Cosmology, the Quantum Vacuum, and Zeta Functions

Talks scheduled for the Workshop

*Catalysis of Black Holes/Wormholes Formation in High Energy Collisions.*
*I. Aref’eva,* (Steklov Mathematical Institute, Russian Academy of Sciences, Russia)

The current paradigm suggests that BH/WH formation in particles collisions will happen when a center-mass energy of colliding particles is sufficiently above the Planck scale (the transplanckian region). We confirm the classical geometrical cross section of the BH production reconsidering the process of two transplanckian particles collision in the rest frame of one of incident particles. This consideration permits to use the standard Thorne's hoop conjecture for a matter compressed into a region to prove a variant of the conjecture dealing with a total amount of compressed energy in the case of colliding particles.

We briefly mention that the process of BH formation is catalyzed by the negative cosmological constant and by a particular scalar matter, namely dilaton, while it is relaxed by the positive cosmological constant and at a critical value just turns off.

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* Vacuum energy and the topology of the Universe
*M. Asorey* (Universidad de Zaragoza)

We analyze the dependence of the quantum vacuum energy on the space topology. In particular we point out the transition between contractive and repulsing regimes in popular cosmological backgrounds.

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*Modelling the growth of structure with evolving dark energy*
*C. Baugh* (Durham University)

I will describe recent N-body simulations of quintessence cold dark matter models carried out by Jennings et al. (2010). These calculations take into account the impact of quintessence on the expansion rate of the universe and the shape of the matter power spectrum. I will also present predictions for the form of redshift space distortions in different cosmologies, which are set by the rate at which structure grows.

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* Vacuum energy between a sphere and a plane at finite temperature*
*M. Bordag* (Leipzig University)
We consider the Casimir effect for a sphere in front of a plane at finite temperature for scalar and electromagnetic fields and calculate the limiting cases. For small separation we compare the exact results with the corresponding ones obtained in proximity force approximation. For the scalar field with Dirichlet boundary conditions, the low temperature correction is of order $T^2$ like for parallel planes. For the electromagnetic field it is of order $T^4$. For high temperature we observe the usual picture that the leading order is given by the zeroth Matsubara frequency. The non-zero frequencies are exponentially suppressed except for the case of close separation.

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**Brane Cosmology with f(R) Contribution**

**M. Bouhmadi-López** (CENTRA, Lisboa)

We propose a generalised induced gravity brane-world model where the brane action contains an arbitrary f(R) term, R being the scalar curvature of the brane. We show that the effect of the f(R) term on the dynamics of a homogeneous and isotropic brane is twofold: (i) an evolving induced gravity parameter and (ii) a shift on the energy density of the brane. This new shift term, which is absent on the Dvali, Gabadadze and Porrati (DGP) model, plays a crucial role to self-accelerate the generalised normal DGP branch of our model. We analyse as well the stability of de Sitter self-accelerating solutions under homogeneous perturbations and compare our results with the standard 4-dimensional one. Finally, we obtain power law solutions which either correspond to conventional acceleration or super-acceleration of the brane. In the latter case, no phantom matter is invoked on the brane nor in the bulk.

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**Casimir effect for the piecewise uniform string**

**I. Brevik** (NTNU, Trondheim, Norway)

The Casimir energy for the transverse oscillations of a piecewise uniform closed string is calculated, and the great adaptability of this string model with respect to various regularization methods is pointed out. Several regularization methods are surveyed: the cutoff method, the complex contour integration method, and the zeta-function method. The most powerful method in the present case is the contour integration method. The Casimir energy is negative, and the more so the larger is the number of pieces in the string. The thermodynamic free energy, and the critical Hagedorn temperature, are calculated for a two-piece string.

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**Background Field Method for d=3, N=3 Supergauge Theories**

**I. L. Buchbinder** (TSPU, Tomsk, Russia)

We develop the background field method for studying quantum structure of N=3, d=3 Chern-Simons and matter theories in N=3 harmonic superspace. As one of the immediate consequences, we prove a nonrenormalization theorem implying the ultra-violet finiteness of the corresponding supergraph perturbation theory.
Cosmography and Large Scale Structure from Higher Order Gravity

S. Capozziello (Università di Napoli “Federico II”, Italy)

Accelerated expansion and missing matter problems can be addressed in the framework of higher order gravity theories. We review recent results on these topics showing how cosmological observations can be addressed by adopting non linear actions in curvature invariants instead of disturbing issues as dark energy and dark matter.

An analysis of the phase space of Hovrava-Lifshitz cosmologies

S. Carloni (IEEC, Barcelona)

Using the dynamical system approach, properties of cosmological models based on the Hovrava-Lifshitz gravity are systematically studied. In particular, the cosmological phase space of the Hovrava-Lifshitz model is characterized. The analysis allows to compare some key physical consequences of the imposition (or not) of detailed balance. A result of the investigation is that in the detailed balance case one of the attractors in the theory corresponds to an oscillatory behavior. Such oscillations can be associated to a bouncing universe, as previously described by Brandenberger, and will prevent a possible evolution towards a de Sitter universe. Other results obtained show that the cosmological models generated by Hovrava-Lifshitz gravity without the detailed balance assumption have indeed the potential to describe the transition between the Friedmann and the dark energy eras. The whole analysis leads to the plausible conclusion that a cosmology compatible with the present observations of the universe can be achieved only if the detailed balance condition is broken.

Interferometric detection of gravitational waves: the definitive test for General Relativity

C. Corda (Associazione Galilei, Italy)

Even if Einstein's General Relativity achieved a great success and overcame lots of experimental tests, it also showed some shortcomings and flaws which today advise theorists to ask if it is the definitive theory of gravity. In this talk we show that, if advanced projects on the detection of Gravitational Waves (GWs) will improve their sensitivity, allowing to perform a GWs astronomy, accurate angular and frequency dependent response functions of interferometers for GWs arising from various Theories of Gravity, i.e. General Relativity and Extended Theories of Gravity, will be the definitive test for General Relativity. The papers which found this talk have been the world's most cited in the official Astroparticle Publication Review of ASPERA during the 2007. This talk is also a resume of the Essay written for the 2009 Gravity Research Foundation Awards which resulted an Honorable Mention Winner, see International Journal of Modern Physics D, Volume: 18, Issue: 14 (2009) pp. 2275-2282

Galaxies, voids and the large-scale structure of the Universe

D. Croton (Swinburne University, Australia)
I will discuss the use of void and higher-order clustering statistics to unravel the nature of structure formation in the Universe using data from the 2dF Galaxy Redshift Survey. These results will be interpreted with cosmological dark matter N-body simulations and semi-analytic galaxy formation models.

Coalescing binaries as possible standard candles
M. De Laurentis (Università di Napoli "Federico II", Italy)

Hamilton--Jacobi Method and Gravitation
R. Di Criscienzo and L. Vanzo (University of Trento & INFN, Italy)

We show how to compute the two-dimensional semi-classical tunneling amplitude from a naked singularity and its agreement with the one-loop result of quantum field theory.

Towards and understanding of the cosmology of f(R) gravity models
P. Dunsby (University of Cape Town, South Africa)

We present a detailed analysis of cosmological perturbation theory in f(R) gravity and give for the first time the complete matter power spectrum for R^n gravity. This leads to the discovery of a characteristic signature in the matter power spectrum, the details of which have not seen before in other studies in this area and therefore provides a crucial test for fourth order gravity on cosmological scales.

Clifton’s spherical solution in f(R) vacuo harbours a naked singularity
V. Faraoni (Bishop's University, Canada)

Clifton’s spherically symmetric exact solution of f(R) = R^(1+δ) gravity describing a dynamical metric which is asymptotically Friedmann–Lemaitre–Robertson–Walker is studied. It is shown that it harbours a strong spacetime singularity which becomes naked at late times.

Unified models of dark matter and energy
A. Feinstein (Universidad del País Vasco, Bilbao, Spain)

Dark metric and the gravitational origin of the conformal factor in modified gravity
M. Francaviglia (University of Torino, Italy)

As is well known, General Relativity cannot be the definitive theory of Gravitation due to several shortcomings both from theoretical and experimental viewpoints. At large scales (astrophysical and cosmological scales) the attempts to match it with the current
observational data lead to invoke Dark Energy and Dark Matter as the bulk components of the cosmic fluid. Since no final experimental evidence, at the fundamental level, exists for such ingredients, it is clear that General Relativity presents shortcomings at infrared scales. On the other hand, the attempts to formulate theories more general than Einstein GR give rise to mathematical difficulties that need workarounds which, in turn, generate problems from the interpretative viewpoint. Moreover a scalar factor, interpreted as a dilaton or as a possible responsible for dark matter, is often invoked. We present here a completely new approach - based on the classical analysis of Ehlers, Pirani & Schild - to the mathematical objects in terms of which a theory of Gravitation may be written in a first-order (’a la Palatini) formalism, and introduce the concept of Dark Metric which could completely bypass the introduction of disturbing concepts as Dark Energy and Dark Matter. The gravitational origin of the conformal factor is discussed both in the second order (purely metric) and in the first order (metric-affine) formalisms.

Running Cosmological Constant and Running Newton Constant in Modified Gravity Theories
R. Garattini (Università di Bergamo, Italy)

We discuss how to extract information about the cosmological constant from the Wheeler-DeWitt equation, considered as an eigenvalue of a Sturm-Liouville problem in a de Sitter and Anti-de Sitter background. The equation is approximated to one loop with the help of a variational approach with Gaussian trial wave functionals. A canonical decomposition of modes is used to separate transverse-traceless tensors (graviton) from ghosts and scalar. We show that no ghosts appear in the final evaluation of the cosmological constant. A zeta function regularization is used to handle with divergences. A renormalization procedure is introduced to remove the infinities together with a renormalization group equation. We apply this procedure on the induced cosmological constant $\Lambda$ and, as an alternative, on the Newton constant $G$. A brief discussion on the extension to a $f(R)$ theory is considered.

Cosmology with galaxy maps
Enrique Gaztañaga (ICE-IEEC/CSIC), Barcelona, Spain

(Super) Particles in an external electromagnetic background. Non-central extensions of (Super) Poincaré algebra
J. Gomis (Universitat de Barcelona, Spain)

We describe the motion of a distribution of charged particles in an generic electromagnetic background in terms of an infinite dimensional symmetry algebra obtained from the Poincare group. Some results of the supersymmetric extension will be also discussed. A possible role of these infinite dimensional symmetries in M/string theory will be conjectured.
Landscaping the Yang-Mills Quantum vacuum

A. González-Arroyo (Universidad Autónoma de Madrid, Spain)

The non-perturbative properties of the Quantum vacuum of Yang-Mills theories, are still to be fully understood. The talk reviews the difficulties encountered in Lattice Gauge Theory studies to achieve this goal. A recent proposal by the author, based upon Supersymmetry is discussed.

Lensing effects in ringholes and the multiverse

P. González-Díaz (IMAFF, Madrid, Spain)

It is argued that whereas the Shatskiy single rings produced by the gravitational inner field of a spherically symmetric wormhole could not be used to identify its presence in the universe or the contents of a parallel universe because such rings may be confused with the most familiar Einstein rings, the image which the inner gravitational field of a ringhole with toroidal symmetry would allow us to detect from a single luminous source situated behind the ringhole in our universe or in a parallel universe is that of two concentric bright rings, and this is a signature that cannot be attributed to any other single astronomical object in whichever universe it may be placed. At the beginning of 2008 the ASA/ESA Hubble Space Telescope revealed a never-before-seen phenomenon in space: a pair of glowing rings, one nestled inside the other like a bull's-eye pattern. It is our alternate proposal in this paper to attribute such a discovery to the first astronomical ringhole found in the universe, rather than to the highly unlikely double lensing effect produced by the required ultra precise alignment of three galaxies along the line of sight.

Yukawa Type Interaction in Non-Equilibrium Thermofield Dynamics.

T. Inagaki (Hiroshima University, Japan)

Zeta functions of quantum graphs and cosmological pistons

K. Kirsten (Baylor University, Texas, USA)

In this talk zeta functions of quantum graphs are considered using a contour integral technique based on the argument principle. Arbitrary graphs $\mathcal{G}$ with general vertex matching conditions are analyzed. Applications to cosmological pistons are provided. These are obtained by considering manifolds of the type $\mathcal{G} \times \mathcal{C} \times \mathcal{N}$, where $\mathcal{G}$ is a graph with two bonds, $\mathcal{C}$ is the two dimensional cross section of the piston and $\mathcal{N}$ represents additional Kaluza-Klein dimensions. In particular we investigate the question how the force on the piston depends on the matching condition at the vertices.

Hamiltonian ADM Gravity in Non-Harmonic Gauges with well defined non-Euclidean 3-spaces:
How much Darkness can be explained as a Relativistic Inertial Effect?

**L. Lusanna** (INFN, Sezione di Firenze, Italy)

The York canonical basis of ADM gravity in asymptotically Minkowskian spacetimes is defined and analyzed in a family of non-harmonic 3-orthogonal gauges. The York time $^3K$ (the relativistic inertial gauge variable, not existing in Newtonian gravity, parametrizing the family and connected to the freedom in clock synchronization, i.e. to the definition of the instantaneous 3-spaces) is put equal to an arbitrary numerical function. The matter are point particles. After a consistent Hamiltonian Post-Minkowskian linearization, we solve the constraints and the Hamilton equations for the tidal variables and we find Post-Minkowskian gravitational waves with asymptotic background propagating on dynamically determined non-Euclidean 3-spaces. The dependence on the York time of the equations of motion of the particles and of quantities like the redshift and the luminosity distance is explicitly given. As a consequence of a discussion on the {it gauge problem in general relativity}, it turns out that there is the possibility that at least part of dark matter (and maybe of dark energy) could be explained as a relativistic inertial effect at the 0.5PN order induced by the York time.

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**Dark energy: an electromagnetic relic from inflation**

**A. Maroto** (Universidad Complutense de Madrid, Spain)

Out of the four components of the electromagnetic field, Maxwell's theory only contains two physical degrees of freedom. However, in an expanding universe, consistently eliminating one of the "unphysical" states in the covariant (Gupta-Bleuler) formalism turns out to be difficult to realize. In this talk we explore the cosmological consequences of the presence of this third electromagnetic polarization. Although the new state is completely decoupled from charged matter and the theory reduces to standard QED in the flat space-time limit, the new polarization can be excited gravitationally. In fact, primordial quantum fluctuations produced during inflation can give rise to super-Hubble temporal electromagnetic modes whose energy density behaves as a cosmological constant. The value of the effective cosmological constant is shown to agree with observations provided inflation took place at the electroweak scale. The theory is compatible with all the local gravity tests and is free from classical or quantum instabilities. Thus we see that, not only the true nature of dark energy can be established without resorting to new physics, but also the value of the cosmological constant finds a natural explanation in the context of standard inflationary cosmology. Finally, we discuss several observational consequences of the theory.

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**Multiple Scattering: Temperature, Dispersion, and Annular Pistons**

**K. Milton** (University of Oklahoma, United States)

The multiple scattering technique allows one in principle to compute quantum vacuum forces exactly between arbitrary bodies. Here we apply such methods to examine temperature and dispersive effects. As a numerical example, the torque on an annular piston will also be discussed.
On the viability of a non-analytical f(R)-theory
G. Montani (ENEA and ICRANet, Italy)

We show how a power law correction to the Einstein-Hilbert action provides a viable modified theory of gravity, passing the Solar system tests, when the exponent is between the values 2 and 3. Then we implement this paradigm on a cosmological setting, outlining how the main phases of the Universe thermal history are properly reproduced, including the late acceleration-dominated era, in which the scale factor exponentially grows. Finally, the propagation of gravitational waves on this modified cosmological background is addressed and some relevant features presented.

Reconstruction of dark energy models
S. Nojiri (Nagoya University, Japan)

Mainly based on 0912.5066 and 1001.0220, we review how we can construct the gravity models which reproduces the arbitrary development of the universe. We consider the reconstruction in the Einstein gravity coupled with generalized perfect fluid, scalar-Einstein gravity, k-essence model, Brans-Dicke type mode, scalar-Einstein-Gauss-Bonnet gravity, Einstein-$F(G)$-gravity, and $F(R)$-gravity, etc. Very explicit formulas are given to reconstruct the models, which could be used when we find the detailed data of the development of the universe by future observations. Especially we find the formulas using e-foldings, which has a direct relation with observed redshift. As long as we observe the time development of the Hubble rate $H$, there exists a variety of models describing the arbitrary development of universe.

Galaxy and Mass Assembly (GAMA): a survey probing fundamental Cold Dark Matter model predictions
P. Norberg (University of Edinburgh, United Kingdom)

The 2dFGRS and the SDSS surveys transformed our view of large scale structure in the low redshift Universe, reinforcing our standard cosmological model: a flat, dark energy dominated collisionless Cold Dark Matter model (LambdaCDM). However, neither survey is able to put stringent constraint on a key CDM model prediction, i.e. the shape of the dark matter halo mass function, a crucial component to all hierarchical galaxy formation models. Therefore, we designed the Galaxy And Mass Assembly (GAMA) survey with primary aim to accurately determine the CDM halo mass function over a large mass range. This deep (ten times fainter than SDSS) and wide (>250 sq.deg.) galaxy redshift survey samples the underlying large scale structure with unprecedented detail. GAMA probes the key scale over which the baryons and baryon physics become critical to our understanding of the structures we see: the kpc to Mpc range. Started in March 2008 using AAOmega on the AAT, GAMA has acquired already more than 95k good quality spectra of galaxies, typically ten times fainter than those targeted by SDSS or 2dFGRS. In this talk, I briefly overview the main GAMA science goals, followed by some preliminary and exciting science results from this new exquisit dataset.
Nonsingular modified gravity with cosmological applications

S. D. Odintsov (ICREA and ICE/CSIC-IEEC, Barcelona, Spain)

Holographic dark energy at the Ricci scale

D. Pavón (Universitat Autònoma de Barcelona, Spain)

We explore the consequences of identifying the Ricci and infrared scales in the context of holographic dark energy, both when matter and dark energy evolve independently and also when they interact with each other.

Zeta-regularization of the product of prime numbers and transalgebraic number theory

R. Pérez-Marco (CNRS Paris, France)

The purpose of this talk is to present an extension of the classical zeta-regularization of infinite products. This allows the computation of the product of all prime numbers. The result is $4\pi^2$. We will discuss open problems on zeta-regularization and its relation with transalgebraic number theory.

Black Hole and Gamma-Ray Bursts

R. Ruffini (ICRA, Italy)

Cosmological Casimir effect, CV formula and entropy bounds near future singularities

D. Sáez-Gómez (ICE/CSIC-IEEC, Barcelona, Spain)

It has been studied that the Casimir effect could have some implications on the cosmological history. In this talk, we show how a Casimir term in a flat FRW Universe affects to the Universe evolution and what effects produce close to the so-called Big Rip singularity. As a different approach, we generalize the CV formula for an arbitrary inhomogeneous perfect fluid, and we can see that in general it is not possible to obtain the correspondence with the Cardy formula, and non with the FRW equation when the entropy bound is reached. Near future singularities, it is shown that this entropy bound is violated, what it could imply the non universal nature of the bound.

Experimental verifications of isoredshift with possible absence of universe expansion, big bang, dark matter, and dark energy

R. M. Santilli (Institute for Basic Research, USA)

We present systematic studies on the insufficiencies of special relativity within physical media, such as water, atmospheres and the interior of astrophysical bodies. We outline the rather large body of research on the deformations of special relativity applicable within physical media, known under the name of \{it isotopies.} We then present, apparently for the first time, experimental verifications of the hypothesis formulated by the
author in 1991, and today known as \textit{isoredshift}, according to which light propagating within a physical medium experiences a shift of its frequency toward the red without any relative motion between the source, the medium and the observer, the shift originating from expected loss of energy to the medium due to interactions. We then confirm the isoredshift in the colors of our atmosphere as well as in the large difference in cosmological redshift between certain quasars and their associated galaxies; we indicate the consequential conceivable absence of universe expansion, big bang, dark matter, and dark energy; and propose \textit{systematic tests for the resolution of cosmological models via experiments on Earth along the teaching of Galileo}

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\textit{On physical equivalence of conformal frames}

\textbf{M. Sasaki} (YITP, Kyoto University, Japan)

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\textit{Testing Modified Gravity with Gravitational Wave Astronomy}

\textbf{C. Sopuerta} (ICE/CSIC-IEEC, Barcelona, Spain)

The emergent area of gravitational wave astronomy promises to provide revolutionary discoveries in the areas of astrophysics, cosmology, and fundamental physics. One of the most exciting possibilities is to use gravitational-wave observations to test alternative theories of gravity. In this talk I will summarize different ways in which observations of sources of gravitational waves can produce such tests. I will also discuss a particular example related to the future space observatory LISA.

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\textit{Massive 3D (super)gravity}

\textbf{P. Townsend} (University of Cambridge, UK)

Non-zero mass is compatible with unbroken gauge invariance in three spacetime dimensions (3D). A systematic procedure for the construction of massive gauge theories will be illustrated by "new massive gravity", which propagates unitarily two massive spin 2 modes in a Minkowski vacuum. The supergravity extension of this model will be presented along with results on supersymmetric adS vacua. The extension to N=8 3D supergravity will be discussed, as will be the adS3/CFT2 correspondence and possible connections to string/M-theory.

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\textit{Very Special Relativity and Noncommutative Space-Time}

\textbf{A. Tureanu} (University of Helsinki and Helsinki Institute of Physics, Finland)

The Cohen-Glashow Very Special Relativity (VSR) theory is shown to be realized as the part of the Poincare symmetry preserved on a noncommutative Moyal plane with light-like noncommutativity. Some physical implications of this noncommutative realization of the Cohen-Glashow VSR will also
Zeta-regularization and exact WKB method for the 1D Schrödinger equation
A. Voros (Inst. de Physique Théorique, CEA-Saclay, France)

The 1D stationary Schrödinger equation with a general polynomial potential (a Sturm--Liouville problem) is exactly solvable by a zeta-regularized WKB treatment. This formalism also unravels the perturbative behavior of global objects such as spectral determinants, resolvent traces, spectral moments.

Nuclear fusion drives present-day accelerated cosmic expansion
L. Ying (Princeton Gamma-Tech, USA)

The widely accepted model of our cosmos is that it began from a Big Bang event some 13.7 billion years ago from a single point source. From a twin universe perspective, the standard stellar model of nuclear fusion can account for the Dark Energy needed to explain the mechanism for our present-day accelerated expansion. The same theories can also be used to account for the rapid inflationary expansion at the earliest time of creation, and predict the future cosmic expansion rate.

Singularities with finite scale factor
A. Yurov (Kaliningrad University, Russia)

Zeta function regularization and multiplicative anomaly
S. Zerbini (Department Of Physics, Trento University, Italy)

A survey of multiplicative anomaly within zeta function regularization is presented, Old and new results will be discussed.