

INTERNSHIP PROPOSAL - Spring 2026

(One page maximum)

Laboratory name: Service de Physique de l'Etat Condensé (SPEC/SPHYNX)

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Internship location: CEA Saclay, site de l'Orme des Merisiers

Thesis possibility after internship: YES

Funding: YES

If YES, which type of funding: CFR

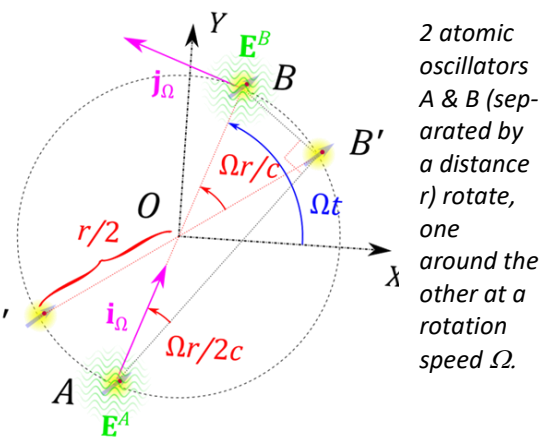
COUPLED FRICTION EFFECTS OF DIRAC SEA AND ELECTROMAGNETIC VACUUM ON ATOMIC MOVEMENTS

Summary (half a page maximum)

Quantum fluctuations induce conservative macroscopic forces such as the Casimir effect. They could also cause dissipative forces, termed vacuum (or quantum) friction. Up to now, this friction effect has been calculated with consideration of the electromagnetic fluctuations only, i.e. without taking into account the Dirac Sea. This project is devoted to the extension of our research in this direction: electrons, as main contributors of the matter-field interaction, also interact with electron-positron virtual pairs in the quantum vacuum.

As part of a doctoral research at SPEC/SPHYNX (Michael Vaz, PhD defense 30 Sept. 2025), we have calculated the conservative [1] and dissipative forces [2] induced by vacuum electromagnetic fluctuations on a rotating pair of atomic oscillators, based on a semi classical model developed previously [3].

How much of quantum friction, at zero or finite temperature, could be due to this type of interaction? A first step will be adapting the present hybrid quantum-classical framework to include vacuum polarization and pair creation. In doing so, one will encounter finite frequency cut-offs, traditionally linked to virtual pair creation; thus one will determine a friction component linked with the finite cut-off of Fourier integrals. On this research path, one shall pay attention to maintaining the mathematical coherence of the whole framework. A longer-term goal remains a complete and consistent quantum relativistic treatment of quantum friction at the atomic level.



[1] Vaz, M., Buhmann, S. Y. & Bercegol H., Complete range of van der Waals attraction mediated by the quantum vacuum at all temperatures, *under review*

[2] Vaz, M., Buhmann, S. Y. & Bercegol H., Quantum Friction on a Rotating Pair of Atomic Oscillators at All Temperatures and All Distances, *under review*

[3] Bercegol, H. & Lehoucq, R., Vacuum friction on a rotating pair of atoms, *Phys. Rev. Lett.* **115**, 090402 (2015).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES

Soft Matter and Biological Physics:

NO

Quantum Physics: YES

Theoretical Physics:

YES