Titles and abstracts of the talks of the conference

Estate Quantistica

Scalea, Italy — September 1 – 5, 2014

Minicourses

Klaus Fredenhagen
Universität Hamburg, Germany

Quantum Field Theory and Gravitation

Abstract: The treatment of quantum field theory in external gravitational field requires to abandon concepts which are fundamental for quantum field theory on Minkowski space, in particular the concept of particles, of the vacuum and of the S-matrix. It is explained how to reformulate quantum field theory such that these concepts are no longer needed. This amounts essentially to adopt the framework of algebraic quantum field theory in the sense of Haag, Araki and Kastler. A crucial new ingredient is a purely local implementation of the positivity requirement of the energy in the algebraic framework in terms of conditions on the wave front sets of correlation functions. It is shown that with this new ingredient the ultraviolet renormalization of quantum field theory can be performed in complete agreement with the principle of general covariance. Moreover, the new framework also allows to include quantum fluctuations of the gravitational field around a classical background, and it is shown that the resulting theory is background independent.

Alejandro Perez
Université de la Méditerranée - Aix-Marseille 2, France

Black holes and quantum gravity

Abstract: The mini-course will be organized as follows:
1) Loop quantum gravity (LQG) in a nutshell, boundary area canonical quantization.
2) Black holes in LQG, isolated horizon boundary condition, Chern-Simons theory treatment and quantization.
3) Near horizon geometry and the semiclassical quasilocal input.
4) Inclusion of matter and the calculation of Bekenstein-Hawking entropy.
5) The hard problem: BH evaporation, information loss, firewalls.

Patrick Peter
Institut d'astrophysique de Paris, France

Quantum cosmological perturbations in inflationary and bouncing models

Abstract: The recently released Planck data have revealed that the primordial spectrum of cosmological perturbations sourcing all structures in the Universe was not exactly scale-invariant but slightly red, and extremely gaussian. These properties were expected in the framework of inflation when the initial conditions for the perturbations are stemming from quantum vacuum fluctuations. Other models, such as the bouncing alternative, share the same kind of initial conditions, which have thus become part of the standard paradigm. The lectures will then focus on understanding how these perturbations are generated in cosmology. The detailled plan of the lectures is:

Lecture 1 - The standard model and its puzzles: inflation & its bouncing alternative.
Lecture 2 - Classical perturbations of a cosmological background.
Lecture 3 - Quantum vacuum fluctuations: natural initial conditions.
Lecture 4 - Data and models, where do we stand?

Manuel Asorey
Universidad de Zaragoza, Spain

Topological entropy and renormalization group flow

Abstract: We analyze the behavior of the holonomic entropy under the renormalization group flow in spaces of constant positive spacial curvature in the high temperature limit. We show that it monotonically decreases as the renormalization group (RG) flows to the infrared. The values of the holonomic entropy do coincide at the conformal fixed points with topological entropies. The monotonicity of the renormalization group flow leads to an inequality $S_{top}^{UV} > S_{top}^{IR}$ between the topological entropies of the conformal field theories connected by such flow. The monotonic behavior suggest that the topological entropy is a good candidate for 3-dimensional generalization of the c-theorem, along the lines of the 2-dimensional c-theorem and the 4-dimensional a-theorem.

Eugênio Ramos Bezerra de Mello
Universidade federal da Paraíba, Brazil

Induced bosonic current by magnetic flux in a compactified cosmic string spacetime.

Abstract: We analyse the bosonic current densities induced by a magnetic flux running along an idealized cosmic string spacetime, admitting that the coordinate along the string's axis is compactified. Additionally we admit the presence of an magnetic flux enclosed by the compactification axis. In order to develop this analysis we calculate the complete set of normalized bosonic wave-functions obeying a general quasiperiodicity condition along the compactified dimension in this spacetime. As we shall see there are no induced charged density or radial currrent. Only azimuthal current will be induced and, due to the compactification, a non-vanishing induced axial current also takes place.

Michael Bordag
Universität Leipzig, Germany

Monoatomically thin polarizable sheets

Abstract: We consider a flat lattice of dipoles modelled by harmonic oscillators interacting with the electromagnetic field in dipole approximation. Eliminating the variables from the coupled equations of motion, we come to effective Maxwell equations. These allow for taking the lattice spacing a to zero. As a result, we obtain reflection coefficients for the scattering of electromagnetic waves off the sheet. These are a generalization of that known from the hydrodynamic model. For instance, we get a non trivial scattering for polarizability perpendicular to the sheet. Also we show that the case of a sheet polarizable parallel to the sheet, can be obtained in a natural way from a plasma layer of finite thickness. As an alternative approach we discuss the elimination of the electromagnetic fields resulting in effective equations for the oscillators. These shown, for $a \to 0$, divergent behaviour, resulting from the electrostatic interaction of the dipoles.

Romeo Brunetti
Università degli studi di Trento, Italy

Locality and tensor products

Abstract: In the setting of locally covariant algebraic quantum field theories we wish to extend the categorical approach by embedding the locality principle directly into the categorical structure.

Saul Carneiro
Universidade federal da Bahia, Brazil

On Dark Degeneracy

Abstract: Cosmological background observations cannot fix the dark energy equation of state, which is related to a degeneracy in the definition of the dark sector components. Here we show that this degeneracy can be broken at perturbation level by imposing two observational properties on dark matter. First, dark matter is defined as the clustering component we observe in large scale structures. This definition is meaningful only if dark energy is unperturbed, which is achieved

if we additionally assume, as a second condition, that dark matter is cold, i.e. non-relativistic. As a consequence, dark energy models with equation-of-state parameter $-1 \leq \omega < 0$ are reduced to two observationally distinguishable classes with $\omega = -1$, equally competitive when tested against observations. The first comprises the ΛCDM model with constant dark energy density. The second consists of interacting models with an energy flux between dark energy and dark matter.

Michel Dubois-Violette
Université Paris-Sud, France

Quantum automorphism groups of regular noncommutative coordinate algebras

Abstract: Regular noncommutative coordinate algebras which generalize the algebras of polynomials are completely specified by a class of multilinear forms, the preregular multilinear forms, (up to the action of linear groups). A m-linear form w on a finite-dimensional vector space E is said to be preregular when it is cyclic twisted by an element of $GL(E)$ and 1-site nondegenerate. Given such a preregular m-linear form w with $m \geq 2$ and an integer N with $m \geq N \geq 2$, one defines a N-homogeneous algebra $\mathcal{A}(w, N)$. Any (A-S)-regular algebra which is N-Koszul is of this form for a certain preregular multilinear form w. We describe the universal quantum group preserving such a preregular multilinear form w, by means of an explicit finite presentation of the corresponding Hopf algebra. This quantum group is, in particular, a quantum automorphism group of $\mathcal{A}(w, N)$. This is a joint work with Julien Bichon.

Betti Hartmann
Universidade federal do Espírito Santo, Brazil & Jacobs University Bremen, Germany

Stability of (asymptotically) Anti-de Sitter space-times

Abstract: Anti-de Sitter (AdS) as well as asymptotically AdS (aAdS) space-times have gained lots of interest recently, mainly due to the Anti-de Sitter/Conformal Field Theory (AdS/CFT) correspondence. Since the boundary of AdS - unlike that of Minkowski space-time - is time-like important differences appear. This includes the properties of black holes as well as the non-linear stability. Black holes in AdS can become thermodynamically unstable to form scalar hair close to their horizon. This onset of an instability has been used in various settings to describe phenomena in strongly coupled field theories. Moreover, while it has been proven that AdS is linearly stable with respect to scalar, vector and tensor perturbations, recent results seem to indicate that AdS is non-linearly unstable to the formation of black holes under arbitrary initial data. If this turns out to be true, the AdS/CFT correspondence would imply that the CFT on the AdS boundary would always thermalize. On the other hand, aAdS solutions exist that can be non-linearly stable. In this talk, I will review what is known about the (in)stability of (a)AdS, mention the implications and point out future directions.

Fedele Lizzi
Università degli studi di Napoli - Federico II, Italy

Noncommutative Geometry and the Standard Model of particle interaction

Abstract: A review of the spectral approach to the standard model based on noncommutative geometry pioneered by Connes and collaborators. The model is now confronting itself with the new data coming from experiments. The possible evolutions of the model, mainly related to the symmetries are described.

Antonio López Maroto
Universidad Complutense de Madrid, Spain

Vacuum energy in perturbed Robertson-Walker backgrounds

Abstract: We will consider the problem of evaluating the vacuum energy of massive quantum fields in an expanding universe taking into account the effects of metric perturbations. We explore the possibility of defining the renormalized energy-momentum tensor by means of a comoving cutoff regularization. Exact solutions for de Sitter space-time show that in a certain range of mass and renormalization scales there is a contribution to the vacuum energy density that scales as non-relativistic matter and that such a contribution becomes dominant at late times. By means of the WKB approximation, we will show that these results can be extended to arbitrary Robertson-Walker geometries. We study the range of parameters in which the vacuum energy density would be compatible with current limits on dark matter abundance. We will extend the calculation to Robertson-Walker backgrounds including scalar perturbations, and will obtain the speed of sound of density perturbations, thus showing that the vacuum energy density contrast can grow on sub-Hubble scales very much in the same way as in standard cold dark matter scenarios.

Oliver Piattella
Universidade federal do Espírito Santo, Brazil

The effect of dark matter velocity dispersion on the evolution of cosmological perturbations

Abstract: We investigate a modification of the standard ΛCDM cosmological model in which the dark matter velocity dispersion is non-negligible. We calculate the effect of the latter on the evolution of cosmological perturbations and determine the modifications on the cosmic microwave background radiation spectrum and on the matter power spectrum by suitably modifying the CAMB code.

Nicola Pinamonti
Università degli Studi di Genova, Italy

Quantum field theory on curved spacetime and semiclassical Einstein equations

Abstract: After reviewing the theory of quantum fields propagating on curved backgrounds, we shall consider their back-reaction on gravity. This will be done in the case of a free massive quantum scalar fields and using the Einstein equations in a semiclassical fashion. The analysis we would like to present requires a careful study of the ultraviolet divergences and their renormalization, which is required in order to obtain meaningful expressions for the expectation values of the stress energy tensor in quantum theories. The resulting stress tensor will have a nontrivial effect on the curvature on cosmological spacetimes too. In the latter case, the semiclassical Einstein equations become a well posed dynamical system provided the quantum state for matter is chosen in an appropriate way. The question of existence of exact solutions of such system will be discussed and some implication for cosmology will be presented.

Nelson Pinto-Neto
Centro Brasileiro de Pesquisas Físicas, Brazil

Quantum cosmology from the de Broglie-Bohm perspective

Abstract: We review the main results that have been obtained in quantum cosmology from the perspective of the de Broglie-Bohm quantum theory. As it is a dynamical theory of assumed objectively real trajectories in the configuration space of the physical system under investigation, this quantum theory is not essentially probabilistic and dispenses the collapse postulate, turning it suitable to be applied to cosmology. In the framework of minisuperspace models, we show how quantum cosmological effects in the de Broglie-Bohm approach can avoid the initial singularity.We then extend minisuperspace in order to include linear cosmological perturbations. We present the main equations which govern the dynamics of quantum cosmological perturbations evolving in non-singular quantum cosmological backgrounds, and calculate some of their observational consequences. These results are not known how to be obtained in other approaches to quantum theory. Finally, we compare some of the results coming from the de Broglie-Bohm theory with other approaches, and discuss the physical reasons for some discrepancies that occur. This is joint work with J. C. Fabris.

References

[1] N. Pinto-Neto and J. C. Fabris, Classical and Quantum Gravity **30**, 143001 (2013).

Pierre Schapira
Univeristé Paris 6, France & Université du Luxembourg

Hyperbolic systems on causal manifolds

Abstract: We shall explain how to solve the global Cauchy problem on Lorentzian manifolds for hyperbolic systems of linear partial differential equations in the framework of hyperfunctions. Besides the classical Cauchy-Kowalevsky theorem, our proofs only use tools and ideas from the microlocal theory of sheaves of [KS90], that is, tools of purely algebraic and geometric nature.

References

[DS99] A. D'Agnolo and P. Schapira, *Global propagation on causal manifolds*, Asian Math. Journ (1999).
[JS14] B. Jubin and P. Schapira, *Topology of causal manifolds and applications to sheaves*, in progress (2014).
[KS90] M. Kashiwara and P. Schapira, *Sheaves on Manifolds*, Grundlehren der Math. Wiss. 292 Springer-Verlag (1990).
[Sc13] P. Schapira, *Hyperbolic systems on causal manifolds*, Lett. Math. Phys. **103** 1149-1164 (2013); arXiv:1305.3535

Ilya L. Shapiro
Universidade Federal de Juiz de Fora, Brazil

Renormalization group in quantum gravity

Abstract: We review several aspects of renormalization group in quantum gravity in 4d. The standard perturbative renormalization group equations can be formulated only in the renormalizable versions of the theory, which have higher derivatives and therefore meet severe problems with unphysical massive ghosts. In some of such theories the renormalization group equations still have certain ambiguity, e.g. due to the gauge fixing dependence. At the same time the renormalization group can provide a necessary non-perturbative information about the presence (or not) of the asymptotic ghost states in the higher derivative theories. At the same time, the non-perturbative versions of renormalization group in gauge theories (including gravity) meet even more ambiguities related to gauge fixing. Finally, there are some gauge-invariant versions of renormalization group.

Teoman Turgut
Boğaziçi University, Turkey

Heat Kernel Methods in Singular Problems

Abstract: We will present some of the results we obtained in understanding singular quantum systems via heat kernel techniques. First we study a nonrelativistic particle under the influence of an attractive delta potential concentrated on a closed curve in two and three dimensions. In a similar way, one can study a many body problem, an over-simplified version of the bosonic Lee model. Another interesting application is given to the Bogoliubov theory of a weakly interacting system of bosons.

Winfried Zimdahl
Universidade federal do Espírito Santo, Brazil

Interactions in the Dark Sector of the Universe

Abstract: Since the interpretation of the SNIa observations by the SCP (Supernova Cosmology Project) and HZT (High-z Supernova Search Team) collaborations as evidence for an accelerated expansion of our present Universe, cosmologists have been challenged to provide a physically consistent description of this phenomenon. Although there exists a standard model, the ΛCDM model, which *grosso modo* seems able to account for the observed dynamics, there remain good reasons to study alternative models both within GR and in the context of alternative gravity. In standard descriptions the matter content of the Universe is modeled in terms of perfect fluids (and/or minimally coupled scalar fields) with simple equations of state. However, if dynamically dominating components deviate from being separately conserved perfect fluids and have a more complicated internal structure, the cosmic evolution, in particular the perturbation dynamics, may differ from that of the standard model. After briefly reviewing basic principles of relativistic fluid dynamics we discuss different phenomenological models of the cosmological dark sector and confront them with observational data. We focus on models in which dark matter and dark energy are non-gravitationally coupled to each other. Potential interactions result in corrections to the dynamics of non-interacting models. Moreover, there are models in which an interaction is crucial and accelerated expansion may be an interaction phenomenon. Examples are decaying vacuum models, specific holographic models and models of transient acceleration. The latter allow for a future evolution different from that of the standard ΛCDM model.

Ghaliah Alhamzi
Swansea University, United Kingdom

From Homotopy to Itô Calculus

Abstract: We begin with a deformation of a differential graded algebra by adding time and using a homotopy. It is shown that the standard formulae of Itô calculus are an example, with four caveats: First, it says nothing about probability. Second, it assumes smooth functions. Third, it deforms all orders of forms, not just first order. Fourth, it also deforms the product of the forms. An isomorphism between the deformed and original differential graded algebras may be interpreted as the transformation rule between the Stratonovich and classical calculus (again no probability).

Cecilia Chirenti
Universidade Federal do ABC, Brazil

No asymptotically highly damped quasi-normal modes without horizons?

Abstract: We explore the question of what happens with the asymptotically highly damped quasi-normal modes when the underlying spacetime has no event horizons. We consider the characteristic oscillations of a scalar field in a large class of asymptotically flat spherically symmetric static spacetimes without (absolute) horizons, such that the class accommodates the cases that are known to be of some sort of physical interest. The question of the asymptotic quasi-normal modes in such spacetimes is relevant to elucidate the connection between the behavior of the asymptotic quasi-normal modes and the quantum properties of event horizons, as put forward in some recent important conjectures. We prove for a large class of asymptotically flat spacetimes without horizons that the scalar field asymptotically highly damped modes do not exist. This provides in our view additional evidence that there is indeed a close link between the asymptotically highly damped modes and the existence of spacetime horizons (and their properties).

Bruno Ferreira Rizzuti
Universidade Federal do Amazonas, Brazil

Classical Description of the Electron as an Extended Object

Abstract: The description of the *Zitterbewegung* at a classical level indicates possible predictions of the electron quantum properties even before quantization: this quivering motion is restricted to a plane, which leads us to only two possible orientations of the corresponding angular momentum, even in the absence of a quantized theory or external fields. Besides, the angular momentum associated with the *Zitterbewegung* turns out to be proportional to $\hbar$. Thus, assuming that this is an observable phenomenon, we recognize this oscillatory motion as a possible classical signature of the spin of the electron. We also propose here an interpretation of the *Zitterbewegung*based on geometrical grounds: it can be seen as the physical degrees of freedom of position variables constrained to a sphere, which enforces the hypothesis of assuming an electron internal structure. This is joint work with Everton M. C. Abreu and Pricles V. Alves.

Júlio C. Fabris
Universidade federal do Espírito Santo, Brazil

An effective model for quantum effects in gravitational theories

Abstract:

Benoît Jubin
Université du Luxembourg, Luxembourg

Causal topology and propagators on spacetimes

Abstract: We introduce the “causal topology” on (Lorentzian) spacetimes and show that it contains all the information about their causal structure. We use this to prove important properties of the causal orders of globally hyperbolic spacetimes, which in turn allow us to construct “propagators” on these spacetimes. These propagators are key ingredients in the study of the global Cauchy problem on spacetimes presented in Pierre Schapira’s talk. This is joint work with Pierre

Schapira.

Elena Konstantinova
Instituto Federal Sudeste de Minas Gerais, Brazil

Scalar-Interchange Potential and Magnetic/Thermodynamic Properties of Graphene-like Materials

Abstract: In order to implement the effect of curved surface to the theoretical description of graphen-like materials, one can introduce an extra intermediate boson, which should be a scalar field in the two-dimensional case. The effect of such a boson can be reduced to a new class of interparticle interaction potential which is a function of external and internal conditions of graphene-like systems. We investigate the behavior of the systems with such a potential by means numerical simulations. The Monte Carlo method - based analysis enables one to explore the curved graphen systems under variations of such parameters as external magnetic field, temperature, and also the dependence on the particular type of the exchanged excitation that generates the potential. We consider the spin configurations, the differences in thermal equilibrium magnetization, magnetic susceptibility and the specific heat that arise in the situation where, in addition to the electromagnetic interaction, there is a potential due to the exchange of a massive scalar, associated to the Kekulé deformations, with a spin-dependent profile.

Based on collaboration with Ricardo Spagnuolo Martins and José Abdalla Helayël-Neto.

Roa Makki
Swansea University, United Kingdom

The Majid-Ruegg model and the Planck scales

Abstract: A novel differential calculus with central inner product is introduced for κ-Minkowski space. The 'bad' behaviour of this differential calculus is discussed with reference to symplectic quantisation and A-infinity algebras. Using this calculus in the Schrödinger equation gives two values which can be compared with the Planck mass and length. This comparison gives an approximate numerical value for the deformation parameter in κ-Minkowski space. We present numerical evidence that there is a potentially observable variation of propagation speed in the Klein-Gordon equation. The modified equations of electrodynamics (without a spinor field) are derived from noncommutative covariant derivatives. We note that these equations suggest that the speed of light is independent of frequency, in contrast to the KG results (with the caveat that zero current is not the same as in vacuum). We end with some philosophical comments on measurement related to quantum theory and gravity (not necessarily quantum gravity) and noncommutative geometry.

Sebastião Mauro Filho
Universidade Federal de Juiz de Fora, Brazil

Equations for metric perturbations in the theory of fourth order gravity

Abstract: Recent studies in the literature have addressed the problem of instability in the theory of fourth order gravity in a similar manner to that discussed in the context of black string in 5-d and bi-metric theory. This is due to the fact assume that the disturbances in the Ricci tensor can be decoupled from the metric perturbations. So when the background metric satisfies Einstein's equations in vacuum we obtain the same equations that characterize the Gregory-Laflamme instability in black string 5-d and bi-metric theory. We consider part of the arguments related to this statement.

Poliane de Morais Teixeira
Universidade Federal de Juiz de Fora, Brazil

Quantum Einstein-Cartan theory with the Holst term

Abstract: Holst term represents an interesting addition to the Einstein-Cartan theory of gravity with torsion. When this term is present the contact interactions between vector and axial vector fermion currents gain an extra parity-violating component. We re-derive this interaction using a simple representation for the Holst term. The same representation serves as a useful basis for the calculation of one-loop divergences in the theory with external fermionic currents and cosmological constant. Furthermore, we explore the possibilities of the on-shell version of renormalization group and construct the equations for the running of dimensionless parameters related to currents and for the effective Barbero-Immirzi parameter.

Tibério de Paula Netto
Universidade Federal de Juiz de Fora, Brazil

One-loop divergences in the Galileon model

Abstract: The investigation of UV divergences is a relevant step in better understanding of a new theory. In this work the one-loop divergences in the free field sector are obtained for the popular Galileons model. The calculations are performed by the generalized Schwinger-DeWitt technique and also by means of Feynman diagrams. The first method can be directly generalized to curved space, but here we deal only with the flat-space limit. We show that the UV completion of the theory includes the $\pi\Box^4\pi$ term. According to our previous analysis in the case of quantum gravity, this means that the theory can be modified to become superrenormalizable, but then its physical spectrum includes two massive ghosts and one massive scalar with positive kinetic energy. The effective approach in this theory can be perfectly successful, exactly as in the higher derivative quantum gravity, and in this case the non-renormalization theorem for Galileons remains valid in the low-energy region.