Water at negative pressure (BSc/MSc project)

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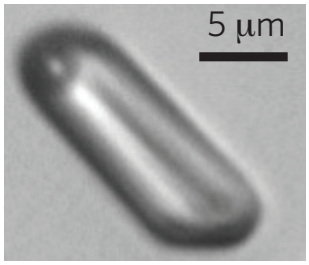
In our daily lives (and in physics books) pressure is generally a positive quantity. But there is no fundamental reason against having *negative* pressure: instead of compressing a liquid (=positive pressure) you simply have to stretch it. Just put some water in an air-tight cylinder and pull on the plunger! Of course, normally when you do this, the water starts to form vapor bubbles until the pressure of the liquid+vapor system is back to ambient (and thus positive). However, the vapor bubbles can only form by nucleation, typically on small contaminations in the liquid. Hence, in super-clean water, bubble formation does not occur (it is for this reason that you can heat clean water above 100°C without it starting to boil), and so negative water pressure becomes feasible. Actually experiments [1,2,3] have shown that water can exist at negative pressures down to –1000 bar! (for comparison, the pressure in a normal bicycle tire is about +2 bar).

So far, very little is known about the properties of water at negative pressure. These properties are expected to be unique, because the behavior of water at negative pressure is dominated by the attractive forces between the molecules, rather than the short-range repulsive forces that dominate the behavior of liquids at normal, positive pressure.

In this project you will explore new ways of creating water at negative pressure, and you will use spectroscopic methods to investigate its properties, both macroscopic and at the molecular level.



Water at –1000 bar. In small inclusions of liquid water in quartz, extremely negative pressures can be attained. From reference [3].

[1] Zheng *et al.* Liquids at large negative pressures: water at the homogeneous nucleation limit. *Science* **254**, 829 (1991).
[2] Green *et al.* Water and Solutions at Negative Pressure: Raman Spectroscopic Study to -80 Megapascal. *Science* **249**, 649 (1990).
[3] Azouzi *et al.* A coherent picture of water at extreme negative pressure. *Nature Physics* **9**, 38 (2013).