Master 2 Internship

Centre de Physique Théorique, UMR 7332 and IRFM CEA

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Name of advisers: Xavier Leoncini and Guilhem Dif-Pradalier
email: Xavier.Leoncini@cpt.univ-mrs.fr, Guilhem.Dif-Pradalier@cea.fr

Title : **Chaotic motion of charged particles in magnetic fields, applications to fusion plasmas.**

General Context:
In the last few years, the impact of low dimensional chaos in the motion of charged particles in ideal plasma configurations has been shown to be able to destroy quasi-invariants in some regions of the phase space. Most notably the existence of an adiabatic constant, namely the magnetic moment μ, which is at the heart of the gyrokinetics reduction appeared to be questionable in these regions, or when it exists, this was shown not to imply the integrability of the dynamics, even in axisymmetric magnetic fields [1, 2]. This local invariant breaking could be a major concern, most notably when considering transport predictions coming out of gyrokinetic codes, which are often considered as "first principles" results by the community. During this internship the student will familiarize himself with the problems, and develop new tools both conceptual and numerical. One of the problems being able to analyze for a large time (up to adiabatic times) particle trajectories that belong to a 6th dimensional phase space and that potentially develop Hamiltonian Chaos. At first we would need to assess the efficiency of an algorithm to compute trajectories using high order Taylor expansions versus a 6-th order symplectic one. After that preliminary set up, we expect to study the dynamics and evolution of particle density functions of « stable » and perturbed configurations.

Scientific Environment: This internship work will be part of a long standing collaboration of the CPT with the IRFM of the CEA Cadarache within the French national research federation of magnetic confinement fusion (FR-FCM).

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[1] B. Cambon, X. Leoncini, M. Vittot, R. Dumont, and X. X. Garbet. Chaotic motion of charged particles in toroidal magnetic configurations. *Chaos*, 24:033101, 2014.

[2] S. Ogawa, B. Cambon, X. Leoncini, M. Vittot, D. Del Castillo-Negrete, G. Dif-Pradalier, and X. Garbet. Full particle orbit effects in regular and stochastic magnetic fields. *Phys. Plasmas*, 23:072506, 2016.

Master2 Internship proposal at CPT, year 2018

Research team:

Nanophysics

Supervisor:

Adeline Crépieux

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Project title:

Finite-frequency noise in an out-of-equilibrium double quantum dot

Description:

The aim of this M2 Intership is to calculate the finite-frequency noise in a double quantum dot using the non-equilibrium Keldysh Green's functions technique. Such a calculation has been preformed previously in the case of a single quantum dot [1,2] and has allowed us to explain successfully the recent emission noise measurements in a carbon nanotube dot in the Kondo regime [3].
In this Intership, the student will focus on the non-interacting case where the two-particles Green's functions of the double quantum dot, appearing in the expression of the noise, can be decoupled into a product of one-particle Green's functions. By solving the Dyson equation of motion for the one-particle Green's functions, the analytical expression for the noise will be established. Then, the student will study its behavior as a function of frequency, temperature, applied bias and gate voltages and couplings to the reservoirs.
The student needs to be familiar with the Green's functions technique and with the current-fluctuations thematic. This work is part of a collaboration with the CEA Grenoble (Mireille Lavagna).

References:

[1] R. Zamoum, M. Lavagna, and A. Crépieux, Phys. Rev. B 93, 235449 (2016).
[2] A. Crépieux, S. Sahoo, T.Q. Duong, R. Zamoum, and M. Lavagna, arXiv:1708.01187 (2017).
[3] R. Delagrange, J. Basset, H. Bouchiat, and R. Deblock, arXiv:1704.00479 (2017).

The internship project may lead to a PhD thesis.

Master2 Internship proposal at CPT, year 2018

Research team: Systemes complexes

Supervisor: Michel ROULEUX

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Project title: VORTICITY ON A LIE GROUP

Description:

Vorticity is an ubiquitous phenomenon in Physics (fluid governed by Euler equations, spin systems with continuous symmetry, Ginzburg-Landau in supraconductivity, gauge theories, etc...). For a vector field $\vec{F}$ it expresses how the integral curves move, in 2-D, around a point called *vortex* or, in 3-D, around a line called *vortex line*. The local circulation of $\vec{F}$ along a loop around the vortex or the vortex line is computed by Green formula.

We are interested in defining vorticity of a smooth field valued in a Lie algebra, and computing its "logarithm" on the corresponding Lie group.

The abelian case is about complex functions. For instance, the local degree of $f : \mathbf{C} \to \mathbf{C}$ defined by

$$\frac{1}{2i\pi} \oint_\gamma \frac{df}{f} \in \mathbf{Z}$$

is non zero if f has a singularity at some points ξ inside γ, and can be computed using Green formula. This is the case for instance for Ginzburg-Landau equation. If moreover f is holomorphic, this reduces to the well-known formula of residues for the meromorphic function $1/f$: the residue at each pole is an integer number, the variation of the logarithm of f along γ encircling the pole.

More generally, when M and N are 2 manifolds of same dimension, we can compute the local degree of a map $M \to N$ in a very general way, see [Mil], [DuFoNo].

When $M \subset \mathbf{R}^n$ is an open set (not necessarily simply connected), and N is a (non abelian) Lie algebra, one can expect to make the theory more precise, at least in some particular cases.

For instance, let $(\mathcal{H}^0_{2\times 2}(\mathbf{C}), \frac{i}{2}[\,\cdot\,,\,\cdot])$ be the Lie algebra of Hermitian matrices with zero trace, that is identified with. $(\mathbf{R}^3, \wedge)$ (so that we recover the case of vector fields above).

The local degree of a matrix field $F : \mathbf{R}^3 \mapsto \mathcal{H}^0_{2\times 2}(\mathbf{C})$ is defined as the integral

$$\frac{1}{2i\pi} \oint_{\partial\Omega} \rho(x)$$

of the 1-form

$$\rho(x) = \frac{i}{2}[F^{-1}(x), dF(x)]$$

and can also been computed using Green formula. This allows to "measure" vorticity in XY classical or quantum Heisenberg spin models [MiRo].

More generally, let ρ be a smooth field valued in a Lie algebra $\mathcal{L}$, then ρ has local integrals (we call "logarithms" of ρ) valued in its Lie groupe $\mathcal{G}$ if it verifies Maurer-Cartan structure equation $d\rho + [\rho, \rho] = 0$.

In this Internship we shall consider other examples of smooth fields valued in a non-abelian Lie algebra:

(i) $F : D \subset \mathbf{R}^3 \to \mathrm{sl}(2; \mathbf{R})$ (traceless 2×2 matrices).

(ii) $F : D \subset \mathbf{R}^{(2n+1)n} \to \mathrm{sp}(2n; \mathbf{R})$ (Hamiltonian matrices). This is related with symplectic vortices and quantum cohomology [CeSa].

(iii) More generally, vorticity related with topological phases that are commonly encountered in Condensed Matter Physics [Wen].

References:

[So] A.Sossinsky. Topology, Lect. Notes. Math. in Moscow. Independent University of Moscow, 2015.

[CeSa] K.Celiebak, D.Salamon. Wall crossing for symplectic vortices and quantum cohomology. Math. Ann. 335 (2006)

[DuFoNo] B.Dubrovin, A.Fomenko, S.Novikov. Modern Geometry-Methods and applications. Vol. I, II, III. Springer, 1985.

[Mil] J.Milnor. Topology from the differentiable viewpoint, Virginia Univ. Press, 1965.

[MiRo] D.Minenkov, M.Rouleux. Quantum Vorticity at positive temperature for spin systems with continuous symmetry. ISQS24, Int. Conference on Integrable Syst. and Quantum symmetries. Prague, 2016. 2017 J. Phys.: Conf. Ser. 804 012031.

[Wen] X-G.Wen. Colloquium: Zoo of quantum-topological phases of matter. Rev. Modern Phys. 89, 2017. DOI: 10.1103/RevModPhys.89.041004

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

This internship would naturally lead to a Thesis, elaborating more closely on the points presented above.

Master2 Internship proposal at CPT, year 2018

Research team: Systemes complexes

Supervisor: Michel ROULEUX

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Project title: HUBBARD LIKE MODELS ON A 2-D LATTICE: DECAY OF CORRELATIONS

Description:

In this Internship we will investigate the correlation decay (2-point functions) for Hubbard model on a lattice and its possible generalization to spin systems with continuous symmetry.

Hubbard model describes the quantum Hamiltonian of a system of electrons with spin up and down, hopping from site to site on the lattice, and possibly subject to an exterior magnetic field.

For 1-D lattices, the system is integrable (Bethe Ansatz); we are interested in 2-D lattices, as $\mathbf{Z}^2$ or an hexagonal lattice.

In a first part we consider the results obtained in an analytic frame by T.Koma and H.Tasaki [KoTa] for the lattice $\mathbf{Z}^2$: in doing so, we start to review the properties of C^*-Operator Algebras, the basic inequalities used in trace estimates (Cauchy-Schwarz inequality, Peierls-Bogoliubov inequality, Golden-Symanzik-Thomson inequality), and the discrete Poisson kernels. Then we pass to the main result of Koma-Tasaki on the polynomial decay of correlations in the special case of the nearest neighbor intereaction. It is based on the method of "complex scaling" (well-known in computing resonances for a Schrödinger operator) that consists in conjugating the Hamiltonian with complex phases, turning the "hyperbolic system" into an "elliptic" one, for which sharp estimates on the Poisson kernel are well known [ItDr].

Next we replace the lattice $\mathbf{Z}^d$ by an hexagonal lattice. This is motivated by Haldane-Hubbard model involving two types of interaction: the nearest neighbors and the next-to-nearest neighbors interations [WuLaSéMa]. One of the problems is to compute the discrete Poisson kernel for an hexagonal lattice.

The method of [KoTa] has been popularized because it can be easily adapted to other models of Quantum Statistical Mechanics. Thus, if times allows it, we elaborate next a generalization of these results to XY model (spin of electrons have continuous symmetry), and XY model for Cooper pairs (in supraconducting materials). To simplify algebra of tensor products (consisting in conjugating with the complex phases) we first need to extend Weyl operators to the fermionic case.

References:

[ItDr] Cl.Itzikson, J.M.Drouffe. Théorie statistique des champs I. InterEditions/Editions du CNRS, Paris (1989)

[KoTa] T.Koma, H.Tasaki. Decay of superconducting and magnetic correlations in 1-D and 2-D Hubbard model, Phys. Rev. Letters 68(21), p.3248-3251, 1992.

[MiRo] D.Minenkov, M.Rouleux. Quantum Vorticity at positive temperature for spin systems with continuous symmetry. ISQS24, Int. Conference on Integrable Syst. and Quantum symmetries. Prague, 2016. 2017 J. Phys.: Conf. Ser. 804 012031.

[WuLaSéMa] J.Wu, J.-P. Latyr-Faye, D.Sénechal, J. Maciejko. Quantum cluster approach to the spinful Haldane-Hubbard model. Phys. Rev. B 93, 075131 (2016)

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

This internship would naturally lead to a Thesis, elaborating more closely on the points presented above.

Master2 Internship proposal at CPT, year 2018

Research team: Particle Physics

Supervisor: Laurent Lellouch

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Project title: The search for new fundamental physics in the anomalous magnetic moment of the muon

Description:

One way to search for new fundamental physics is to look for small deviations of experimental measurements from standard model (SM) predictions. In this project we propose to focus on an observable which may already carry signs of new physics: the anomalous magnetic moment of the muon, $a_\mu = (g_\mu - 2)/2$. In the E821 experiment conducted at Brookhaven National Laboratory at the beginning of the century, a_μ was measured with an incredible precision of 0.54ppm [1]. Since the first results were published, a persistent discrepancy of more than 3 standard deviations has been observed between the SM prediction and experiment [2–7]. It is, in fact, the largest deviation from the SM observed in a clean electroweak observable, and it has led to much speculation as to the possible new physics scenarios that could explain it.

At present the theoretical and experimental uncertainties in a_μ are pretty much matched [2, 6, 7]. However, a new experiment has begun taking data at Fermilab [8], and a second one is being considered at J-PARC [9]. They aim at dividing the experimental error on a_μ by 4. To leverage these new measurements, it is mandatory to reduce the uncertainties in the SM prediction, which is a highly non trivial theoretical challenge.

In the SM, the dominant source of uncertainty in the calculation of a_μ comes from two hadronic contributions [2,6,7]. This is due to the fact that the strong interaction is dominated by nonperturbative quantum chromodynamics (QCD) effects at the typical energies required to compute a_μ in the SM. The first of these contributions is the hadron vacuum polarization (HVP) term.

My collaborators and I have recently published the most complete lattice QCD calculation of this contribution to date [10, 11]. While the 2% total uncertainty that we have obtained represents a significant achievement, it is still a factor of 10 too large to fully leverage the results expected from the Fermilab experiment in 2020.

In the present project, the student will learn about the phenomenology of the muon $(g_\mu - 2)$, which receives contributions from all interactions in the SM. S/he will also learn the basics of large-scale lattice QCD calculations, as well as the specifics concerning its application to the computation of the HVP. The goal of this project and the ensuing PhD thesis is to perform the lattice QCD calculations required to determine the SM prediction for a_μ with a precision that matches that of the upcoming measurements of a_μ, so as to be able to determine unambiguously whether these measurements display new fundamental physics. In particular, this will require conceptual developments to account for electromagnetic and strong-isospin breaking corrections that have been neglected in our calculations to date and whose calculation our team has pioneered [12].

References

[1] **Muon g-2** Collaboration, G. W. Bennett et al., *Final Report of the Muon E821 Anomalous Magnetic Moment Measurement at BNL*, *Phys. Rev.* **D73** (2006) 072003, [hep-ex/0602035].

[2] J. P. Miller, E. de Rafael, and B. L. Roberts, *Muon (g-2): Experiment and theory*, *Rept. Prog. Phys.* **70** (2007) 795, [hep-ph/0703049].

[3] F. Jegerlehner and A. Nyffeler, *The Muon g-2*, *Phys. Rept.* **477** (2009) 1–110, [arXiv:0902.3360].

[4] M. Davier, A. Hoecker, B. Malaescu, and Z. Zhang, *Reevaluation of the Hadronic Contributions to the Muon g-2 and to alpha(MZ)*, *Eur. Phys. J.* **C71** (2011) 1515, [arXiv:1010.4180]. [Erratum: Eur. Phys. J.C72,1874(2012)].

[5] K. Hagiwara, R. Liao, A. D. Martin, D. Nomura, and T. Teubner, *$(g-2)_\mu$ and $\alpha(M_Z^2)$ re-evaluated using new precise data*, *J. Phys.* **G38** (2011) 085003, [arXiv:1105.3149].

[6] M. Davier, *Update of the Hadronic Vacuum Polarisation Contribution to the muon $g-2$*, in *14th International Workshop on Tau Lepton Physics (TAU 2016) Beijing, China, September 19-23, 2016*, 2016. arXiv:1612.0274.

[7] F. Jegerlehner, *Muon g-2 Theory: the Hadronic Part*, in *KLOE-2 workshop on e^+e^- collider physics at 1 GeV, INFN-Laboratori Nazionali di Frascati, Italy, 26-28 October 2016*, 2017. arXiv:1705.0026.

[8] J. L. Holzbauer, *The Muon g-2 Experiment Overview and Status as of June 2016*, *J. Phys. Conf. Ser.* **770** (2016), no. 1 012038, [arXiv:1610.1006].

[9] **E34** Collaboration, M. Otani, *Status of the Muon g-2/EDM Experiment at J-PARC (E34)*, *JPS Conf. Proc.* **8** (2015) 025008.

[10] **Budapest-Marseille-Wuppertal** Collaboration, S. Borsanyi, Z. Fodor, T. Kawanai, S. Krieg, L. Lellouch, R. Malak, K. Miura, K. K. Szabo, C. Torrero, and B. Toth, *Slope and curvature of the hadronic vacuum polarization at vanishing virtuality from lattice QCD*, *Phys. Rev.* **D96** (2017), no. 7 074507, [arXiv:1612.0236].

[11] **Budapest-Marseille-Wuppertal** Collaboration, S. Borsanyi, Z. Fodor, T. Kawanai, S. Krieg, L. Lellouch, R. Malak, K. Miura, K. K. Szabo, C. Torrero, and B. Toth, "Hadronic vacuum polarization contribution to the anomalous magnetic moments of leptons from first principles." In preparation, 2017.

[12] **Budapest-Marseille-Wuppertal** Collaboration, S. Borsanyi et al., *Ab initio calculation of the neutron-proton mass difference*, *Science* **347** (2015) 1452–1455, [arXiv:1406.4088].

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

Only top students will be considered, as this project is very challenging. Such a student, who does well during her/his internship, will be seriously considered for the continuation PhD project.

Master2 Internship proposal at CPT, year 2018

Research team: Non-Linear Dynamics

Supervisor: Michel VITTOT

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

Project title:

Hamiltonian Description of the Electrodynamics, via the Poisson Algebra of Maxwell-Vlasov. Application to the Physics of Magnetically Confined Plasmas, in Tokamaks (like ITER).

Description:

This thesis will study the Hamiltonian approach of classical electrodynamics, via (non-canonical) Poisson structures. This relativistic Hamiltonian framework (introduced by Morrison, Marsden, Weinstein) is independent of the gauge potentials, and is well suited for a perturbation theory, in a strong inhomogeneous magnetic field (expansion in $1/|B|$, with all the curvature terms...). This algebraic and geometric description of the Maxwell-Vlasov kinetics yields some very concrete applications.

The work will focus in particular on the explicitation of the reduced dynamics of the "gyro-center", by lifting and perturbing the reduced "guiding-center" dynamics, in order to improve the efficiency of the computation and the confinement of the magnetically confined plasmas. For instance in view of the thermonuclear fusion, as in Tokamaks (international project ITER, in CEA-Cadarache) or Stellarators. The geometric approach may be implemented in any coordinates, for instance adapted to the Tokamak (toroidal coordinates or even more adapted...).

More precisely, this algebraic approach introduces a Poisson bracket which yields the Maxwell and Abraham-Lorentz equations. This is useful to describe some optimized coordinates ("normal form"), adapted to the non-trivial constants of motions ("actions"), when the magnetic field is strong. The numerical integration in these coordinates is simplified since its spatial dimensionality is reduced from 6 to 4.

Another application is the generation of higher harmonics in "Free Electron Lasers" (FEL), to create Lasers with high frequencies (toward X-rays), by interaction of ultra-relativistic electrons in a strong inhomogeneous magnetic field.

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

References:

R. G. LITTLEJOHN, "A guiding-center Hamiltonian: a new approach", J. Math. Phys. 20, 2445 (1979).

P. J. MORRISON, "The Maxwell-Vlasov equations as a continuous Hamiltonian system", Phys. Lett. 80A, 383 (1980).

P. J. MORRISON, "Poisson brackets for fluids and plasmas", AIP Conference Proceedings 88, 13 (1982).

J. E. MARSDEN, A. WEINSTEIN, "The Hamiltonian structure of the Maxwell-Vlasov equations", Physica D 4, 394 (1982).

M. VITTOT: "Perturbation Theory and Control in Classical or Quantum Mechanics by an Inversion Formula", J. Phys. A: Math. Gen., 37, 6337 (2004).

N. TRONKO, M. VITTOT, C. CHANDRE, Ph. GHENDRIH, G. CIRAOLO: "Barriers for the reduction of transport due to the ExB drift in magnetized plasmas". J. Phys. A: Math. Gen., 42, 085501 (2009).

P. J. MORRISON, M. VITTOT, L. DE GUILLEBON: "Lifting particle coordinate changes of magnetic moment type to Vlasov-Maxwell Hamiltonian dynamics", Physics of Plasmas, 20, 3 (2013).

L. DE GUILLEBON, M. VITTOT: "Gyro-gauge independent formulation of the guiding-center reduction to arbitrary order in the Larmor radius". Plasma Physics and Controlled Fusion 55, 105001 (2013).

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

This internship project may naturally lead to a PhD thesis.

Master2 Internship proposal at CPT, year 2018

Research team: Dynamical Systems: Theory and applications

Supervisor: Stéphane Delliaux (UMR MD2) and Xavier Leoncini (CPT)

e-mail: Stephane.Delliaux@univ-amu.fr, Xavier.Leoncini@cpt.univ-mrs.fr

Project title: Modelling Physiology using Physics

Description:

Modelling and simulaton in medicine are focused mainly on anatomy and surgery. Untl today, physiology has not been really concerned by medical simulation. But homeostasis that is ofen described as an automated system is one of the eight main concepts in biology, and the major concept of systems physiology. In this project, we propose to study and model homeostasis using nonlinear physics and associated signal analysis tools. The goal will be to put into equations the bases of a homeostatic model that will be sufficiently general so that it can evolve into a more quantitative one. For this purpose, the student will consider the main physiological functons involved in the main homeostats. Brain, heart, vessels, lungs, and kidneys functional anatomy will be described individually and collectvely, taken as a whole, through existng and new developed structural and functonal models. The aim is to create a model describing the dynamical behavior of the whole system that will be able first to be used as a pedagogical tool for training physicians in detecting complex interplay between the organs, and hopefully end up as an efectve help for diagnostc and early detecton of pathologies. The global philosophy will be to be able to build a tool that will both be satisfactory for the end user and built on solid scientfic grounds, i.e not an artfcial intelligence black box producing results by processing big data.

This project requires a solid base in Nonlinear Physics and dynamical systems as well as statistical physics, a good knowledge of numerical simulations and code development is also a plus. The desire to work in between disciplines in an interdisciplinary setting is a must.

References:

P. Ivanov P., *Focus on the emerging new felds of network physiology and network medicine.* New J Phys 2016.

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

This internship could naturally lead to a PhD.

Master2 Internship proposal at CPT, year 2018

Research team:

Particle theory

Supervisor:

Aoife Bharucha

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Project title:

Properties of ALPs mediated dark matter beyond freeze out and existing limits.

Description:

The tremendous progress in direct and indirect detection limits on the nature of dark matter has started to put the standard picture of the freeze out of WIMPs in question. Here we will consider a simple model where the dark matter particle interacts with the SM via an axion-like particle which plays the role of a mediator. The project will involve calculating the relic density for this model using either the freeze-in, freeze-out, or reannihilation mechanisms, depending on the region of parameter space. We will then examine the dependence on different type of axion models, with different coupling to the standard model, and the limits on these models coming from existing particle physics experiments.

References:

1. The Four Basic Ways of Creating Dark Matter Through a Portal
   By Xiaoyong Chu, Thomas Hambye, Michel H.G. Tytgat.
   arXiv:1112.0493 [hep-ph].
   JCAP 1205 (2012) 034.

2. Revised constraints and Belle II sensitivity for visible and invisible axion-like particles
   By Matthew J. Dolan, Torben Ferber, Christopher Hearty, Felix Kahlhoefer, Kai Schmidt-Hoberg.
   arXiv:1709.00009 [hep-ph].

3. ALPs Effective Field Theory and Collider Signatures
   By I. Brivio, M.B. Gavela, L. Merlo, K. Mimasu, J.M. No, R. del Rey, V. Sanz.
   arXiv:1701.05379 [hep-ph].
   Eur.Phys.J. C77 (2017) no.8, 572.

Master2 Internship proposal at CPT, year 2018

Research team:

Cosmology

Supervisor:

Federico Piazza

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Project title:

Entanglement entropy and localization in expanding Universe

Description:

The so-called Bunch-Davis vacuum in an expanding Universe represents perhaps the easiest—and yet non-trivial—example of a time-dependent quantum state. The purpose of this internship is to understand its properties in terms of entanglement entropy of "subregions of space" and to see if and how one could extend to this time-dependent situation alternative localization schemes such as the one induced by the Newton-Wigner position operator.

References

[1] C. G. Callan, Jr. and F. Wilczek, "On geometric entropy," Phys. Lett. B **333**, 55 (1994) [hep-th/9401072].

[2] H. Casini and M. Huerta, "Entanglement entropy in free quantum field theory," J. Phys. A **42**, 504007 (2009) [arXiv:0905.2562 [hep-th]].

[3] S. Cacciatori, F. Costa and F. Piazza, "Renormalized Thermal Entropy in Field Theory," Phys. Rev. D **79**, 025006 (2009) [arXiv:0803.4087 [hep-th]].

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

I do not know.

Master2 Internship proposal at CPT, year 2018

Research team:

Cosmology

Supervisor:

Julien Bel

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Project title:

From the galaxy distribution to the neutrino mass and the dark energy equation of state

Description:

Both the late time acceleration of the universe and massive neutrinos leave a specific imprint on the formation of large-scale structures. On one hand, it is well established, that galaxies, clusters and super-clusters of galaxies are organized in a different way according to the supposed mechanism responsible for the acceleration and on the other hand massive neutrinos slow down the growth of structures [1] which affects in an alternative way the large scale galaxy clustering.

During the proposed internship, the goal will be to study the impact of the modelling of the galaxy distribution in the universe on the constraints that will be potentially achievable from future large scale galaxy surveys such as Euclid and LSST.

It consists first , in understanding from a theoretical point of view how galaxies follow the underlaying dark matter distribution. 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. The second step will be to use simulated data coming from the high resolution simulation DEMNUnii [2] including dark energy and massive neutrinos and check the reliability of the developed models.

Finally, the student will develop is own numerical Monte Carlo Markov Chain code in order to forecast the constraints on parameters such as the dark energy equation of state and the neutrino mass.

References:

[1] Julien Lesgourgues and Sergio Pastor, 2006, *Massive neutrinos and cosmology*
[2] Castorina, Carbone, Bel, Sefusatti and Dolag, 2015, *DEMNUni: The clustering of large-scale structures in the presence of massive neutrinos*

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

It is unlikely that the internship may lead to a PhD thesis, it is more a self consistent pedagogical project useful for students who want to do a PhD thesis somewhere else.

Master2 Internship proposal at CPT, year 2018

Research team: Cosmology

Supervisor: Ch. Marinoni

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Project title: Effects of the global cosmological expansion on the local dynamics of the solar system

Description:

Modern cosmology is described within the framework of General Relativity and thus inherits its distinctive mark: the geometry of cosmic spacetime is subject to dynamical change. Indeed, the standard model of cosmology predicts that space is expanding. The question addressed in this project is whether, and to what extent, cosmological expansion influence the dynamics on small, local scales (as compared to cosmological ones). Notably the student will investigate the influence of particularly in our Solar System. The student will construct a metric model describing a bound system immersed in an expanding cosmos. He will solve the geodesic equations of motion of a test particle subject to this gravitational field, and gauge the amplitude of the resulting cosmological effects on local scales.

References:

- R. Gautreau, "Imbedding a Schwarzschild mass into cosmology" *Phys. Rev D* 1984, 29, p 198
- B. C. Nolan, "A point mass in an isotropic universe. Global Properties" *Classical and Quantum Gravity* 1999, p. 1227

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

Master2 Internship proposal at CPT, year 2018

Research team: Cosmology

Supervisor: Ch. Marinoni

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

Project title: Cosmic aberration drift in a modified gravity scenario

Description:

Our proper acceleration with respect to the Cosmic Microwave Background results in a real-time change of the angular position of distant extragalactic sources. The cosmological component of this aberration drift signal, the non-inertial motion generated by the large-scale distribution of matter, can in principle be detected by future high-precision astrometric experiments. It will provide interesting consistency tests of the cosmological scenario, and be instrumental in searching for evidence of new physics beyond the standard model of cosmology. The student will predict the amplitude of this cosmic effect in a specific non-standard cosmological model, the so called Lemaitre-Tolmann-Bondi cosmology. This is a model of the universe in which cosmic acceleration is not explained by augmenting the Einstein Field Equations with the cosmological constant term Λ, but by decreasing the amount of cosmic matter in the local universe. The goal is to assess wether observations of the cosmic aberration drift effect can disentangle among the standard and the LTB cosmological models

References:

- Bel and Marinoni “E pur si muove! A real-time detection of our acceleration through space" 2018, arXiv.

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

Master2 Internship proposal at CPT

Research team: NANOPHYSICS

Supervisor: Thierry Martin, Thibaut Jonckheere, Jérôme Rech

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Project title: Andreev Reflection from superconducting topological quantum matter

Description:

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.

The nanophysics team of CPT is looking for a motivated M2 student to study quantum transport, in particular Andreev reflection, between a topological superconductor nano-wire and a normal metal lead. Transport will be 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.

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. An extension of these considerations to the finite frequency noise characteristics of this TS-N junction is also envisioned.

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, depending on the academic performance.