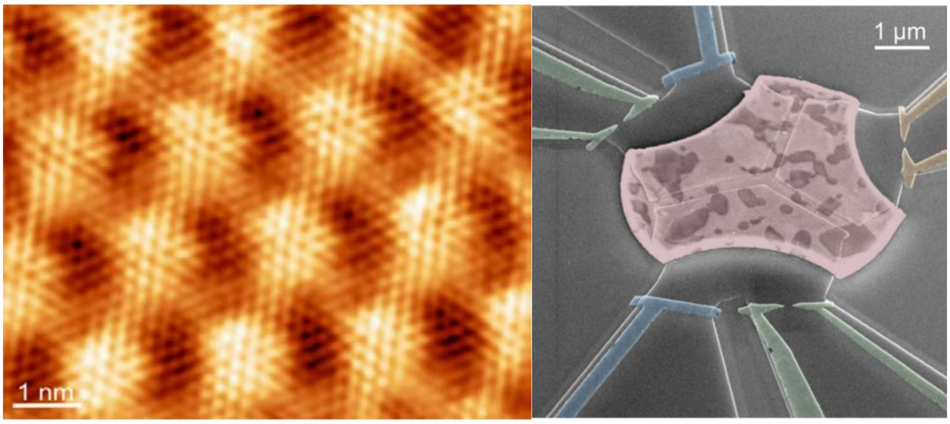
GDR PHYSIQUE QUANTIQUE MESOSCOPIQUE

Session plénière 2020

23 -26 Novembre 2020



Les organisateurs : **Julien Basset & Rémi Avriller**

Directeur : **Patrice Roche**

Secrétaire : **Marie-France Mariotto**

Dû aux contraintes sanitaires exceptionnelles la réunion du GDR MESO est maintenue en distanciel.

Les invités :

Audrey Cottet (ENS Paris)

Thomas Ebbesen (ISIS Strasbourg)

Gwendal Fève (ENS Paris)

Çağlar Girit (Collège de France Paris)

David Hagenmüller (ISIS Strasbourg)

Hélène Le Sueur (CEA Saclay)

Florence Levy-Bertrand (Institut Néel Grenoble)

Freek Massee (LPS Orsay)

Julia Meyer (CEA Grenoble)

Frédéric Pierre (C2N Palaiseau)

Guillaume Schüll (IPCMS Strasbourg)

Matias Urdampilleta (Institut Néel Grenoble)

Dear Participants,

Here are important informations regarding the meeting of the GDR Mesoscopic Quantum Physics 2020 which will be held online from Monday 23rd of November to Thursday the 26th of November 2020.

The platform that will be used is ZOOM. You will receive each day, by e-mail, the link for the coming session.

Regarding ZOOM, if you want to take full advantage of the conference, especially the poster session, **we encourage you to update your zoom version here (at least v5.3):**

https://support.zoom.us/hc/en-us/articles/360042414611-New-Updates-for-Zoom-Client

For attendees

- In the Zoom meeting rooms please keep your microphone muted until you are ready to talk.
- **Please raise your hand or write in the chat to the chairperson if you want to ask a question as the talk is progressing. The chair of the session will then serve as host and call upon you to ask your questions directly (allowing speaking/microphone privileges).**
- Do not ask the question in an anonymous mode as we will not be able to find you to give you microphone access

For speakers

- Please be there 5-10 minutes before your session.
- We will then provide you with co-host rights so that you can share your screen.
- **Please be there and finish on time.**
- A chairperson will help you to keep on time.

For chairpersons

- Please be there 5-10 minutes before your session.
- We will then provide you with co-host rights so that you can chair the session.
- **We ask you to keep track of the schedule and time for each presentations:**
    - 20 + 5 min questions (contributed talks)
    - 30 + 5 min questions (invited talks)
    - 45 + 5 min questions (tutorials)

For posters

- **Presenters:**
    - Each poster has been attributed a number for which a breakout room has been created (see program and/or website).
    - We ask the poster presenters to stay in their break-out room and share their screen with their poster and wait for participants to visit them.

- **Poster attendees:**
    - Please connect to Zoom and choose a break-out room number referenced to a specific poster (see program and/or website)
    - You will be able to switch between breakout-rooms then attending posters at will.

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GDR Physique Mésoscopique - Plénière 2020

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10:20 - 10:55	› Atomic scale current noise and atom manipulation in a high-Tc superconductor - *Freek Massee, Laboratoire de Physique des Solides*
10:55 - 11:25	Pause café
11:25 - 12:40	**Aux frontières du STM - II**
11:25 - 11:50	› Boundary Modes from Impurity-induced States - *Vardan Kaladzhyan, Royal Institute of Technology [Stockholm], University of Basel*
11:50 - 12:15	› Heterostrain and interactions on flat bands of TBLG in STM Measurements - *Florie Mesple, cea/pheliqs/irig/lateqs*
12:15 - 12:40	› Skyrmion zoo in graphene at charge neutrality in a strong magnetic field - *Jonathan Atteia, Laboratoire de Physique des Solides*
12:40 - 14:00	Déjeuner
14:00 - 15:15	**Systèmes 2D - I**
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16:10 - 16:35	› A tunable Fabry-Pérot quantum Hall interferometer in graphene - *Corentin Déprez, Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel*
16:35 - 17:00	› Signature of Landau Band Coupling in higher order Fractal Energy Spectrum - *Abhishek JUYAL, Institut Néel*
17:00 - 17:25	› Experimental detection of graphene's singular orbital diamagnetism at the Dirac point. - *Jorge Vallejo Bustamante, Laboratoire de Physique des Solides*

Mardi 24 novembre 2020

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11:35 - 12:00	› Gauge Fixing for Strongly Correlated Electrons coupled to Quantum Light - *Olesia Dmytruk, Collège de France*
12:00 - 12:25	› Relativistic corrections to the magnetic response of gold nanoparticles - *Mauricio Gómez Viloria, Institut de Physique et Chimie des Matériaux de Strasbourg*
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16:20 - 16:45	› Probing the Density of States in Low Dimensional Electronic Systems - *Alexis Jouan, Département de Physique [ENS Lyon]*
16:45 - 17:10	› Circuit-QED with phase-biased Josephson weak links - *Cyril Metzger, Quantronics group*

Transport, transfert d'énergie, réactivité chimique en cavité plasmonique

The Alchemy of Vacuum

Thomas Ebbesen * [1]

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Light-matter strong coupling can give rise to a multitude of physical effects through the formation of hybrid light-matter states that have been extensively studied. However, the implications for molecular and material properties have remained mostly unexplored. After introducing the fundamental concepts, examples of modified properties of strongly coupled systems in the ground state, such as superconductivity, charge and energy transport, and chemical reactivity will be given to illustrate the potential of light-matter states.

*Intervenant

Charge-Transfer Chemical Reactions in Nanofluidic Fabry-Pérot Cavities

Lorenzo Mauro * [1]

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We investigate the chemical reactivity of molecular populations confined inside a nanofluidic Fabry-Pérot cavity. Due to strong light-matter interactions developing between a resonant electromagnetic cavity-mode and the electric dipole moment of the confined molecules, a polariton is formed. The former gets dressed by environmental vibrational and rotational degrees of freedom of the solvent. We call the resulting polariton dressed by its cloud of environmental excitation a "reacton", since it further undergoes chemical reactions. We characterize how the reacton formation modifies the kinetics of a photoisomerization chemical reaction involving an elementary charge-transfer process. We show that the reaction driving-force and reorganization energy are both modulated optically by the reactant concentration, the vacuum Rabi splitting and the detuning between the Fabry-Pérot cavity frequency and targeted electronic transition. Finally, we compute the ultrafast picosecond dynamics of the whole photochemical reaction. We predict that despite optical cavity losses and solvent-mediated non-radiative relaxation, measurable signatures of the reacton formation can be found in state-of-the-art pump-probe experiments

*Intervenant

Controlling charge and energy transport with cavity quantum electrodynamics

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The interplay between light and transport in condensed-matter is at the heart of optoelectronic devices. While it is known that electronic transport in, e.g., quantum Hall systems [1,2], superconductors [3,4], and nanocircuits [5], can be controlled using an external radiation, an interesting question is whether transport properties can be also affected by coupling the relevant matter excitations to the vacuum field of a cavity [6,7]. In particular, one of the most important phenomenon in cavity-quantum electrodynamics is the so-called strong coupling regime, which occurs when the interaction between light and matter is so strong that the latter mix together to create two hybrid light-matter states called "polaritons", and a continuum of "dark states" that are completely decoupled from light. In this talk, I will discuss different toy models where a chain of two-level systems is resonantly coupled to a cavity field. I will show that the transmission of charges through the chain can be modified by the cavity coupling, which leads to a current enhancement even in the dissipative regime where the cavity photon decay rate is the largest parameter

. The effect of an on-site disorder will be also discussed. Here, we find that the cavity coupling can modify the localization properties of the system and lead to efficient transport of excitations via the dark states [10].

M. A. Zudov et al. Phys. Rev B. 64, 201311(R) (2001)

R. Mani et al. Nature 420, 646 (2002)

A. F. G. Wyatt et al., Phys. Rev. Lett. 16, 1166 (1966)

D. Fausti et al., Science 331, 189 (2011)

M. Ludwig et al., Nat. Phys. 16, 341 (2020)

E. Orgiu et al., Nat. Mater. 14, 1123 (2015)

G. L. Paravicini-Bagliani et al., Nat. Phys. 15, 186 (2019)

D. Hagenmuller et al., Phys. Rev. Lett. 119, 223601 (2017)

D. Hagenmuller et al., Phys. Rev. B 97, 205303 (2018)

T. Botzung et al., arXiv:2003.07179 (2020)

*Intervenant

Heat Conductance in a Quasi-ballistic InAs Nanowire

Danial Majidi * [1], Mukesh Kumar , Lars Samuelson [2,3], Herve Courtois [4,5], Clemens Winkelmann , Ville F. Maisi [6]

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[2] Lund University – Lund, Suède
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In the past decades, InAs nanowires have attracted considerable attention due to their great potential for devices from optics to thermoelectricity . In many of these devices heat flow plays a significant role in device performance [1], either because heat flow is a parasitic effect and is therefore undesired, as is the case in thermoelectrics , or because high heat flow is critically required for thermal management [2]. We report on combined measurements of heat and charge transport in an individual InAs nanowire at milliKelvin temperatures using a sensitive superconductor-insulator-normal metal (SIN) electron thermometer integrated inside the device. The nanowirefield-effect transistor acts as a heat valve controlled by the back gate voltage, $ V_ {BG} $. The Wiedemann -Franz law (WFL) for the ratio of the electronic contribution of heat and charge conductances is found to hold in the conducting state of the device. As the Fermi level is tuned below the 1D conduction band edge the WFL is gradually broken [3].

*Intervenant

Ferromagnetic instability in ensembles of gold nanoparticles

Gaetan Percebois * [1]

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While gold is weakly diamagnetic in the bulk, peculiar magnetic properties have been found for ensembles of gold nanoparticles. In some samples, an unusual ferromagnetic order has been experimentally observed. In order to elucidate the mechanism that is at the origin of such a ferromagnetic response, we theoretically study assemblies of nanoparticles in the presence of a dipolar magnetic interaction between their orbital magnetic moments. A ferromagnetic instability at zero external field is found for the case of an interacting dimer. The parameter relevant for this instability is the individual zero-field susceptibility of the nanoparticles. We determine the critical value and find an extremely high value. Within our model, the ferromagnetic phase in a dimer of gold nanoparticles can only be reached at very low temperatures. In a chain of nanoparticles, this critical zero-field susceptibility decreases as the number of particles in the system increases, with a saturation at still rather high values.

*Intervenant

Polaritons in periodic chains of metallic nanoparticles: a QED approach

Thomas Allard * [1]

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We study the effect of the light-matter interaction for a one-dimensional chain of metallic nanoparticles supporting localized surface plasmons, modelled by near-field coupled point dipoles in either transverse or longitudinal polarization. Taking into account the photonic environment allows to include retardation effects along the chain and is therefore a necessary ingredient when considering relatively long arrays.
By investigating the light-matter coupling using a quantum electrodynamics approach, we find the exact energy spectrum and the radiative decay rate of the collective mode. The excitation along the one-dimensional array becomes a hybrid light-matter quasiparticle, namely a plasmon-polariton, and we find a typical avoided-crossing dispersion for the transversely polarized dipoles.

Our results are in agreement with those found using fully classical methods based on Maxwell's equations but show a slight shift in energy, with a notably increased radiative decay rate. These new results are also in agreement with the perturbative computation, for which an analytical expression is available.
Keywords: plasmon polaritons, light-matter coupling

*Intervenant

Collisional interferometry of levitons in quantum Hall edge channels at nu=2

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We consider a Hong-Ou-Mandel interferometer for Lorentzian voltage pulses applied to quantum Hall edge channels at filling factor nu=2. Due to interedge interactions, the injected electronic wave packets fractionalize before partitioning at a quantum point contact. Remarkably enough, differently from what was theoretically predicted and experimentally observed by using other injection techniques, we demonstrate that when the injection occurs through time-dependent voltage pulses (arbitrarily shaped), the Hong-Ou-Mandel noise signal always vanishes for a symmetric device and that a mismatch in the distances between the injectors and the point of collision is needed to reduce the visibility of the dip. We also show that by properly tuning these distances or by applying different voltages on the two edge channels in each arm of the interferometer, it is possible to estimate the intensity of the interedge interaction. Lorentzian-type voltage pulses are chosen because of their experimental relevance.

*Intervenant

Relativistic corrections to the magnetic response of gold nanoparticles

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The last two decades have witnessed various experiments reporting very unusual magnetic properties of ensembles of gold nanoparticles surrounded by organic ligands, including ferromagnetic, paramagnetic, or (large) diamagnetic responses. Such behavior is at odds with the small diamagnetic response of macroscopic gold samples. We theoretically investigate the possibility that the observed unusual magnetism in capped gold nanoparticles could be of orbital origin, considering in particular the influence of the confinement on the spin–orbit coupling.

Employing quantum mechanical perturbation theory and semiclassical approximations, we calculate the orbital component to the zero-field susceptibility of individual as well as ensembles of metallic nanoparticles in the weak relativistic limit. While the result for the non-relativistic orbital response of individual nanoparticles can exceed by orders of magnitude the bulk Landau susceptibility in absolute value, and can be either diamagnetic or paramagnetic depending on nanoparticle size, we show that the magnetic susceptibility of a noninteracting ensemble of nanoparticles with a smooth size distribution is always paramagnetic at low magnetic fields. The calculated field-dependent magnetization of an ensemble of diluted nanoparticles is shown to be in good agreement with existing experiments that yielded a large paramagnetic response. While for spherical nanoparticles the spin-orbit corrections are dominated by other weakly-relativistic effects, a spatial symmetry breaking considerably enhances the spin-orbit contribution.

*Intervenant
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Gauge Fixing for Strongly Correlated Electrons coupled to Quantum Light

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We discuss the problem of gauge fixing for strongly correlated electrons coupled to quantum light, described by projected low-energy models such as those obtained within tight-binding methods. Drawing from recent results in the field of quantum optics, we present a general approach to write down quantum light-matter Hamiltonian in either dipole or Coulomb gauge which are explicitly connected by a unitary transformation, thus ensuring gauge equivalence even after projection. The projected dipole gauge Hamiltonian features a linear light-matter coupling and an instantaneous self-interaction for the electrons, similar to the structure in the full continuum theory. On the other hand, in the Coulomb gauge the photon field enters in a highly non-linear way, through phase factors that dress the electronic degrees of freedom. We show that our approach generalises the well-known Peierls approximation, to which it reduces when local, on-site orbital contributions to light-matter coupling are disregarded. As an application, we study a two-orbital model of interacting electrons coupled to a uniform cavity mode, recently studied in the context of excitonic superradiance and associated no-go theorems. Using both gauges we recover the absence of superradiant phase in the ground state and show that excitations on top of it, described by polariton modes, contain instead non-trivial light-matter entanglement. Our results highlight the importance of treating the non-linear light-matter interaction of the Coulomb gauge non-perturbatively, to obtain a well-defined ultrastrong coupling limit and to not spoil gauge equivalence.

*Intervenant

Aux frontières du STM

Atomic scale current noise and atom manipulation in a high-Tc superconductor

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Conventional scanning tunnelling microscopy uses the time-averaged tunnel current to probe the lattice and electronic states at the atomic scale. To gain access to time-dependent information, we recently implemented cryogenic circuitry into our home-built scanning tunnelling microscope that allows us to measure current noise, including shot noise, at 1 MHz [1]. In this talk I will briefly discuss some details of this technique, and show how it enabled us to detect remarkable charge dynamics at select atomic sites in the high temperature superconductor Bi2Sr2CaCu2O8+x [2]. Then, I will demonstrate how we can use the electric field of the tip to manipulate these sites, as well as other individual atoms. The electric field manipulation, which may be applicable to other correlated electron material, reveals a strong link between the position of individual atoms and the spectral properties of this system [3]. Time permitting, I will present additional examples of current noise measurements in related systems.

F. Massee et al., Rev. Sci. Instrum. **89**, 093708 (2018)

F. Massee et al., Nature Communications **10**, 544 (2019)

F. Massee et al., Science **367**, 68-71 (2020)

*Intervenant

Boundary Modes from Impurity-induced States

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We introduce an alternative method of calculating boundary modes based on the T-matrix formalism. Instead of treating a boundary in a finite-size system conventionally, we introduce localised impurities with potentials corresponding to the shape of the boundary into an infinite system, and we calculate the associated impurity-induced states. The latter morph into the sought-for boundary modes in the limit of infinite-amplitude impurity potentials. More saliently, we show how to extract boundary Green's functions within our formalism. Finally, we demonstrate the power of the method by showing immediate applications in studying quasiparticle interference patterns.

*Intervenant

Heterostrain and interactions on flat bands of TBLG in STM Measurements

Florie Mesple * [1], Ahmed Missaoui [2], Tommaso Cea [3], Loïc Huder [4], Francisco Guinea [3], Guy Trambly De Laissardière [5], Claude Chapelier [6], Vincent Renard† [7]

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The moiré of twisted graphene layers can lead to the formation of flat bands in which charge carriers do not posses enough kinetic energy to escape Coulomb interactions with each other. This allows for the formation of novel strongly correlated electronic states. This exceptionally rich physics relies on the precise arrangement between the layers. By performing a survey of published Scanning Tunnelling Microscope (STM) measurements, we investigate the effect of native heterostrain, ***the relative arrangement of the layers***. Specifically, we use tight binding calculations that by taking heterostrain into account, ***fit very well the experiments. They*** show that the electronic properties depend on the amplitude of heterostrain but also on other fine details, in particular on the angle at which uniaxial strain is applied. By determining this heterostrain in each studied sample, we show that the relative deformations between the layers is needed in addition to interlayer twist to describe quantitatively the flat bands. This is the case in the absence of interactions, a situation accessed experimentally at large dopings. In the opposite situation of low doping, we find that electronic correlation further renormalise the flat bands in a way that strongly depends on experimental details. This extreme sensitivity marks a striking difference with other highly correlated systems.

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Skyrmion zoo in graphene at charge neutrality in a strong magnetic field

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As a consequence of the approximate spin-valley symmetry in graphene, the ground state of electrons in graphene at charge neutrality is a particular SU(4) quantum-Hall ferromagnet to minimize their exchange energy. If only the Coulomb interaction is taken into account, this ferromagnet can appeal either to the spin degree of freedom or equivalently to the valley pseudo-spin degree of freedom. This freedom in choice is then limited by subleading energy scales that explicitly break the SU(4) symmetry, the simplest of which is given by the Zeeman effect that orients the spin in the direction of the magnetic field. In addition, there are also valley symmetry breaking terms that can arise from short-range interactions or electron-phonon couplings. Here, we build upon the phase diagram, which has been obtained by Kharitonov [Phys. Rev. B **{**85}, 155439 (2012)], in order to identify the different skyrmions that are compatible with these types of quantum-Hall ferromagnets. Similarly to the ferromagnets, the skyrmions at charge neutrality are described by the ${Gr}(2,4)$ Grassmannian at the center, which allows us to construct the skyrmion spinors. The different skyrmion types are then obtained by minimizing their energy within a variational approach, with respect to the remaining free parameters that are not fixed by the requirement that the skyrmion at large distances from their center must be compatible with the ferromagnetic background. We show that the different skyrmion types have a clear signature in the local, sublattice-resolved, spin magnetization, which is in principle accessible in scanning-tunneling microscopy and spectroscopy.

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Sub-molecular fluorescence microscopy with STM

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The electric current traversing the junction of a scanning tunneling microscope (STM) may lead to a local emission of light that can be used to generate sub-molecularly resolved fluorescence maps of individual molecules. Combined with spectral selection and time-correlated measurements, this hyper-resolved fluorescence microscopy approach allowed us to scrutinize the vibronic structure of individual molecules [1] in a very similar way than in the recent TERS reports, without requiring an optical excitation. We used this approach to characterize the photonics properties of charged species [2] to track the motion of hydrogen atoms within free-based phthalocyanine molecules [3], and to address energy transfers between complex chromophore architectures.
Together with other recent reports [4,5], these results constitute an important step towards photonic measurements with atoms-scale resolution.

B. Doppagne et al., Phys. Rev. Lett. 118, 127401 (2017)

B. Doppagne et al. Science, 361, 251 (2018)

B. Doppagne et al. Nature Nanotechnol.15, 207(2020).

Y. Zhang et al. Nature 531, 623 (2016)

H. Imada et al., Nature 538, 364 (2016) Zewail, A. H., Science, 2010, 328, 187-193

*Intervenant

Inductances cinétiques supraconductrices- Supraconducteurs désordonnés

Electrodynamics of granular aluminum from superconductor to insulator: observation of collective superconducting modes

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When superconductivity establishes the electrons condensate and form one wave function with a unique phase breaking the U(1) symmetry. Associated with this symmetry breaking two types of collective modes are expected to emerge: the amplitude and the phase fluctuations of the superconducting order parameter. The amplitude mode (or Higgs-mode) is decoupled from electromagnetic waves, and foreseen to occur at twice the superconducting gap energy. The phase mode (or Goldstone-mode) is a longitudinal mode with a linear dispersion in a neutral fluid, transformed into a dispersiveness mode at the plasma energy, well above the superconducting gap, when taking into account the unscreened long range Coulomb interactions. Typical optical spectroscopy probe transverse electromagnetic excitations at almost zero momenta. Thus, in principle, no optical absorptions are expected below twice the superconducting gap.

In this work, we provide direct evidence for well resolved sub-gap absorptions in superconducting granular aluminum thanks to an original high resolution optical spectroscopy technique [1]. Granular aluminum is formed of superconducting nanometric grains of pure aluminum which are coupled via Josephson coupling through aluminum oxide barriers. Varying the Josephson coupling (through oxygen pressure variation when evaporating the aluminum) tuned the material from a superconductor to an insulator. From pure aluminum to insulating composition the superconducting critical temperature Tc presents a dome shape. We explored the superconductor to insulator phase diagram by combined transport and optical spectroscopy measurements to determine the superconducting gap, the critical temperature Tc and the phase stiffness J (that is here the Josephson energy). The onset of the sub-gap absorptions occurs in the vicinity of the maximum of the superconducting dome. The phase diagram is discussed as resulting from an interplay between the Josephson energy, the Coulomb repulsion and the superconducting gap.

*Intervenant

A Josephson junction coupled to a high-impedance granular Aluminum resonator

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We have realized a granular Aluminum resonator galvanically coupled to a Josephson junction. The modes of the resonator have a high quality factor (_~30000), as well as a large characteristic impedance up to 4.5 kOhm. Because this characteristic impedance is comparable to the quantum of resistance, high order non-linear processes involving many photons and the tunneling of one Cooper pair or quasiparticle are allowed and modify both the characteristics of the resonator and of the junction. When the junction is biased below the superconducting gap, the inelastic tunneling of Cooper pairs populates the different cavity modes. We directly measure the photon emission in one of the mode mode close to 6 GHz and observe more than 70 emission peaks as a function of bias voltage, a clear signature of the high non-linearity. At larger voltages close to the gap, the tunneling of quasiparticle modifies both the resonance frequency and the linewidth of the modes. A quantum treatment of this dissipative process in terms of Lamb shift and quantum jumps is required to quantitatively explain our measurements. These results show the potential of granular Aluminum to realize quantum optics experiments in a regime where charge transport and microwave photons are strongly coupled.

*Intervenant

Overactivated transport in the localized phase of the superconductor-insulator transition

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Despite decades of study, there are still major grey areas to the understanding of the Superconductor-to-Insulator Transition (SIT). While beyond a critical disorder, two-dimensional superconducting films become insulating, some systems transit to a strong insulating regime at low temperature which cannot be accounted for by conventional theories. During this talk, I will present a systematic study on insulating amorphous NbSi in the vicinity of the SIT. At the lowest temperatures, electronic transport is activated with two distinct activated regimes, which could be identified with over-activated regimes found in other systems.
I will analyze our data in light of an extensive numerical model on disordered quasi-two dimensional systems, showing that the appearance of superconducting grains among the insulating matrix may explain the stronger-than-activation behavior observed in the immediate vicinity of the SIT. Charge carriers have to overcome two competing energies – the superconducting gap and the charging energy – resulting in a larger activation energy.
These findings and the subsequent model will be applied to various systems showing the validity of the model on various quasi two-dimensional systems.

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Charged fluctuators in high kinetic inductance superconductors

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Lossless high inductances are instrumental for quantum technologies (qubits, sensors), as they enable strong light-matter coupling, and offer some protection against DC offset charge noise. One method developped recently is to use the intrinsically high kinetic inductance of disordered superconducting thin films. Such inductors have already been shown to reach impedances much larger than the resistance quantum h / 4 e^2, while keeping a reasonably low level of losses. However, quantum phase slips Qubits made from nanoinductors have never achieved proper coherence times, and upon increasing the impedance of devices one strives with a systematic increase of their losses.

We present here a decoherence mechanism at work in superconductors arising from kinetic inductance fluctuations.
We show that charged Two Level Systems (TLS) which couple to the conduction electrons in the BCS ground state can be responsible for such, and we use standard theories of mesoscopic disordered conductors to derive orders of magnitudes. This effect, linking electronic (microscopic) and electromagnetic (macroscopic) decoherence in superconductors was surprisingly never taken into account.
By analyzing experiments on thin-film nanoresonators of NbSi and TiN we show evidence of (too) strongly coupled charge fluctuators and frequency noise, which get enhanced as impedance is increased.
Given the omnipresence of charged TLS in solid-state systems, this decoherence mechanism affects all experiments involving disordered superconductors, and more strongly so devices with smaller cross-sections. In particular, we show it easily explains the poor coherence observed in quantum phase slip experiments and may contribute to lowering the quality factors in disordered superconductor resonators.

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Supraconductivité mésoscopique

Weyl Josephson Circuits

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Multiterminal superconductor-normal-superconductor junctions have been a focus of theoretical and experimental work due to their potential topological properties, but so far they remain far out of experimental reach due to lack of microscopic control. Here we propose an alternative approach based on standard Josephson tunnel junction circuits, immediately enabling experimental pursuit. We find that these circuits can be designed to simulate Weyl band structures, which can mimic the properties of massless ultrarelativistic particles known as Weyl fermions. We dubbed these Weyl Josephson circuits.
In this work, we first explain a general approach to construct small quantum circuits that exhibit topological band structures of a desired symmetry class, and which are governed by a designable set of controllable parameters. We then construct and analyze in detail a six-junction device that produces a 3D Weyl Hamiltonian with broken inversion symmetry and in which topological phase transitions can be triggered *in situ*. Finally we propose specific experiments probing the topological character of Weyl Josephson circuits which are readily accessible using standard nanofabrication and measurement techniques.

This work breaks open a field of research that merges the technological readiness and theoretical clarity of superconducting circuits with the notions of quantum geometry and band topology.
V. Fatemi, A. R. Akhmerov, L. Bretheau, *Weyl Josephson Circuits*, arXiv:2008.13758 (2020)

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Transconductance quantization in a topological Josephson tunnel junction circuit

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Superconducting circuits incorporating Josephson tunnel junctions are widely used for fundamental research as well as for applications in fields such as quantum information and magnetometry. The quantum coherent nature of Josephson junctions makes them especially suitable for metrology applications. Josephson junctions suffice to form two sides of the quantum metrology triangle, relating frequency to either voltage or current, but not its base, which directly links voltage to current. We propose a five Josephson tunnel junction circuit in which simultaneous pumping of flux and charge results in quantized transconductance in units $4e^2/h = 2e/\Phi0$, the ratio between the Cooper pair charge and the flux quantum. The Josephson quantized Hall conductance device (JHD) is explained in terms of intertwined Cooper pair pumps driven by the AC Josephson effect. We describe an experimental implementation of the device and discuss the optimal configuration

of external parameters and possible sources of error. The JHD has a rich topological structure and demonstrates that Josephson tunnel junctions are universal, capable of interrelating frequency, voltage, and current via fundamental constants.

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Circuit-QED with phase-biased Josephson weak links

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By coupling a superconducting phase-biased weak link to a microwave resonator, recent experiments have probed the spectrum[1,2] and achieved the quantum manipulation[3] of Andreev states in various systems. Motivated by the recent observation in InAs weak links[1] of single quasiparticle transitions between spin-split Andreev levels (Fig 1), efforts are now directed towards implementing in such hybrid systems an Andreev spin qubit, as a route alternative to quantum dots for coupling a single fermionic spin to a microwave resonator[4,5]. However, the quantitative understanding of the response of the resonator to changes in the occupation of a multi-level many-body system of Andreev levels has so far been missing. Using Bogoliubov-de Gennes formalism to describe the weak link and a general formulation of the coupling to a resonator, we calculate the resonator frequency shift as a function of the levels occupation and describe how transitions are induced by means of a phase or electric field microwave drive.
In this talk, I will apply this formalism to recent experimental results, obtained using circuit-QED techniques on superconducting atomic contacts and semiconducting nanowire Josephson junctions, and show how it is able to describe the measured spectra, in particular the transition lines intensity and the existence of selection rules associated to the spin[6,7]. References

L. Tosi et al., Phys. Rev. X **9**, 011010 (2019)

L. Bretheau et al., Nature **499**, 312 (2013)

C. Janvier et al., Science **349**, 1199 (2015)

S. Park et al., Phys. Rev. B **96**,1059125416 (2017)

M. Hays et al., arXiv:1908.02800

S. Park et al., Phys. Rev. Lett. **125**, 077701

C. Metzger et al., arXiv:2010.00430

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Tutorial: Topological properties of multi-terminal Josephson junctions

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Topological phases of matter have been a subject of intense studies in recent years. In many instances, topological properties are encoded in the band structure and one has to find the right material or combination of materials in order to realize them. More recently, an alternative approach to finding and exploring topological states of matter has emerged: namely, one can "imitate" necessary physical ingredients by using other degrees of freedom.
Multi-terminal Josephson junctions are of interest both as probes of the topological properties of the superconducting leads and as synthetic topological matter.

Using the superconducting phases of the terminals in n-terminal Josephson junctions as variables, one may realize topological band structures in d=n-1 dimensions. In particular, a 4-terminal junction may realize a 3-dimensional Weyl semimetal, possessing topologically protected crossings in its Andreev bound state spectrum.

As the phases can be controlled externally, furthermore, one has access to lower-dimensional subspaces. Namely, a 2-dimensional subsystem may have a finite Chern number that manifests itself in a quantized transconductance, like in the quantum Hall effect.

It turns out that, in 3-terminal Josephson junctions made with topological superconductors, the quantized transconductance provides a new and striking signature of the coupling between Majorana zero modes. The quantization value is $\pm 2e2/h$ for any such device with broken time-reversal symmetry.
The analogy between the spectrum of Andreev bound states in an n-terminal Josephson junction and the bandstructure of an n-1-dimensional material opens the possibility of realizing topological phases in higher dimensions, not accessible in real materials.

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From single hole quantum dot regime to supercurrent: the gate tuneable transport properties of an Al-pure Ge-Al nanowire heterostructure

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The diverse applications and rich physics of hybrid superconducting-semiconducting systems has attracted significant research interest in improving the quality and materials of these devices. Significant focus has been made on hybrid systems using a combination of germanium and silicon as the semiconductor, such as Ge/Si core/shell nanowires and Ge/Si planar junctions, to form high mobility hole gas. However, there has been little research on pure germanium systems. Through annealing, we have realised highly transparent crystalline aluminium contacts to a short gate tuneable crystalline germanium segment. We will present the transport properties of this Al-Ge-Al nanowire heterostructure at 300mK. Using a back gate voltage, we have access to a large variety of quantum transport regimes in a single device: from a quantum dot with single hole filling up to supercurrent inside the pure germanium segment induced by the proximity effect.

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Implementing low-impedance resonators resilient to magnetic field and dielectric losses for nanoscale paramagnetic resonance detection

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Electron spin resonance signals are typically detected by embedding spins in a microwave resonator matching their Larmor precession frequency. The use of superconducting high-quality factor resonators, low temperatures, and quantum-limited detection [1-3] has recently pushed the sensitivity of this detection technique to a new limit (12 spins/sqrt Hz) and enables detection of samples with femtolitre-volume. These enhanced techniques have however only been applied to crystalline samples. Here, we report our progress towards implementing superconducting high-quality factor resonators resilient to both magnetic fields and dielectric samples, which would enable to probe more diverse sample types.
The resonator is designed to have a low-impedance to maximize the coupling to the spins as well as an 'active' area for the sample with maximized magnetic field and minimized electric field. It is fabricated out of NbTiN for magnetic field resilience [4]. We validate these choices by benchmarking its quality factor against well-known designs made out of Al. Tests for magnetic field resilience and dielectric loss resilience are also planned.

S. Probst et al., Applied Physics Letters 111, no. 20 (2017)

V. Ranjan et al., Applied Physics Letters 116, no. 18 (2020)

AKV. Keyser et al., Journal of Magnetic Resonance (2020)

Jg. Kroll et al., Nature communications 9, no. 1 (2018)

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Josephson junction spectrometer for wideband, on-chip nonlinear spectroscopy of quantum systems

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Spectroscopy is a powerful tool to probe physical, chemical, and biological systems. A sensitive, general purpose spectrometer for artificial quantum systems is lacking. We demonstrate an on-chip spectrometer based on a voltage-biased superconducting quantum intereference device functioning well into the millimeter wave band. We explain the design of the spectrometer, couple it to a tunable non-linear resonator in the 40-50 GHz range, investigate the energy spectrum of the device-under-test, and measure the spectrometer sensitivity. The Josephson junction based spectrometer, with a broad frequency range, high sensitivity, and strong coupling strength will enable new experiments in linear and non-linear spectroscopy of mesoscopic quantum systems.

*Intervenant

Evidence for spin-dependent energy transport in a superconductor

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The ground state of conventional superconductors can carry a dissipationless current (a supercurrent) but not energy or spin currents. In contrast, single-particle excitations, known as quasi-particles, can carry spin, charge and heat currents. In this work quasiparticles were injected into a superconducting Al wire by tunneling from a normal metal. If a Zeeman field is applied the created excitations can be spin polarized. By performing spin-sensitive spectroscopy on this out-of-equilibrium state it was found that the distribution function becomes spin-dependent. This shows that a new out-of-equilibrium mode is excited in the superconductor: the spin-energy mode (most easily exemplified by a different temperature for spin up and spin down quasiparticles) which couples transport spin and energy transport.

*Intervenant

Robust supercurrent in graphene Josephson junctions assisted by strong spin-orbit interaction

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A magnetic field is known to destroy the spin-singlet Cooper pair via the Zeeman effect. But the orbital effect of a magnetic flux also destroys proximity-induced superconductivity. Since spin-orbit interactions (SOI) can moderate these effects thanks to the spin-momentum locking it provides, one can wonder if supercurrent can be made more robust to an orbital magnetic field in materials with enhanced spin-orbit interaction. To investigate this question, we compare Josephson junctions built with two different graphene-based systems, a hBN/G/hBN stack, or a hBN/WS2/G stack, in which strong SOI have been induced in graphene via the van der Waals-coupled WS2. We measure the supercurrent induced through these systems in varying perpendicular magnetic fields and for different junction lengths.
We find similar signatures of induced superconductivity in both systems when the junctions are short (100nm), for fields up to 1T.

However, signatures of induced superconductivity in the longest junctions (500 nm) are found only in the hBN/WS2/G –based junction. The signatures survive up to 7 T.
We argue that the robust superconducting signatures arise from the existence of quasi-ballistic edge states stabilized by strong SOI induced in graphene by WS2.

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Qubits hybrides, semiconducteurs et électrodynamique quantique

Proposal for a nanomechanical qubit

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Mechanical oscillators have been demonstrated with very high quality factors over a wide range of frequencies. These also couple to a wide variety of fields and forces, making them ideal as sensors. The realization of a mechanically-based quantum bit could therefore provide an important new platform for quantum computation and sensing. Here we show that by coupling one of the flexural modes of a suspended carbon nanotube to the charge states of a double quantum dot defined in the nanotube, it is possible to induce sufficient anharmonicity in the mechanical oscillator so that the coupled system can be used as a mechanical quantum bit. This can however only be achieved when the device enters the ultrastrong coupling regime. We discuss the conditions for the anharmonicity to appear, and we show that the Hamiltonian can be mapped onto an anharmonic oscillator, allowing us to work out the energy level structure and how decoherence from the quantum dot and the mechanical oscillator are inherited by the qubit. Remarkably, the dephasing due to the quantum dot is expected to be reduced by several orders of magnitude in the coupled system. We also outline qubit control and readout protocols.

Ref: arXiv:2008.10524v1

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Graphene based quantum superconducting circuits

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Devices based on the control of quantum states will revolutionize information and communications technologies. Several implementations of the quantum bit (Qubit), i.e. the building block for systems targeting quantum-enabled functionalities, were already demonstrated. Approaches based on all-superconducting materials provide the most advanced solid-state platform to date but they must rely on magnetic effects for control and operation, which is not an industry standard for devices and might induce unwanted interaction between different elements of the circuit. We report the integration of graphene in the key element of superconducting circuits: the Josephson junction. The field effect enables the junction to gain electrical tunability, a breakthrough for control and future integration. This has recently been implemented in superconducting qubits[1,2,3]. The poster will show how to incorporate a graphene Josephson junction in a superconducting microwave resonator whose resonance frequency can thus be modified by a gate voltage. It will especially focus on the critical current engineering which is directly related to the non-linearity of the system. One might want especially high critical current for some applications. We investigated the use of Ti/Al contacts on graphene as well as MoGe.

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Superradiant Quantum Phase transition in Rashba and Zeeman Cavity QED

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In cavity quantum electrodynamics (QED), the interaction between an atomic transition and the cavity field is measured by the vacuum Rabi frequency Ω_0. The regime with Ω_0 comparable to the two-level transition frequency is called the ultrastrong coupling regime. In such a regime, and for a large number of atoms coupled to the same cavity mode, a superradiant quantum phase transitions (SQPT) has been predicted, e.g. within the Dicke model, which is one of the paradigmatic models of cavity quantum electrodynamics[1].
This necessary large value of Ω_0 has been reached in the last five years in somesystems, such as superconducting circuits and Landau polaritons [2,3]. The latter ones, are the ones on which we are focusing. In fact, very recently, in our laboratory LPMMC (CNRS-UGA) Grenoble, my thesis directors Pierre Nataf, Thierry Champel and Denis Basko have discovered that the Rashba spinorbitcoupling could allow the Landau polaritons, which are a mixed system made of a two-dimensionalelectron gas under a perpendicular magnetic field and the photons of a resonating cavity, to undergo thesuperradiant transition [4].We now want to develop this new topic by studying the conditions of occurence of thesuperradiant phase in Landau polaritons by studying theoretically some possible additional physical ingredients,and we have started to do so by studying the impact of Zeeman coupling.

Bibliography:

C. Emary and T. Brandes, PRE, 67, 066203 (2003).

D. Hagenmüller, S. De Liberato, and C. Ciuti, PRB, 81, 235303 (2010).

G. Scalari et al., Science, 335, 1323 (2012).

P. Nataf, T. Champel, G. Blatter, and D. M. Basko, Phys. Rev. Lett. 123, 207402 (2019).

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Superradiant Quantum Phase transition in Rashba and Zeeman Cavity QED

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Bibliography:

C. Emary and T. Brandes, PRE, 67, 066203 (2003).

D. Hagenmüller, S. De Liberato, and C. Ciuti, PRB, 81, 235303 (2010).

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P. Nataf, T. Champel, G. Blatter, and D. M. Basko, Phys. Rev. Lett. 123, 207402 (2019).

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Probing the Density of States in Low Dimensional Electronic Systems

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The density of states of low dimensional systems has characteristic singularities that directly affects their quantum capacitance. We will show how the quantum capacitance in two-dimensional electron gas (2DEG) structures can be measured through the dispersive shift of an LC resonator. I will then present a first result of a 1D system, where a quantum point contact formed using split gates in a GaAs 2DEG exhibits Van Hove singularities [1]. Secondly, I will show how the spin-dependent compressibility of a double quantum dot in Silicon can be measured in single shot [2].

Both results were obtained during my postdoc at the University of Sydney (2018-2020).

M. C. Jarratt, A. Jouan, A. C. Mahoney, S. J. Waddy, G. C. Gardner, S. Fallahi, M. J. Manfra, and D. J. Reilly *Dispersive Gate Sensing the Quantum Capacitance of a Point Contact,* arxiv 1903.07793 (2019)

A. West, B. Hensen, A. Jouan, T. Tanttu, C.H. Yang, A. Rossi, M.F. Gonzalez-Zalba, F.E. Hudson, A. Morello, D.J. Reilly, and A.S. Dzurak *Gate-based single-shot readout of spins in silicon*, Nature Nanotechnology (2019)

*Intervenant

Multiplexed photon number measurement using a superconducting qubit

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The evolution of quantum systems under measurement is a central aspect of quantum mechanics. Decades of experimental progress have enabled the observation of the inner dynamics of a quantum measurement and the determination of the number of bits of information it reveals [1,2,3].
When a two level system – a qubit – is used as a probe of a larger system, it naturally leads to answering a single yes-no question about the system state followed by its corresponding quantum collapse. Each measurement thus reveals at most one bit of information. Is it possible to lift this constraint by not using the qubit as an ancilla?
Here we report an experiment where more than 3 bits of information about the photon number in a microwave resonator are simultaneously recorded by a superconducting qubit into 9 propagating modes of a transmission line. This recording occurs by exciting these 9 modes using multiplexed spectroscopy owing to the dependence of the qubit frequency on photon number [4,5]. We demonstrate the simultaneous acquisition of microwave signals emitted by the qubit into the nine propagating modes that each reveals information about a photon number from 0 to 8, enabled by the large bandwidth of present near quantum limited amplifiers [9]. Further observing the multiplexed measurement back-action on the resonator allowed us to evidence an optimal qubit drive amplitude for information extraction. Our experiment unleashes the full potential of quantum meters by bringing the measurement process in the frequency domain. It extends the reach of simultaneous probing of a single qubit by multiple observers [6,7] to arbitrary systems such as our resonator. This concept can be applied to improve or renew quantum

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control based on measurement [8] with possible applications in quantum error correction and sensing.

: Guerlin, C.et al. Progressive field-state collapse and quantum non-demolition photoncounting. Nature 448, 889–93 (2007).

: Murch, K. W., Weber, S. J., Macklin, C. & Siddiqi, I. Observing single quantum trajectories of a superconducting quantum bit. Nature 502, 211–214 (2013)

: Minev, Z. K.et al. To catch and reverse a quantum jump mid-flight. Nature (2019)

: Schuster, D. I.et al. Resolving photon number states in a superconducting circuit. Nature 445,515–518 (2007)

: Gely, M. F.et al. Observation and stabilization of photonic Fock states in a hot radio-frequency resonator. Science 363, 1072–1075 (2019)

: Hacohen-Gourgy, S.et al. Dynamics of simultaneously measured non-commuting observables. Nature 538, 491 (2016)

: Ficheux, Q., Jezouin, S., Leghtas, Z. & Huard, B. Dynamics of a qubit while simultaneously monitoring its relaxation and dephasing. Nature Communications 9, 1926 (2018)

: Wiseman, H. M. & Milburn, G. J. Quantum Measurement and Control (Cambridge University Press, 2009)

: Macklin, C.et al. A near – quantum-limited Josephson traveling-wave parametric amplifier. Science 350, 307 (2015)

1,2,3...many photons emitted by a Josephson junction strongly coupled to a microwave resonator

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Two photon emission processes are at the heart of many quantum information with continuous variables experiment. Although multiphoton processes could in principle be interesting, the weak non linearity of optical media makes them hard to observe. Circuit quantum electrodynamics offers a platform to engineer and increase the light-matter coupling, allowing the observation of three-photon processes. In the case of a Josephson junction biased at a voltage V and coupled to a single mode of frequency nu_0, the relative magnitude of the multiphoton processes is governed by r, the ratio of the impedance of the mode to the resistance quantum which thus plays the role of the fine structure constant. In this system, photon emission is triggered by the inelastic tunneling of a Cooper pair through the junction: the work provided by the DC bias voltage source is converted in k photons when the resonance condition 2eV=khnu_0.
We have developed a technique to produce high impedance lumped element microwave resonators allowing us to reach r = 1. This makes it possible to observe processes where the inelastic tunneling of a single Cooper pair through the junction is associated to the emission of up to 6 photons. These multiphoton processes yield to a strong bunching of the emitted photons, which we characterize by their second order coherence function and Fano factors.

*Intervenant

Spin qubits in CMOS quantum dots

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Silicon-based qubits are particularly attractive in view of the possibility to leverage the well-established engineering and integration capabilities of microelectronics technology. This represents an asset in terms of upscaling potential, since fault-tolerant surface-code architectures are expected to include millions of physical qubits, individually addressed by classical circuitry for initialization, manipulation and readout. However, while one and two-qubit gates have been achieved in silicon devices fabricated in academic facilities, such realization on a foundry-compatible platform is still lacking. In this presentation, we will show how we form good quality quantum dot using CMOS transistors out of a 300 mm fab line. We then investigate how we can manipulate and readout spins in such structure. In particular, we focus on gate-based reflectometry which offers two different approach: dispersive readout and charge sensing. By exploiting these two methods we investigate the different spin configurations and dynamics in a double quantum dot and their single shot readout. We obtain fidelity above 98% for 100 us integration time. Moreover, the demonstrated high read-out fidelity is fully preserved up to 0.5 K. This results holds particular relevance for the future co-integration of spin qubits and classical control electronics.

*Intervenant

Mesoscopic QED: from atomic-like systems to condensed matter

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Circuit QED techniques have turned out to be instrumental to probe or manipulate coherently two level systems based on superconducting circuits [1]. In the last decade, this approach was generalized to hybrid mesoscopic circuits which combine nanoconductors and fermionic reservoirs [2, 3]. This Mesoscopic QED architecture is appealing since new degrees of can be used in the context of cavity QED. In this tutorial, I will explain how to describe a Mesoscopic QED setup. Then, I will review recent experiments in which cavity photons are coupled to a single charge [4, 5, 6] or a single spin [7, 8, 9, 10] or more complex degrees of freedom. Finally, mesoscopic circuits are model systems for quantum transport and condensed matter phenomena, due to the presence of fermionic reservoirs. I will discuss various experiments which reveal the rich dissipative tunneling dynamics between quantum dots and reservoirs [11, 12]. I will also show how dissipative tunneling in mesoscopic circuits could be exploited to modify non-trivially the cavity state [13].

A. Wallraff et al., Nature (London) 431, 162 (2004).

Delbecq et al, Phys. Rev. Lett. **107**, 256804 (2011).

Frey et al, Phys. Rev. Lett. **108**, 046807 (2012).

Mi et al., Science **355** 156 (2017)

Stockklauser et al. Phys. Rev. X **7**, 011030 (2017)

Bruhat et al. Phys. Rev. B 98, 155313 (2018).

Viennot, Dartiailh, Cottet, and Kontos, Science **349**, 408 (2015).

Mi, Benito, Putz, Zajac, Taylor, Burkard, Petta,, Nature 555, 599 (2018)

Landig et al., Nature 560, 179 (2018).

Samkharadze et al., Science 2018

L.E. Bruhat et al., Phys. Rev. X, 6, 021014 (2016).

M. M. Desjardins et al. Nature 545, 71 (2017)

A. Cottet, Z. Leghtas and T. Kontos, Phys. Rev. B 102, 155105 (2020)

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Ultrafast charging in a two-photon Dicke quantum battery

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We consider a collection of two level systems embedded into a microwave cavity as a promising candidate for the realization of high power quantum batteries. In this perspective, the possibility to design devices where the conventional single-photon coupling is suppressed and the dominant interaction is mediated by two-photon processes is investigated, opening the way to an even further enhancement of the charging performance. By solving a Dicke model with both single- and two-photon coupling we determine the range of parameters where the latter unconventional interaction dominates the dynamics of the system leading to better performances both in the charging times and average charging power of the QB compared to the single-photon case. In addition, it is found that the scaling of the charging power with the finite number of qubits N shows a quadratic growth leading to a relevant improvement of the charging performance of quantum batteries based on this scheme with respect to the purely single-photon coupling case.

Reference:

A. Crescente, M. Carrega, M. Sassetti, D. Ferraro, arXiv:2009.09791

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Squeezing of edge_magnetoplasmon states in Quantum Hall edge channels

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In quantum Hall conductors, charge excitations propagate ballistically along chiral one dimensional waveguide at the edge of the sample. These edge channels have been used to propagate non-classical fermionic states of matter by manipulating electron wavefunctions in electronic interferometers for example. However, one dimensional charge propagation can also be described in terms of bosonic collective excitations called edge magneto_plasmon (EMP). So far, most of the works have focused on the classical description of these waves [ref ?]. The tools of quantum electronics, such as the quantum point contact (QPC), allow for the generation of non-classical EMP states such as squeezed states. In that study, we show that the partitioning of a high frequency (few GHz) AC signal on top of a DC voltage can be used to generate squeezed EMP states, in analogy with a previous experiment performed on tunnel junctions [1].

This technique opens the possibility to generate non-classical bosonic states in a very high impedance transmission line, with a strong coupling to the mesoscopic systems.

G. Gasse, C. Lupien, and B. Reulet, Phys. Rev. Lett. 111, 136601 (2013).

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Systèmes 2D

Guiding Dirac Fermions in Graphene with a Carbon Nanotube

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Relativistic massless charged particles in a two-dimensional conductor can be guided by a one-dimensional electrostatic potential, in an analogous manner to light guided by an optical fiber. In this seminar, I will present how we use a carbon nanotube to generate such a guiding potential in graphene and create a single mode electronic waveguide. In our architecture, the nanotube and graphene are separated by a few nanometers and can be controlled and measured independently. As we charge the nanotube close to the surface of graphene, we observe in the latter the formation of a single guided mode that we detect using the same nanotube as a probe [1].
I will discuss why the small dimensions of the nanotube and the linear dispersion relation of Dirac fermions gives these electronic waveguides promising characteristics for potential applications.

I will also show that, in presence of magnetic field, our electronic waveguides host discrete electronic levels resembling Landau levels of 2D Dirac particles but with no C-symmetric counterpart, i.e. they exist only for one sign of energy, positive or negative, depending on the voltage applied on the nanotube. This unusual behavior is a generic signature of Dirac surface states, which are predicted to be protected to a great extent to surface disorder.
Austin Cheng, Takashi Taniguchi, Kenji Watanabe, Philip Kim, and Jean-Damien Pillet Phys. Rev. Lett. 123, 216804 (2019)

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Demonstration of PdSe2 van der Waals MISFETs

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PdSe2 is a (nobel) transition-metal dichalcogenide (group 10 TMD). Its buckled structure gives rise to interlayer coupling resulting in a strong bandgap suppression in few-layer and bulk crystals. Its excellent air stability, low bandgap and high electron mobility predispose PdSe2 transistors for fast IR optoelectronics. Here we report on DC transport and microwave compressibility in few-layer and semi-bulk field-effect PdSe2-hBN-metal transistors (FETs), made of exfoliated high-quality PdSe2 crystals (chemical doping < 10^17 cm^-3) and equipped with low Schottky-barrier Pd contacts. On comparing thin and thick devices, we demonstrate the metal-insulator-semiconductor (MISFET) behaviour of semi-bulk devices including the characteristic inversion, depletion and accumulation regimes. We find a depletion length of 15nm, and electron/hole mobility of 110/40 cm2/Vs. Thermal activation study of the Schottky-barriers (valence and conduction bands) and of the depletion resistance provide independent and consistent estimates of the bulk band gap of 0.2 eV. The PdSe2-FETs and PdSe2-MISFETs sustain large currents limited by velocity saturation in the FET geometry and self-heating activated bulk transport in the MISFET one.

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Fractional statistics of anyons in a mesoscopic collider

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In three-dimensional space, elementary particles are divided between fermions and bosons according to the properties of symmetry of the wave function describing the state of the system when two particles are exchanged. When exchanging two fermions, the wave function acquires a phase, phi=pi. On the other hand, in the case of bosons, this phase is zero, phi=0. This difference leads to deeply distinct collective behaviors between fermions, which tend to exclude themselves, and bosons which tend to bunch together. The situation is different in two-dimensional systems which can host exotic quasiparticles, called anyons, which obey intermediate quantum statistics characterized by a phase phi varying between 0 and pi [1,2].
For example in the fractional quantum Hall regime, obtained by applying a strong magnetic field perpendicular to a two-dimensional electron gas, elementary excitations carry a fractional charge [3,4] and have been predicted to obey fractional statistics [1,2] with an exchange phase phi=pi/m (where m is an odd integer). I will present how fractional statistics of anyons can be demonstrated in this system by implementing and studying anyon collisions at a beam-splitter [5]. The collisions are first studied in the low magnetic field regime, where the elementary excitations are electrons which obey the usual fermionic statistics. It leads to the observation of an antibunching effect in an electron collision: electrons systematically exit in two different arms of the beam-splitter. The observed result is completely different in the fractional quantum Hall regime. Fractional statistics leads to a suppression of the antibunching effect and quasiparticles tend to bunch together in larger packets of charge in a single output of the splitter. This effect leads to the observation of negative correlations of the current fluctuations [5] in perfect agreement with recent theoretical predictions [6].

B. I. Halperin, Phys. Rev. Lett. **52**, 1583–1586 (1984).

D. Arovas, J. R. Schrieffer, F. Wilczek, Phys. Rev. Lett. **53**, 722–723 (1984).

R. de Picciotto et al., Nature **389**, 162–164 (1997).

L. Saminadayar, D. C. Glattli, Y. Jin, B. Etienne, Phys. Rev. Lett. **79**, 2526–2529 (1997)

H. Bartolomei et al. Science **368**, 173-177 (2020).

B. Rosenow, I. P. Levkivskyi, B. I. Halperin, Phys. Rev. Lett. **116**, 156802 (2016).

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Thermal transport in quantum Hall states in graphene

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While electronic transport has been widely used to understand the properties of mesoscopic systems, thermal transport in the same systems is much less understood due to the more involved setup that is needed to measure it. Thermal transport can not only be due to electrons, but also to charge-less collective modes. This reveals new phenomena (e.g. heat Coulomb blockade [1]) and may be of great use to understand electrically insulating correlated states where electronic transport is absent. Our aim is to investigate thermal transport in graphene, particularly in the nu=0 state of the quantum Hall effect, which stems from the interplay between spin and valley symmetries and electronic interactions. While this state is electrically insulating, its thermal conductance is expected to be non-zero, and to reflect the various possible phases describing nu=0, which correspond to different spin & valley polarization configurations [2]. To this end, we designed an experiment in which the thermal conductance is obtained from the monitoring of the temperature of floating metallic islands connected to the graphene sample. Following an approach developed in [3], we obtain the thermal conductance of the sample by extracting the temperature of the metallic islands through Johnson-Nyquist noise measurements, and by equilibrating Joule heating in the islands with cooling down through well-defined channels provided by the quantum Hall effect. We present preliminary experiments testing different approaches to defining the floating metallic islands, such as generating locally highly doped regions in the graphene sample with a combination of electrostatic gates embedded in a van der Waals heterostructures. [1] Sivré et al. Nat. Phys. **14,** 145 (2018) [2] Pientka et al., Phys. Rev. Lett. **119,** 027601 (2017) [3] Jezouin et al., Science **342,** 601-604 (2013)

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A tunable Fabry-Pérot quantum Hall interferometer in graphene

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Electron interferometry with quantum Hall edge channels holds promise to probe and harness exotic exchange statistics of anyons. In semiconductor heterostructures, however, quantum Hall interferometry has proven challenging and often obscured by charging effects. In this talk, I will show that high-mobility monolayer graphene equipped with a series of gate-tunable quantum point contacts provides a model system to perform Fabry-Pérot quantum Hall interferometry. In the integer quantum Hall regime, we observe high-visibility Aharonov-Bohm interference free of charging effects and widely tunable through electrostatic gating or magnetic field in remarkable agreement with theory. I will also show that a coherence length of 10 μm allows us to further achieve coherently-coupled double Fabry-Pérot interferometry, as envisioned in braiding schemes of non-Abelian anyons.

Reference: arXiv:2008.11222

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Investigating Ising and Triplet Superconductivity in few-monolayer NbSe2

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We perform a spectroscopic study of NbSe2 superconducting flakes of different thicknesses from bilayer to 25 monolayers using van der Waals tunnel junctions, measuring the quasiparticle density of states as a function of the applied in-plane magnetic field up to 33T. Few-monolayer NbSe2 has a density of states which is well-described by a single band superconductor model. In addition, due to the thinness of the device, the magnetic field acts only on the electron spin degree of freedom, and not its orbit. At low fields, superconductivity is protected by Ising spin-orbit coupling and the energy gap, which we extract from the tunnelling spectra, behaves largely as predicted for Ising-protected superconductors as a function of magnetic field. However, close to the critical field (as high as 30T bilayers, much larger than the Pauli limit), superconductivity appears to be more robust than expected. This could be explained by a subdominant equal spin, even-frequency triplet order parameter coupled to the singlet order parameter. Indeed, recent calculations indicate such field-induced singlet-triplet mixing in NbSe2.

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Signature of Landau Band Coupling in higher order Fractal Energy Spectrum

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The energy spectrum of a two-dimensional electron gas, simultaneously subjected to a perpendicular homogenous magnetic field and a periodic potential with a triangular lattice of antidots is composed of Landau bands with subbands and minigaps. We present significant advances by quantum Hall transport as a tool for investigating Hofstadter butterfly-like energy spectrum. The development in fabrication procedures for creating a short period of antidots (a= 35nm) with minimal consequences on the mobility offer access to the regime of high order minigaps. The Hall conductance in minigaps is quantized, which allows differentiating minigaps and prove to be more sensitive than longitudinal resistivity. We observed the complex behavior of Hall conductance in high order minigaps which we interpret as Landau band-coupling induced by the periodic lattice.

*Intervenant

Robust electronic states due to inhomogeneous spin-orbit couplings in graphene heterostructure

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Robust electronic states due to inhomogeneous spin-orbit couplings in graphene heterostructure Recent experimental progress in designing electronic states in layered heterostructures raises questions about inducing topological states in inhomogeneous systems. In particular, we investigate numerically and analytically several types of inhomogeneous spin-orbit coupling terms in graphene. We begin by studying domain walls in Kane-Mele spin-orbit coupling, addressing the robustness of gapless helical electronic modes and the emergence of gapped Landau-level-like modes bound to the domain wall. Our numerical analysis shows that the domain-wall modes are gapped by Rashba spin-orbit coupling of any strength, even while the Kane-Mele topological bulkgap remains open. The domain-wall states are also gapped by randomness in the Kane-Mele term even without breaking the conserved spin component.

On the other hand, the combination of homogeneous Valley-Zeeman and Rashba types of spin-orbit coupling also opens a bulkgap, which is not topological as in the case of Kane-Mele coupling. Nevertheless, we find that should one of these two spin-terms have a sign-changing domain wall, it binds electronic modes which are robust to inclusion of the competing Kane-Mele term, as long as the bulkgap remains open.

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Negative Delta-T Noise in the Fractional Quantum Hall Effect

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We study the current correlations of fractional quantum Hall edges at the output of a quantum point contact subjected to a temperature gradient. This out-of-equilibrium situation gives rise to a form of temperature-activated shot noise, dubbed delta-T noise. We show that the tunneling of Laughlin quasiparticles leads to a negative delta-T noise, in stark contrast with electron tunneling. Moreover, varying the transmission of the quantum point contact or applying a voltage bias across the Hall bar may flip the sign of this noise contribution, yielding signatures that can be accessed experimentally.

*Intervenant

Experimental detection of graphene's singular orbital diamagnetism at the Dirac point.

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The electronic properties of Graphene have been intensively investigated over the last decade, and signatures of the remarkable features of its Dirac spectrum have been displayed using transport and spectroscopy experiments. In contrast, the orbital magnetism of graphene, which is probably the most fundamental signature of graphene's characteristic Berry phase, has not yet been measured at the level of a single flake. In particular, the striking prediction of a divergent diamagnetic response at zero doping calls for an experimental test.
Using a highly sensitive Giant Magnetoresistance sensor (GMR) we have measured the gate voltage-dependent magnetisation of a single graphene flake encapsulated between boron nitride (BN) crystals. The signal exhibits a diamagnetic peak at the Dirac point whose magnetic field and temperature dependences agree with theoretical predictions starting from the work of McClure in 1956 [1]. Our measurements open a new field of investigation of orbital currents in graphene and 2D topological materials, providing a new means of monitoring Berry phase singularities and exploring correlated states generated by combined effects of Coulomb interactions strain or Moiré potentials.
McClure, J. W., Physical Review, 104(3), 666, 1956.

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Scanning gate microscopy of a pn junction in graphene

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We report on a scanning gate microscopy (SGM) experiment that provides spatial information on the position of the backscattering between chiral quantum Hall edge states in a high-mobility graphene Hall bar. The electrically polarized tip of the microscope allows local manipulation of edge states, promoting tunnelling of charge carriers between the counter-propagating modes, either directly or trough localized quantum Hall islands. This disorder-induced tip-mediated backscattering is revealed by deviations from the zero longitudinal resistance, as observed in narrow mesoscopic Hall bars. We identify a series of concentric arcs which are typical of charge resonances through a percolative state gated by the tip. The diamond-shaped stability diagrams recorded at finite source-drain bias allow us to demonstrate the key-role of Coulomb blockade in the backscattering process through a disordered potential landscape.

*Intervenant

Transport quantique d'électrons et de chaleur

Influence de l'anomalie chirale sur le transport non-local des semi-métaux de Weyl

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La propagation des électrons à l'interface entre deux milieux est semblable à la réfraction de la lumière, où la trajectoire des rayons lumineux minimise le chemin optique. A la fin des années 1960, Veselago montre que l'indice optique, qui apparaît dans l'expression du chemin optique, peut être négatif et ouvre ainsi la voie à de nouvelles techniques d'imagerie, dont la précision peut dépasser les limites imposées par la diffraction. Dans le cas des électrons de Dirac, il existe un phénomène analogue et qui s'observe dans la configuration d'effet tunnel de Klein. Ce phénomène a en grande partie été étudié dans le cas des semi-métaux de Dirac bidimensionnels, tels que le graphène, et nous l'étudions dans le cas de leur équivalent tridimensionnel. Au contraire du cas bidimensionnel, il est possible d'altérer différemment le potentiel chimique des cônes d'un semi-métal de Weyl en présence d'un champ magnétique, grâce à l'anomalie chirale. Ce qui peut permettre de manipuler indépendamment des cônes de chiralités opposées.

Avec ce poster, je discute de l'effet de lentille de Veselago et de la façon dont il se transpose au cas des semi-métaux de Weyl. Je présente aussi nos travaux sur le calcul des oscillations de Friedel et de la conductivité non-locale en présence de l'effet de lentille de Veselago. Ces réponses peuvent être altérées par la diffusion par les impuretés, par l'extension de l'interface et par la présence d'un champ magnétique. En particulier, je discute de nos progrès concernant l'étude de l'influence de l'anomalie chirale sur la conductivité non-locale des semi-métaux de Weyl.

*Intervenant

Electric field control of photonic heat transport in a superconducting circuit

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Very few experiments probe quantum heat transport by photons, and all are made difficult by the forbidding use of a magnetic field to control heat flows [1,2]. Here we present a magnetic field-free circuit where charge quantization in a superconducting island enables thorough electric field control [3]. We thus tune the thermal conductance, close to its quantum limit, of a single photonic channel between two mesoscopic reservoirs. We observe heat flow oscillations originating from the competition between Cooper-pair tunnelling and Coulomb repulsion in the island, well captured by a simple model. Our results highlight the consequences of charge-phase conjugation on heat transport, with promising applications in thermal management of quantum devices and design of microbolometers. In addition, preliminary results indicate that the use of ultrasmall Josephson junctions coupled to high-impedance thermal baths leads to non-trivial thermal conduction mechanisms due to the bath back-acting on the junctions, providing an example of quantum thermal transport in strongly coupled systems.

M. Meschke et al., Nature **444**, 187–190 (2006)

A. Ronzani et al., Nat. Phys.**14**, 991–995 (2018)

O. Maillet et al., Nat. Commun. **11**, 4326 (2020)

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Quantum Quasi-Monte Carlo

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Quantum dots coupled to leads can contain different phenomena. At low interaction strength, Fabry-Perot interference is well described with a non-interacting quantum transport theory. In the opposite regime, at strong interaction, Coulomb blockade is explained with a semi-classical theory. At intermediate interaction strength, fast, controlled and high precision theoretical method are lacking despite interesting phenomena, namely the Kondo effect.

In this talk, I will present our approach to this challenge [2]. It is based on the diagrammatic quantum Monte Carlo method (DiagQMC), where one systematically integrates all possible Feynman diagrams up to a given order. Precision of the result and the maximum interaction strength are limited by the number and precision of calculated orders. Advancements in DiagQMC have enabled precise calculations even at large orders [1].

Yet, DiagQMC remains plagued by slow integration. We drop the Markov chain Monte Carlo method and switch to quasi-Monte Carlo method, which promises faster integration. For this, a good approximation of the integrand is necessary. I will present how we can build such approximation in an automated way. We observed a speed-up of more than four orders of magnitude in favourable regimes [2]. For a quantum dot coupled to leads out of equilibrium, we were now able to perform large parameter sweeps for current on the quantum dot and study the system outside of the quantum dot.

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Spectroscopy of the many-body ground states of the graphene zeroth Landau level

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Charge neutral graphene develops a quantum Hall topological insulator phase when the Coulomb potential is screened by a high-k dielectric environment. This phase features spin-filtered helical edge channels and exhibits the quantum spin Hall effect, which are of high interest for spintronics and topological superconductivity. In this work we present STM spectroscopy performed on high-mobility graphene devices with a home-made hybrid AFM-STM operating at 4 K and up to 14 T. Using SrTiO3 high-k dielectric as a substrate, we screen the long-range Coulomb interaction and induce the quantum Hall topological insulator phase in the zeroth Landau level of graphene. The interaction-induced gap at half filling of the zeroth Landau level is measured as a function of magnetic field in both unscreened and substrate-screened graphene. We also show that the ground-state of the zeroth Landau level in unscreened graphene is a Kekulé distortion, while the topological insulator phase induced by the substrate-screening is ferromagnetic. Last, we present the evolution of the density of states upon approaching the graphene edges.

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Heat conductance of a single quantum dot junction

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Single electron devices are an attractive model system for basic studies and applications in thermoelectricity, owing to their tunable electronic transmission and electron-hole asymmetry [1].

In quantum dot (QD) junctions, which involve transport through a single quantum level, we demonstrate gate control of electronic heat flow in the presence of cotunneling. Electron temperature maps taken in the immediate vicinity of the junction, as a function of the gate and bias voltages applied to the device, reveal clearly defined Coulomb diamond structures. We observe a maximum heat conductance right at the charge degeneracy point, in agreement with the numerical calculations [2]. Recently, we have combined measurements of the gate-modulated charge and heat conductances through a QD junction. This allows a quantitative test of the Wiedemann-Franz law in the presence of strong cotunneling effects to the contacts [3].

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Quantum ammeter: Measuring full counting statistics of electron currents at quantum timescales

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We present the theoretical model of the quantum ammeter, a device that is able to measure the full counting statistics of an electron current at quantum timescales. It consists of an Ohmic contact perfectly coupled to chiral quantum Hall channels and of a quantum dot attached to one of the outgoing channels. At energies small compared to its charging energy, the Ohmic contact fractionalizes each incoming electron and redistributes it between outgoing channels. By monitoring the resonant tunneling current through the quantum dot, one gets access to the moment generator of the current in one of the incoming channels at timescales comparable to its correlation time. E. G. Idrisov, I. P. Levkivskyi, and E. V. Sukhorukov, Phys. Rev. B 101, 245426 (2020)

*Intervenant

Coulomb blockade of heat, noise and electricity in a temperature-biased quantum channel

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The transport properties of quantum conductors can strongly change when embedded in an on-chip mesoscopic circuit. At the heart of this phenomenon is the Coulomb energy required to change the charge in small interconnect nodes of the circuit. Up to now, the main body of experimental studies have focused on the suppression of the electrical conductance of tunnel junctions with all parts of the circuit at the same temperature. Here, I will present an investigation of the flow of heat [1,2], the shot noise [2] and the electrical conductance [3] across a temperature biased electronic quantum channel of arbitrary transmission probability.

'Heat Coulomb blockade of one ballistic channel'. E. Sivre *et al.*, Nat. Phys. **14**, 145 (2018).

'Electronic heat flow and thermal shot noise in quantum circuits'. E. Sivre *et al.*, Nat. Commun. **10**, 5638 (2019).

'Dynamical Coulomb blockade under a temperature bias'. H. Duprez *et al.*, in preparation.

*Intervenant

A wavefront dislocation reveals the topological index of an insulator

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In 1974, John Nye and Michael Berry discovered a fundamental wave phenomenon: The surfaces of constant phase may exhibit *wavefront dislocations*. The dislocation source is a phase singularity in the wavefield and does not depend on any wave equation. Wavefront dislocations are then ubiquitous, from the physics of tides and sound to electromagnetism and singular optics. Singularities in the phase of wave functions are also at the heart of the topological classification of insulators in condensed matter physics. Despite identical singular features, topological insulators and singular waves have remained two distinct fields. I will present an experiment emulating a 1D insulator with dielectric resonators inside a microwave cavity [1]. When the system undergoes a topological phase transition, local fluctuations of the bulk density of states reveal a wavefront dislocation. I will show that the change in the number of interference fringes at the transition is a direct measurement of the topological index that characterizes the bulk states. Combining such a bulk-state measurement to the standard resolution of midgap edge states ultimately enables the experimental demonstration of the bulk-boundary correspondence.
C. Dutreix, M. Bellec, P. Delplace, and F. Mortessagne, arXiv:2006.08556

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GDR MESO Réunion Plénière 23 au 26 novembre 2020

Posters

Qubits hybrides, semiconducteurs et électrodynamique quantique

(1)- 1,2,3...many photons emitted by a Josephson junction strongly coupled to a microwave resonator
Gerbold Ménard, Iouri Mukharsky, Ambroise Peugeot, Chloé Rolland, Denis Vion, Philippe Joyez, Patrice Roche, Daniel Esteve, Carles Altimiras, Fabien Portier

(2)-Graphene based quantum superconducting circuits
Guilliam Butseraen, François Lefloch, Julien Renard

(3)-Multiplexed photon number measurement using a superconducting qubit
Antoine Essig, Quentin Ficheux, Théau Peronnin, Nathanael Cottet, Raphaël Lescanne, Alain Sarlette, Pierre Rouchon, Zaki Leghtas, Benjamin Huard

(4)-Squeezing of edge_magnetoplasmon states in Quantum Hall edge channels
Hugo Bartolomei, Rémi Bisognin, Erwann Bocquillon, Antonella Cavanna, Ulf Gennser, Yong Jin, Jean-Marc Berroir, Bernard Plaçais, Gwendal Feve

(5)-Superradiant Quantum Phase transition in Rashba and Zeeman Cavity QED
Guillaume Manzanares

(6)-Ultrafast charging in a two-photon Dicke quantum battery
Alba Crescente

Transport, transfert d’énergie, réactivité chimique en cavité plasmonique

(7)-Collisional interferometry of levitons in quantum Hall edge channels at $\nu=2$
Giacomo Rebora, Matteo Acciai, Dario Ferraro, Maura Sassetti

(8)-Ferromagnetic instability in ensembles of gold nanoparticles
Gaetan Percebois

(9)-Heat Conductance in a Quasi-ballistic InAs Nanowire
danial MAJIDI, Mukesh Kumar, Lars Samuelson, Herve Courtois, Clemens Winkelmann, Ville F. Maisi

(10)-Polaritons in periodic chains of metallic nanoparticles: a QED approach
Thomas Allard

Systèmes 2D

(11)-Demonstration of PdSe2 van der Waals MISFETs
Romaric Le Goff, Zheng Liu, Takashi Taniguchi, Kenji Watanabe, Christophe Voisin, Jean-Marc Berroir, Erwann Bocquillon, Gwendal Fève, Jean Chazelas, Emmanuel Baudin, Bernard Placais

(12)-Investigating Ising and Triplet Superconductivity in few-monolayer NbSe2
Marko Kuzmanović, Tom Dvir, David Möckli, Stefan Ilić, Julia Meyer, Manuel Houzet, Marco Aprili, Maxim Khodas, Hadar Steinberg, Charis Quay

(13)-Robust electronic states due to inhomogeneous spin-orbit couplings in graphene heterostructure
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(14)-Scanning gate microscopy of a pn junction in graphene
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Transport quantique d'électrons et de chaleur

(16)-Electric field control of photonic heat transport in a superconducting circuit
Olivier Maillet, Diego Subero, Joonas Peltonen, Dmitry Golubev, Jukka Pekola

(17)-Influence de l'anomalie chirale sur le transport non-local des semi-métaux de Weyl
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Supraconductivité mésoscopique, Qubits hybrides, semiconducteurs et électrodynamique quantique

(18)-Implementing low-impedance resonators resilient to magnetic field and dielectric losses for nanoscale paramagnetic resonance detection
Arne Bahr, benjamin huard, Audrey Bienfait

(19)-Robust supercurrent in graphene Josephson junctions assisted by strong spin-orbit interaction
NianJheng WU, Taro Wakamura

(20)-Transconductance quantization in a topological Josephson tunnel junction circuit
Léo Peyruchat, Joël Griesmar, Jean-Damien Pillet, Çağlar Girit

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Montambaux Gilles
Moukharski Iouri
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Rafsanjani Amin Kazi
Rebora Giacomo
Rech Jérôme
Renard Julien
Renard Vincent
Ribeiro Rebeca
Roch Nicolas
Roche Patrice
Rodriguez Ramiro
Sacépé Benjamin
Safi Ines
Saminadayar Laurent
Schiro Marco
Schmitt Vivien
Schopfer Félicien
Schull guillaume
Sellier Hermann
Seurre Kévin
Simon Pascal
Stanisavljevic Ognjen
Taktak Imen
Tarento René-Jean
Tchoumakov Sergueï
Tommaso
Touchais Jean-Baptiste
Trastoy Juan
Urbina
Urdampilleta Matias
Vallejo Bustamante
Velluire Pellat Zoe
Vethaak Tom
Vignaud
Vincent Estelle
Waintal Xavier
Weick Guillaume
Weinmann Dietmar
Whitney Robert
Winkelmann Clemens
Wu NianJheng
Yang
Yu Cécile