µm)

[1] Poole *et al.*, *Nature* **360** 324 (1992)
[2] Gallo *et al.*, *Chem. Rev.* **116** 7463 (2016)
[3] Sellberg *et al.*, *Nature* **510** 381 (2014).
[4] Goy *et al.*, *Phys. Rev. Lett.* **120** 015501 (2018).
[5] Holten *et al.*, *J. Phys. Chem. Lett.* **8** 5519 (2017).