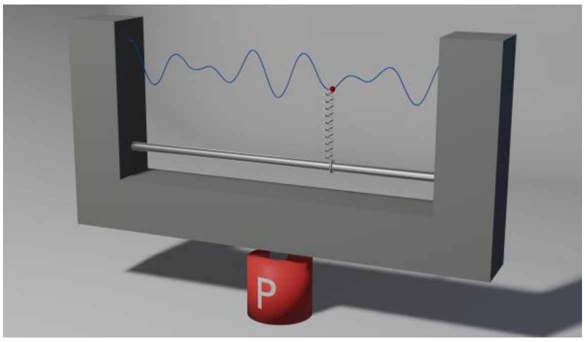
INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2021-2022

Quantum foundations : the wave-particle duality on a vibrating string

General Scope :

Quantum mechanics is well known for its apparent weirdness. But at the beginning of quantum history, the likes of Einstein, de Broglie, and later Bohm tried to decipher the meaning behind it through the use of classical analogies and mechanisms that were well understood at the time. The aim of our approach is to venture back to this lost realm of clarity in classical physics without renouncing the great achievements of modern quantum mechanics. Works by de Broglie, Bohm, and Einstein will serve as a foundation to study how some (if not all) quantum effects can be experimentally reproduced using adequately locked and fine-tuned mechanical oscillators interacting within a wavy background.



Using classical systems, either oscillating bubbles moved by and within an acoustic field or (in one dimension) a spring-mass particle moved along a vibrating string by the resulting radiation force,we address fundamental issues such as the **wave-particle duality , non-locality and the emergence of of gravitational forces**.

Figure 1: Sketch of the masslet-spring system as proposed in [1]

This approach is based on the crucial role played by the fluctuations of the vacuum energy and its decisive role in key experiments exemplified by the **Casimir effect (see our acoustic Casimir effect proposal for more info.)**An isotropic and random acoustic band-pass noise can indeed be used to mimic the vacuum fluctuations and its associated effects. The main advantage of this setup lies in its flexibility: the sound can be fine-tuned to a certain spectrum, turned on or off (unlike the real Zero Point Field), and can of course be probed, thereby allowing us to address very exciting questions.

As we have recently shown [1], a mass-spring moving along a vibrating string can represent, for some weel-chosen specific conditions a classical analog of a quantum wave-particle object. Furthermore, an acoustic bubble could represent a 3D extension of the masslet on a string,achieving a 3D quantum behaviour, in the spirit of recent works with droplets bouncing on a two-dimentionnal bath and inducing a macroscopic wave-particle duality [2].Ultimately, we are interested in possibly achieving a classical analog of a quantum entanglement and observing non local correlations.

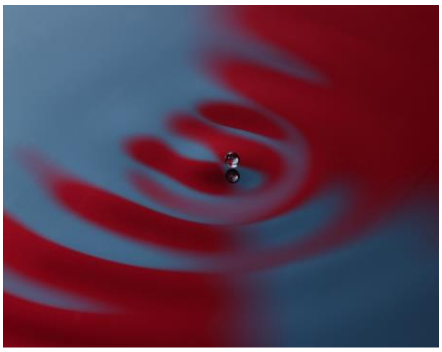


Figure: An oil droplet bouncing on a vibrating bath, generating and interacting with its own wave(see for example: [2] J.W. M. Bush, Annu. Rev. Fluid. Mech. **47**, 269-92 (2015))

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The goal of the intership is to work on this subject by a joint theoretical and numerical approach. A Python code was recently developped to simulate various behaviours for the masslet on a string. The objective is to study in more details the quantum regime as well as to start developing the Python code for the 3D case.

Research topic and facilities available :

This work is led within the Nano Optic and Force (NOF) team of Néel institue,
see https://neel.cnrs.fr/equipes-poles-et-services/nano-optique-et-forces-nof for more information.

Possible extension as a PhD :

The PhD position will be open in Autumn 2022 and motivated applicants should contact us in advance for further discussions.

Req**uired skills:**

Applicants must have a solid background in physics and mathematics as well as a very god knowledge of the Python langage.

Starting date : January 2022

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[1] A. Drezet *et al*, Phys. Rev. E. **102**, 052206 (2020) at:

https://journals.aps.org/pre/abstract/10.1103/PhysRevE.102.052206

[2] J.W. M. Bush, Annu. Rev. Fluid. Mech. **47**, 269-92 (2015))