Acoustic quantum Analogues for Casimir Forces

Context :

In 1948, Hendrik Casimir showed that fluctuations of an electromagnetic field, so called **zero-point field** (ZPF) fluctuations, give rise to an attractive force between objects. Casimir's calculations were idealized - he considered two perfectly conducting parallel plates at absolute-zero temperature - but there are implications for more realistic objects. Although the Casimir effect is deeply rooted in the quantum theory of electrodynamics, there are analogous effects in classical physics.

A striking example was discussed in 1836, in P. C. Caussée's *L'Album du Marin* (*The Album of the Mariner*). Caussée reported a mysteriously strong attractive force that can arise between two ships floating side by side — a force that can lead to disastrous consequences (see Figure). A physical explanation for this force was, however, offered only recently, by Boersma [1], who suggested that it originates in the radiation pressure of water waves acting differently on the opposite sides of the ships. Analogous arguments can be employed for the Casimir effect itself. In this case, the radiation pressure is due to quantum electromagnetic waves rather than classical fluctuating water waves.

Historically, the Casimir effect has been considered to be an exotic quantum phenomenon, but now it is starting to take on technological importance. Because of its relatively short range, it has only a very small effect on the dynamics of macroscopic mechanical systems. But the Casimir force has a major role in modern micro and nanoelectromechanical systems (MEMS and NEMS), where the distances between neighboring surfaces are typically far less than 1 µm. In tiny devices such as these, the Casimir force can cause mechanical elements to collapse onto nearby surfaces, resulting in permanent adhesion - an effect called 'stiction', which often proves to be an important factor in the malfunction of NEMS.

Project:

In this thesis, we propose to address the Casimir and ZPF effects with **an hydrodynamic approach** based on an **acoustical analogy**: the acoustic Casimir force. Here, when two plates are immersed in a fluid insonified by ultrasound radiation, a force arises from the acoustic radiation pressure difference between the inner and outer domain delimitated by the plates.

Recently, we reproduced most features of the quantum ZPF effects by a classical acoustic analogy.

Indeed, an isotropic and random acoustic band-pass noise can be used to mimic the vacuum fluctuations and its associated effects. The main advantage of this setup relies in its flexibility: the sound can be fine-tuned to a certain spectrum, turned on or off (unlike the real ZPF) and can of course be probed.

Thus, we have shown that this acoustic analogy enable us to attract or repel two facing plates, and quantify the role played by the propagative and evanescent field respectively, thereby raising very exciting questions.

- First, is it possible to manufacture chiral structures in order to achieve rotation and hence extract energy from the ZPF fluctuating bath?
- Second, what happens when the field is screened or altered by massive objects at large distances? Is it possible to recreate an artificial gravitation in the lab?

For this thesis, we will explore these fundamental issues by means of mechanical and optical analogies, in the spirit of the founder of quantum mechanics.

Required Skills : Acoustics / optics, Interest for experimental problems in fundamental and applied Physics,

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*[1] S.L. Boersma, Am. J. Phys. **64**, 539-41 (1996).*