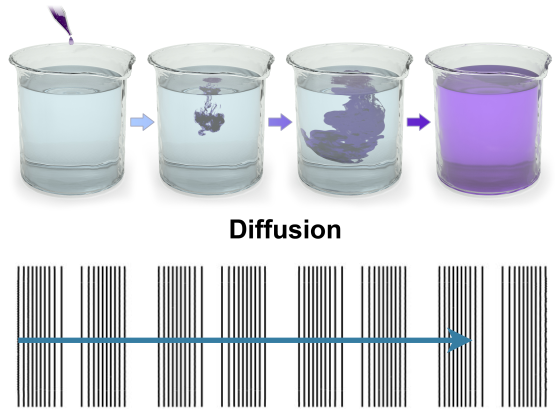
ABSTRACT FOR THE GENERAL PUBLIC

Imagine a particle so massive it cannot be accelerated by any known force, these hypothetical particles would be anchored to their position and would not be allowed to move.

In the area of quantum information scientists discovered a certain class of quantum theories with hypothetical particles that cannot move, and dubbed them as *Fractons*. From a technological perspective, fractons would be useful for the processing of quantum information and quantum computing. On the other hand, from a fundamental physics viewpoint, observing fractonic systems would be an enormous breakthrough since they correspond to a highly exotic phase of matter where the laws of physics (as we know them) would not be obeyed.



Top: Different stages of the diffusion process of a drop of ink in a liquid. Bottom: Pattern of a longitudinal sound wave, the higher density of lines refer to largest value of the pressure, whereas low density regions to low pressure

Now let us imagine a liquid made of tiny particles with an intrinsic rotational property that we call spin. In experiments involving high-energy heavy-ion collisions, a quantum mechanical, very hot liquid known as the quark-gluon plasma (QGP) is produced. One of the constituents of the QGP are the quarks which are fundamental particles with spin-1/2. This liquid has a very short lifetime (approximately $10^{-23}s$) after which it "evaporates" into a huge variety of spin-full particles that experimentalists can observe with their detectors. These experiments suggest the existence of a process in which the angular momentum of the QGP is transferred into the spin of the final particles. However, our current theories of hydrodynamics fail to explain accurately such mechanism.

The goal of this project is to dive deep into physical models capable of describing the hydrodynamics of both fractons and particles with spin. This theoretical research program, by considering different scenarios and theories, intends to find the differences between fracton and ordinary phases of matter respectively. Moreover, it will also explore the necessary modifications to hydrodynamics that properly describe spinning quantum liquids.

Actually notice, that ordinary hydrodynamics predicts that in a liquid, perturbations from an equilibrium configuration are carried out by sound waves and particles diffusion (see the Figure). In a given liquid, sound propagates always at the same speed. On the other hand, particles diffuse with a decelerating speed with the process ceasing once the particle's distribution becomes homogeneous.

Surprisingly, recent studies for fracton theories predict that a liquid made of them can flow. However, such a liquid would not be an ordinary one, since the speed of sound would depend strongly on the wavelength of the wave. Even more surprisingly is the fact that the particles' diffusion, as long as energy is conserved, would happen as in ordinary fluids!