



SÉMINAIRE MATIÈRE CONDENSÉE

Jeudi 29 janvier 2026 à **11h**

LPS, bât 510, **Moyen amphi + ZOOM** (en ligne)

Meeting ID: 914 3703 3545; **Password:** LPS91405

Quartets in Dimension Two

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The progress in nanofabrication technology now allows fabricating all kinds of Josephson weak links connecting an arbitrary number of terminals. The multiterminal Josephson junctions have rich physics in the enhanced multiterminal parameter space.

With my collaborators, as soon as 2011, I generalized to three terminals the Anderson and Josephson works that establish a connection between gauge invariance, the superconducting phase variables and the supercurrent. The resulting microscopic process of the quartets involves a transient intermediate state supporting correlations among four fermions and coupling to the three-body quartet phase. This produces DC-resonance lines when the differential conductance is plotted as a function of the two independent bias voltages. The quartets were observed in successive collaborations that were developed with Lefloch's group (Grenoble) on metallic devices, with Heiblum's group (Weizmann Institute), Pribiag's group (Minnesota) on semi-conducting nanowires, and, on graphene, with Kim's group (Harvard) and Kayyalha's group (Penn State).

I will introduce the quartets and propose a general theoretical picture for the voltage-biased ballistic 2D metal-based devices, that captures both features of the Kayyalha's group experiment (Penn State) on three-terminal Andreev interferometers and the Kim's group experiment (Harvard) on four-terminal Josephson junctions. This new approach is based on both physical ingredients of the spectrum and the electronic populations, starting from the long-junction limit. Their coupling to the two- or three-body Josephson or quartet modes is operated via a new nonlocal Keldysh process that we call "phase-Andreev reflection". This extends the physics of Andreev interferometers to the ballistic limit and to the multiterminal Josephson effect, putting the emphasis on the ballistic 2D metal voltage-tunable nonequilibrium Fermi surface.

In the second half of the talk, I will extend the theory to capture the recent experimental results (Penn State group) on the superconducting tunneling spectroscopy of graphene three-terminal Josephson junctions. We obtain from the RPA theory two families of the quartet resonances that are topologically distinct in the sense of different winding numbers across the torus of the superconducting phases. The experimental data reveal avoided crossings in the plane of the superconducting phases, which demonstrates the quantum nature of the quartets. Thus, in the considered device, topology alone is not enough to fully characterize the spectra of Andreev bound states.