

INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: NO (not sure at this time) If YES, which type of funding:

Time-braiding of anyons in graphene

Anyons, emergent quantum particles that transcend the conventional fermion–boson dichotomy, are central to modern topological quantum physics. Exhibiting fractional electric charge and exotic exchange statistics, they appear under extreme physical conditions, namely in the fractional quantum Hall effect regime occurring in two-dimensional systems at low temperature and high magnetic field. Although anyons were predicted in the late 1970s and early 1980s, their existence was only formally demonstrated in 2020, in two major experiments [1,2] realized in semiconductor heterostructures based on gallium arsenide (GaAs). In particular, the experiment described in [1], performed in the Mesoscopic Physics team of LPENS, used a “collider” geometry to reveal the fractional exchange statistics of anyons in the quantum Hall effect regime. This was done by measuring the fluctuations of the current generated at the collider, performing a *time-braiding* operation where two anyons are rotated one around the other in space and time.

Those two landmark experiments revolutionized the field of anyon physics, which actively seeks to understand the properties of these exotic particles, as well as their potentialities to use them in quantum information processing schemes. In particular, probing the existence of anyons in the quantum Hall effect of graphene is a major challenge, as graphene hosts a large number of exotic phases that are thought to have anyonic properties, including some in absence of magnetic field.

In this project, we propose to implement the time-braiding experiments in ultra-clean graphene samples showing a large number of robust fractional quantum Hall states. We will fabricate high quality graphene samples in a collider geometry, and perform high-sensitivity noise measurements at ultra-low temperature and high magnetic field to reveal the anyonic exchange properties. This project will also aim at exploring exotic anyonic states specific to graphene, particularly in bilayer graphene and rhombohedral multilayers which can show fractional quantum Hall states in absence of magnetic field.

The project will be implemented in the Mesoscopic Physics team of LPENS, which has pioneered anyonic time-braiding experiments, in collaboration with the *Centre de Nanosciences et de Nanotechnologies* (C2N, Palaiseau). We are looking for highly motivated candidates who are interested in all aspects of the project, both experimental (sample fabrication, low noise measurements, cryogenics) and theoretical.

[1] Bartolomei, et al., Science **368**, 173 (2020)

[2] Nakamura, et al., Nature Physics **16**, 931 (2020)

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:	NO