Master2 Internship proposal at CPT

Research team:

GPS

Supervisor:

Oleg Ogievetsky

e-mail:

oleg@cpt.univ-mrs.fr

Project title:

Weyl groups and shuffles

Description:

Shuffle elements appear in many applications of the Weyl group of the general Lie group (problems of sorting, symmetrization of tensors, vanishing of certain cohomology classes, multiple zeta-values etc.) The aim of the project is to introduce shuffle elements for other Weyl groups as well as their q-deformations, and analyze the properties of these shuffle elements, in particular, the spectrum and multiplicities of eigenvalues.

References:

P. Diaconis, J. A. Fill and J. Pitman, *Analysis of top to random shuffles*, Combin. Probab. Comput. **1** no. 2 (1992) 135.
N. R. Wallach, *Lie algebra cohomology and holomorphic continuation of generalized Jacquet integrals*, Representations of Lie groups, Kyoto, Hiroshima, 1986; Adv. Stud. Pure Math. **14** 123; Academic Press, Boston, MA, 1988.
A. P. Isaev and O. V. Ogievetsky, Braids, shuffles and symmetrizers. J. Phys. A: Math. Theor. **42** (2009) 1–15.

Duration:

16 weeks

Any self-financial support? *(if longer than 2 months)*

No

Specify whether the internship project may naturally lead to a PhD thesis.

Yes

Master2 Internship proposal at CPT

Research team: Dynamical Systems: Theory and applications

Supervisor: Xavier Leoncini

e-mail: Xavier.Leoncini@cpt.univ-mrs.fr

Project title: Dynamics and allocations on networks

Description:

This internship will mostly concerns two different exploratory research apsects of dynamics on or of networks. One aspect will be concerned mainly with the different dynamical regimes that a growing network subject to ressources allocations can display. The main objective of this aspect of internship is to study the dynamics with growth, plasiticity, degradatation of tree like networks. These type of networks appear in various domains such as biology (trachéo-bronchitus tree, corals, plants), geologie (river networks for instance), or man made (Water distribution networks, sewage collection). Despite great differences in the nature of the phenomena and their scale these networks posses common characteristics. Beyond their tree like nature, meaning that no loops exist, these network can grow or be damaged through time. This growth and damage dynamics lead to numerous interesting questions : What is the cost/benefit ratio to increase the size of the network? How do we define the notion of optimal network when it is growing, when rare external and damaging effects are present what is the best growth strategy? If the different part of the network compete for the same ressource is there an optimal strategy that emerge? We shall consider a simple model an analyze the different dynamical outcomes that can occur depending on parameters, we shall then allow some variability of the parameters within the structure and try to understand how our initial analysis with fixed parameters allows us to understand the different structures that emerge, or if unexpected phenomena appear. The other aspect is more concerned with the analysis of the dynamics per se on networks. We will be concerned with the study relative complexity of large dynamical systems, and use it to eventually reduce the dimensionality of the effective dynamics and invent effective diagnostics to detect coherent motion (synchronization or self-organization phenomenon).

References:

1. K. H. Jensen et al., Sap flow and sugar transport in plants, Rev. Mod. Phys., 88, 2016

2. Jens Leth Hougaard, An Introduction to Allocation Rules, Springer-Verlag Berlin Heidelberg 2009

3. B. Mohar, and W. Woess, A survey on spectra of infinite graphs, Bull. London Math. Soc. 21 (1989)

4. Afraimovich, Valentin; Gong, Xue; Rabinovich, Mikhail. "Sequential memory: binding dynamics". Chaos25(2015),no. 10,103118, 11 pp.

Duration: 4 months

Any self-financial support? No *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

Yes

Master2 Internship proposal at CPT

Research team:

Nanophysics

Supervisor:

A. Crépieux

e-mail:

adeline.crepieux@cpt.univ-mrs.fr

Website:

www.cpt.univ-mrs.fr/∼crepieux/

Project title:

Current fluctuations in spin-polarized nanosystems

Description:

The aim of the internship is to calculate the current fluctuations in a spin-polarized nanosystem using the nonequilibrium Keldysh Green function technique, following a method of calculation convincingly tested for a quantum dot connected to electronic reservoirs [1]. Coulomb interactions in the nanosystem will be treat firstly at the level of Hartree approximation, and secondly, if time permits, using an equation of motion technique with a proper decoupling of the two-particle Green functions [2]. The ultimate goal will be to determine the Fano factor (defined as the ratio between the zero-frequency fluctuations and the electrical current) in order to compare with the experimental results, in particular the ones obtained for a carbon nanotube connected to metallic leads on a silicon wafer [3].

References:

[1] R. Zamoum, M. Lavagna, and A. Crépieux, Phys. Rev. B 93, 235449 (2016).
[2] M. Lavagna, J. of Physics: Conf. Series 592, 012141 (2015).
[3] M. Ferrier, T. Arakawa, T. Hata, R. Fujiwara, R. Delagrange, R. Weil, R. Deblock, R. Sakano, A. Oguri, and K. Kobayashi, Nature Physics 12, 230 (2016).

Duration: *March 2017 – June 2017*

Any self-financial support?

Specify whether the internship project may naturally lead to a PhD thesis: *Yes*

Master2 Internship proposal at CPT

Research team: Geometry, Physics & Symmetries (GPS)

Supervisor: Serge Lazzarini

e-mail: Serge.Lazzarini@cpt.univ-mrs.fr

Project title: Finding a Lagrangian for the Schrödinger-Newton equation

Description:

The Schrödinger-Newton (SN) equation was introduced in 1984, by Diósi [2] in order to inhibit free *spreading of the wave packets* & describe the quantum localization of macro-objects. Then in '96–'14, Sir R. Penrose [5, 6] appealed to the SN eq in his proposal to *Gravitize Quantum Mechanics* as opposed to . . . Quantize Gravity. The SN eq carries remarkable scaling properties found in 3-D space case [1, 4] and proved in arbitrary space dimension in [3]. SN eq turns out to be equivalent to a system of three coupled PDE's.

The goal of the internship is to construct a Lagrangian –along the line followed in [7]– such that by variational principle it gives back the PDE's as eq of motion. Study of the e-m tensor and conserved quantities are also in order.

References:

1. M. Bahrami, A. Grossardt, S. Donati and Angelo Bassi, "The Schrödinger equation and its foundations", *New Journal of Physics* **16** (2014) 115007.
2. L. Diósi, "Gravitation and quantum-mechanical localization of macro-objects", *Phys. Lett.* **A 105** (1984) 199–202.
3. C. Duval and S. Lazzarini. "On the Schrödinger-Newton equation and its symmetries: a geometric view". Class. Quant. Grav. 32 (2015) p.175006. `arXiv:1504.05042`.
4. D. Giulini and A. Grossardt, "Gravitationally induced inhibitions of dispersion according to the Schrödinger-Newton equation", *Class. Quantum Grav.* **28** (2011) 195026.
5. I. M. Moroz, R. Penrose and P. Tod, "Spherically-symmetric solutions of the Schrödinger-Newton equations", *Class. Quantum Grav.* **15** (1998) 2733–2742.
6. R. Penrose, "On Gravity's Role in Quantum State Reduction", *Gen. Relat. Grav.* **28** (1996) 581–600. "On the Gravitization of Quantum Mechanics I : Quantum State Reduction", *Found. Phys.* (2014) 44 : 547–575.
7. Duval, C. and Horvathy, P. A. and Palla, L., "Conformal symmetry of the coupled Chern-Simons and gauged nonlinear Schrodinger equations", Phys. Lett. **B325** (1994) 39-44, doi:10.1016/0370-2693(94)90068-X, `hep-th/9401065`.

Duration: 4 months

Any self-financial support? *(if longer than 2 months)* No

Specify whether the internship project may naturally lead to a PhD thesis. Yes

Master2 Internship proposal at CPT

Research team: E7

Supervisor: Michel Vittot

e-mail: vittot@cpt.univ-mrs.fr

Project title

A Lie-Jordan Framework for Classical and Quantum Mechanics & Quantization by Deformation

Description

The Lie-Jordan Algebraic structure is a non-associative generalization of the Poisson structure. It is well adapted to describe the Classical or Quantum Hamiltonian Dynamics (via its Lie structure), as well as the associated "States" (via its Jordan structure), giving rise to an "Heisenberg Uncertainty Principle". Cf ArXiv: quant-ph/0703060 by Doering & Isham.

Another nice theory is given by Kontsevich (Fields Medal 1998) in ArXiv: q-alg/9709040. This generalizes the Moyal Quantization by Deformation (only valid in a canonical Poisson structure) from a general Poisson algebra to a C*-Algebra (or Lie-Jordan Algebra).

This Master2 project consists in an introduction to this framework, and to some extensions.

References

cf above

Duration

standard

Any self-financial support? *(if longer than 2 months)*

No

Specify whether the internship project may naturally lead to a PhD thesis.

I am available to continue this internship project into a PhD thesis. The financial aspect is open...

Master2 Internship proposal at CPT

Research team:

Cosmology

Supervisor:

Julien Bel

e-mail:

jbel@cpt.univ-mrs.fr

Project title:

Simulating the acceleration of the universe

Description:

The late time acceleration of the universe leaves a specific imprint on the formation of large-scale structures. It is well known, that galaxies, clusters and super-clusters of galaxies are organized in a different way according to the supposed mechanism responsible for the acceleration. In addition, large scale under-dense regions such as cosmic voids are also affected by the homogeneous accelerated expansion of the universe.

During the proposed internship, the goal will be to study the way cosmic voids are moving with respect to the cosmic matter. It consists on one hand, in understanding from a theoretical point of view how voids can move under the influence of an accelerating background and on the other hand in simulating this effect on a large cosmological volume. With this project, the student will learn standard approximate methods allowing to explain the cosmological structure formation in order to be able to generalize them for the purpose of the internship. He will also develop is own numerical simulation in order to model accurately the motion of cosmic voids. As a results, the student will be able to relate these motions to a specific theoretical model for the acceleration of the cosmic expansion; understanding the nature of dark energy.

Finally, he will have access to powerful computing resources in order to run cosmological N-body simulations which could be used as a comparison with the specific approach developed during the internship.

References:

Bernardeau, Colombi, Gaztañaga, Scoccimarro, 2002, *Large-scale structure of the Universe and cosmological perturbation theory*, PhR, 367, 1

Duration:

16 weeks

Any self-financial support? *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

Depending upon funding and the results found during the intership, this project could open to a PhD thesis.

Master2 Internship proposal at CPT

Research team: NANOPHYSICS

Supervisor: Thierry Martin

e-mail: martin@cpt.univ-mrs.fr

Project title: Andreev Reflection from superconducting topological quantum matter

Description:

The nanophysics team of CPT is looking for a motivated M2 student to study quantum transport between a topological superconductor nano-wire and a normal metal lead. Transport is characterized by the charge or spin current, but also by more involved quantities giving additional informations, like the current-current correlations in time, called noise. The study of hybrid structures containing new materials like topological superconductors offer new perspectives in this domain.

In hybrid structures containing superconductors, when voltage biases are applied to the leads, one has to resort to specific methods, in particular the Keldysh Green's function formalism. The CPT nanophysics team has a strong tradition in using these tools to study the current and noise correlations in superconducting hybrid structures, where a special transport channel called Andreev Reflection operates (the reflection of an electron incident on the superconductor into a hole). The physics of topological matter also has potential applications to quantum information scenarios.

In topological superconductors, a lot of attention was drawn recently to the possibility for detecting the presence of Majorana fermions at their extremities: excitations which are their own antiparticle. Such excitations have been studied a century ago in the context of particle physics, but they are now believed to occur in the collective phenomena of condensed matter systems. It is therefore natural for the nanophysics team to study Andreev reflection in a device consisting of a topological superconductor nanowire and a normal metal lead. The manifestation of Majorana fermions could posses a particular signature.

During the internship, the first part of the work will be to get familiar with the bibliography on topological superconductors (theory and experiment) as well as to familiarize oneself with the non equilibrium methods of quantum field theory. Then the average current and zero frequency noise will be computed using the Keldysh Dyson equation. The boundary Green's function from the topological superconductor will be derived from the microscopic model of the Kitaev chain. Results will be illustrated by current voltage and noise voltages plots which will be computed numerically.

References:

Noise in mesoscopic physics, Thierry Martin, les Houches Session LXXXI, H. Bouchiat et. al. eds. (Elsevier 2005). arXiv:cond-mat/0501208

Y. Nazarov and Y. Blanter, Quantum Transport, Cambridge University Press.

T. Jonckheere, J. Rech, A. Zazunov, R. Egger, T. Martin, Hanbury Brown and Twiss noise correlations in a topological superconductor beam splitter, arXiv:1611.03776

T. Jonckheere, J. Rech, T. Martin, B. Douçot, D. Feinberg, and R. Mélin, Multipair dc Josephson resonances in a biased all-superconducting bijunction Phys. Rev. B 87, 214501 (2013)

A. Zazunov, R. Egger, and A. Levy Yeyati, Losw energy transport in Majorana wire junctions, Phys Rev B 94, 014502 (2016).

Duration: the normal duration of a CPT internship

Any self-financial support? *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

In principle Yes. For sure the team intends one day to recruit a students on this or a similar topic. Nevertheless, I cannot provide a definite answer on this matter because it depends on the level of other CPT student who apply to the PhD program via the doctoral school ED 352

Master2 Internship proposal at CPT

Research team: Cosmology

Supervisor: C. Marinoni

e-mail: marinoni@cpt.univ-mrs.fr

Project title: Disturbing the peace (without causing damage!)

Description:

Perplexing observations such as the accelerated expansion of the universe (the dark energy phenomenon), the rotation curves of galaxies or the gravitational lensing from large clusters of galaxies (the dark matter phenomenon), as well as the spatial and temporal variation fundamental constants (e.g., the fine structure constant) seem to call into question the very structure of the Einstein's theory of gravity. It is thus tempting to explore beyond the standard scenario and to look for alternative descriptions of gravity which might explain away current interpretational conundrums.

If the standard set of cosmological assumptions about the 4 dimensional distribution of matter are augmented by a specific symmetry principle, a very peculiar, and observationally viable, model for the background evolution of the cosmic metric is obtained. After investigating the characteristic predictions and the specific phenomenology arising in this non-standard scenario, the student will be led to develop the (linear) perturbative sector of the model. He/she will *a)* derive the equation of motions of large-scale matter fluctuations, *b)* check that the solutions are not plagued by neither classical nor quantum pathologies, *c)* calculate the amplitude of fundamental observables describing the inhomogeneous universe, and *d)* assess, finally, whether the model is still viable when perturbative predictions are contrasted with empirical evidences.

Duration: 4 months

Any self-financial support? *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

Yes

Master2 Internship proposal at CPT

Research team: Statistical physics and complex systems

Supervisor: Alberto Verga

Alberto.Verga@univ-amu.fr
Alberto Verga web page

Project: Graph states and quantum walks

A deep and far reaching idea relates matter and information through the concept of entropy. Trying to understand the measurement process in quantum mechanics as first thoroughly discussed by Niels Bohr, von Neumann associated an entropy to a quantum state, described by the density matrix. Later, in one of the most influential papers of the twenty century, Shanon found a definition of the information as the negative of the entropy: precisely the same entropy Boltzmann used to assess the second principle of thermodynamics.

Entanglement, that can be measured by the von Neumann entropy, is a central concept in quantum mechanics. On one hand, it is this property of quantum states that reveals the existence of correlations in physical systems that cannot arise from classical mechanisms. On the other hand, from the quantum computing point of view, entanglement constitutes a supplemental resource without equivalent in classical computing, allowing us to think that a quantum computer might solve problems of higher complexity than their classical counterpart.

In parallel to its relation to information, entanglement, is important in the characterization of topological phases of matter, as encountered in many-body interacting systems (spin liquids, fractional quantum Hall states, many-body localization). One of the goals of this project is just to exploit this relation between information, quantum states, and physical properties of condensed matter systems.

We are in particular interested in the link between *entanglement and interactions*. Indeed, the physical mechanism by which entanglement develops is particle interactions. As a specific system suitable to reveal the influence of interactions on entanglement, we investigate a two particle system evolving on general networks (quantum walk on graphs), whose interaction can be easily modified by choosing different "collision" operators (coin). We can in this way play, for instance, on the internal degree of freedom (spin) of the particles. Comparison between the free evolution (non interacting) and interacting one, can discriminate between quantum correlations related to the graph topology and quantum walk dynamics (swap and coin operators) and genuine interaction effects. The candidate will use analytical and numerical tools to explore the phenomenology of the interacting quantum walk, develop the appropriated information-theoretic measuring quantities, characterize the system's topology (for instance using an effective Hamiltonian or the symmetries of the unitary evolution operator), and eventually characterize the behavior of the quantum states.

References:

- B. Zeng, X. Chen, D.-L. Zhou, and X.-G. Wen. Quantum Information Meets Quantum Matter – From Quantum Entanglement to Topological Phase in Many-Body Systems. ArXiv e-print:1508.02595 (2015). pdf.
- T. Kitagawa. Topological phenomena in quantum walks: elementary introduction to the physics of topological phases, Quantum Information Processing, 11, 1107 (2012). pdf.

Thesis: This internship project may be continued by a PhD thesis.

Master2 Internship proposal at CPT

Research team:

Cosmology

Supervisor:

Federico Piazza

e-mail:

fedosquare@gmail.com

Project title:

Analytical approaches to cosmological perturbation theory in the presence of dark energy.

Description:

The large scale structures that we see in the sky originated by primordial density perturbations that grew under gravitational attraction and finally underwent gravitational collapse. Even in the early linear regime, the study of these perturbations involves, in most cases, numerical computations. Among the known codes for this task are CAMB and CLASS.

The wavelength L of each perturbation mode starts its evolution while much longer than the Hubble length H^{-1}. Gradually, the mode "enters the horizon" and finally we will have that $L < H^{-1}$. This is where the dynamics induced by gravity becomes more dramatic.

This project aims to developing analytical tools to study the evolution of cosmological perturbations in the presence of a scalar field (dark energy) in a power series. On the one hand, we want to do an expansion in early times/long wavelengths, that is, basically, in the variable $1/(LH)$. This will accompany us from the given initial perturbation spectrum (typically given by inflation) down to the entering of the horizon. On the other hand, it will be interesting to expand also at short wavelengths at late time (i.e. in LH), to capture the dynamics well inside the Hubble horizon before it becomes non linear. Finally, we want to see weather this two limits can be consistently matched in the middle and give a complete and self consistent picture of the evolution of cosmological perturbations.

References:

C. P. Ma and E. Bertschinger, "Cosmological perturbation theory in the synchronous and conformal Newtonian gauges," Astrophys. J. **455**, 7 (1995) [astro-ph/9506072].

Duration:

4

Any self-financial support? *(if longer than 2 months)*

No

Specify whether the internship project may naturally lead to a PhD thesis.

Maybe

Master2 Internship proposal at CPT

Research team: Geometry, Physics and Symmetries

Supervisor: R. Coquereaux

e-mail: robert.coquereaux@gmail.com

Project title: Thresholds and intertwining operators for integrable representations of SU(N) affine Lie algebras

Description:

It is known that the Littlewood-Richardson (LR for short) coefficient giving the multiplicity of a given branching of irreducible representations $\lambda \otimes \mu \to \nu$ of SU(N) (reduction of the tensor product of irreps into irreducible components) is an increasing function of the non-negative integer k, when one replaces Lie algebras by affine Lie algebras at level k. Typically, the multiplicity of a given branching, which is an increasing function of the level, ceases to be zero when k, starting from 0, reaches a special value k_{min}, called the threshold of the branching, it then grows with k until it stabilizes (at a level k_{max}) where it becomes equal to its classical value. The problem is to study and describe the behavior of the LR coefficients as a function of the level k.

In the case of SU(2) and SU(3), everything is known : for SU(2), the multiplicity, as a function of k is a step function equal to 0 or 1, whereas for SU(3), it is an increasing monotonic function with slope +1 between k_{min} and k_{max}. For SU(N), $N \geq 4$, and for Lie groups belonging to other series, there are partial results scattered in the literature.

Several nice combinatorial tools that go under the generic name of pictographs have been introduced not so long ago in order to study multiplicity problems in tensor products of irreps. The basic idea is that to a given branching with classical (i.e. the level $k \to \infty$) multiplicity μ, one can associate μ distinct pictographs. These pictographs are of several kinds: one can use KT-honeycombs, BZ-triangles or O-blades (KT standing for Knutson-Tao, BZ for Berenstein - Zelevinsky and O for Ocneanu). When the level is finite –"the quantum case"'– the multiplicity is smaller than in the classical case, but, with proper care, one can still use the same pictographs.

The first purpose of the project is to summarize what is known about the level dependence of LR coefficients in the SU(2) and SU(3) cases; this part is easy since it can be found in chapters of appropriate textbooks. The next purpose, about SU(N), $N > 3$, or other simple Lie groups, is to gather and summarize what can be found on this subject in the literature (journals). Finally, in the case of SU(4) at least, the student should perform computer experiments using an already available code for affine Lie algebras at level k, and study the properties of the corresponding pictographs (see above). The last part of the project is therefore to run mathematical experiments, and to make new observations (to prove theorems if possible) that will pave the way to a better global understanding of the level dependence of LR coefficients.

References:

- P. Di Francesco, P. Mathieu and D. Sénéchal, *Conformal Field Theory*, Springer 1997
  See subsection on BZ-triangles and thresholds.

- R. Coquereaux, J.-B. Zuber. Conjugation properties of tensor product multiplicities, arXiv:1405.4887. J. Phys. A: Math. Theor. 47 (2014) 455202
  See subsection on honeycombs, oblades, etc.

Duration:

Standard.

Any self-financial support? *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

It may. . . : the answer is fellowship dependent.

Master2 Internship proposal at CPT

Research team: NANOPHYSICS

Supervisor: Thierry Martin, Thibaut Jonckheere

e-mails: martin@cpt.univ-mrs.fr, jonckheere@cpt.univ-mrs.fr

Project title: Circuit theory of multiple pair resonances in three lead superconductor devices

Description:

The nanophysics team of CPT is looking for a motivated M2 student to study off equilibrium quantum transport in a three superconducting lead device where all leads are connected to a central node (a "large", metallic quantum dot). In similar devices with 3 superconducting leads only (each with phases 0, ϕ_a, ϕ_b and voltages bias 0, V_a, V_b) it has been shown that if V_a and V_b are commensurate ($n_a V_a + n_b V_b = 0$), a phase dependent, DC dissipation-less current Josephson-like signal can be generated although the system is out of equilibrium.

The physics of this phenomenon is understood to be the coherent exchange of Cooper pairs between the three leads. One crucial ingredient is the possibility to spit a Cooper pair from a superconducting lead, and to redistribute its constituent electrons in the other two other superconducting leads. This process is called Crossed Andreev Reflection (CAR), and it has been studied on many occasions by the nanophysics team of CPT. If $V_a = -V_b$, and if such CAR process from superconductor 0 occurs two times in a row, and the receiving superconductor leads each absorb their two electrons as Cooper pairs, the process is called a "quartet": two CAR processes are required and two "normal" Andreev reflections are required.

So far this effect has been studied theoretically assuming that nano-wire quantum dots act as the junctions between pairs of superconductors. Nevertheless, the initial (pioneering) experiment for probing such multiple pair resonances has been performed in Grenoble by the group of François Lefloch at CEA, using a central metallic node connecting all three superconductors.

Our central motivation is thus to use Nazarov's circuit theory in order to study multiple Cooper pair resonances when the three leads are connected to a metallic node. This now well established theory is based on the diffusive superconductor approach to quantum transport due to Usadel. At the origin is the Larkin Ovshinikov Gorkov theory of superconducting quantum transport where impurity scattering is taken into account via self energies. This equation can be simplified by using the semiclassical approximation (averaging the fast oscillations on the scale of the Fermi wavelength), and by considering the dirty limit, where electron motion is diffusive due to impurity scattering, and the Green functions become isotropic. This leads to the so-called Usadel equation. Nazarov circuit theory simpifies further the problem by discretizing the system in nodes, where the Green function is homogeneous. Expressing current conservation in the nodes leads to a recursive solution for the nodes Green function. In the present case of a device with our three superconductor leads, each lead Green's function is known, but the Green's function of the central node needs to be evaluated self consistently using Nazarov's circuit theory.

During the internship, the first part of the work will be to get familiar with the bibliography on multiple pair resonances (theory and experiment) as well as to familiarize oneself with the non equilibrium methods of quantum field theory. Bibliography will also be needed for Nazarov's circuit theory. The student will not be required to proceed to the derivation of the Circuit Theory equations: he/she will need to be able to understand and specify the assumptions of this theory, and his/her crucial role will be to understand how to use this formalism. The key point will be to understand how to derive the node Green's function and how to extract from it the different current flowing into the leads.

We will start by investigating in particular the quartet configuration where $V_a = -V_b$ (particular case of commensurate voltages). In this situation all currents can be expressed in terms of harmonics of a Josephson like frequency, as the system is time-periodic. The self consistent solution for the node Green's function then relies on a peculiar Fourier transform which is specific to two superconductors junctions (here generalized to three).

If time allows, it will be possible to include dephasing effects on the quartet current and to include counting fields in the transport formalism in order to compute not only the partial currents, but also the quantum noise.

References:

- Noise in mesoscopic physics, Thierry Martin, les Houches Session LXXXI, H. Bouchiat et. al. eds. (Elsevier 2005). arXiv:cond-mat/0501208

- Y. Nazarov and Y. Blanter, Quantum Transport, Cambridge University Press.

- T. Jonckheere, J. Rech, T. Martin, B. Douçot, D. Feinberg, and R. Mélin, Multipair dc Josephson resonances in a biased all-superconducting bijunction Phys. Rev. B 87, 214501 (2013)

- Subgap structure in the conductance of a three-terminal Josephson junction A. H. Pfeffer, J. E. Duvauchelle, H. Courtois, R. Mélin, D. Feinberg, and F. Lefloch Phys. Rev. B 90, 075401 (2014).

- Proposal for the observation of nonlocal multipair production, J. Rech, T. Jonckheere, T. Martin, B. Douçot, D. Feinberg, and R. Mélin Phys. Rev. B 90, 075419 (2014).

- Current and noise correlations in a double-dot Cooper-pair beam splitter, D. Chevallier, J. Rech, T. Jonckheere, and T. Martin Phys. Rev. B 83, 125421 (2011).

- Handwritten notes on circuit theory (T. Martin)

- Tunable minigaps due to non-local coherent transport in voltage biased three-terminal Josephson junctions, C. Padurariu, T. Jonckheere, J. Rech, T. Martin, and D. Feinberg (preprint)

Duration: the normal duration of a CPT internship

Any self-financial support? *(if longer than 2 months)*

Specify whether the internship project may naturally lead to a PhD thesis.

I cannot provide a definite answer on this matter because it depends on the level of other CPT students who apply to the PhD program via the doctoral school ED 352

Master2 Internship proposal at CPT

Research team:

Particle Physics

Supervisor:

Aoife Bharucha

e-mail:

aoife.bharucha@cpt.univ-mrs.fr

Project title:

Dark matter from mixed multiplets at the LHC

Description:

We will study the propects for dark matter models consisting of a singlet mixed with the neutral component of a SU(2) multiplet. This will involve writing a model file using the package FeynRules for the program Mathematica in order to obtain inputs for the program micromegas which can be used to obtain the dark matter properties for given parameter values. We will then study the prospects for this class of models at the LHC via monojet searches, searches for long-lived charged particles and other exotic searches.

References:

1. *Collider searches for next-to-minimal dark matter*, A. Bharucha, F. Bruemmer, N. Desai and R. Ruffault, In preparation.
2. *The last refuge of mixed wino-Higgsino dark matter.* By Martin Beneke, Aoife Bharucha, Andrzej Hryczuk, Stefan Recksiegel, Pedro Ruiz-Femenia, [arXiv:1611.00804 [hep-ph]].
3. *Relic density of wino-like dark matter in the MSSM.* By M. Beneke, A. Bharucha, F. Dighera, C. Hellmann, A. Hryczuk, S. Recksiegel, P. Ruiz-Femenia, [arXiv:1601.04718 [hep-ph]]. JHEP 1603 (2016) 119.

Duration:

4 months

Any self-financial support? *(if longer than 2 months)*

Yes

Specify whether the internship project may naturally lead to a PhD thesis.

No.