Wednesday, June 4

Morning Main Session

The Acceleration of the Universe: Dark Energy or Inhomogeneity?

George Ellis
Mathematics Department, University of Cape Town

The explanation of dark energy is a central pre-occupation of present day cosmology. Its presence is indicated by the recent speeding up of the expansion of the universe indicated by supernova observations and confirmed by other observations such as those of the cosmic background radiation anisotropies. However this deduction is based on the assumption that the universe has a Robertson-Walker (spatially homogeneous and isotropic) geometry on a large scale. The observations can at least in principle be accounted for without the presence of any dark energy, either by taking into account the effect on dynamics and/or on observations of relatively small scale inhomogeneities, which certainly exist, or by assuming there is a large scale inhomogeneity of the observable universe such as that described by the Lemaitre-Tolman-Bondi spherically symmetric models. These possibilities will be described, and it will be emphasized that if the standard analysis of the supernova data suggest there is a redshift range where $w := p/m < -1$, this may well be an indication that one of these explanations is preferable to the Robertson-Walker assumption, for otherwise the matter model indicated by these observations is non-physical. It follows that observational tests of the Copernican (spatial homogeneity) assumption are of considerable importance; possible such tests will be described briefly.

General Relativity and Completeness

Spiros Cotsakis
Department of Information and Communication Systems Engineering, University of the Aegean

We review recent results about sufficient conditions for geodesic completeness and spacetime singularities that help to rephrase the classical singularity problem in terms useful for global existence studies in general relativity. Applications of these results to study the nature of singularities that may develop during the evolution of cosmological models of current interest are briefly discussed.

Alternative Estimates of the Dark Energy Equation of State

Manolis Plionis[1*], **S. Basilakos**[2]
[1]*Institute of Astronomy and Astrophysics, National Observatory of Athens*
[2]*Research Center for Astronomy and Applied Mathematics, Academy of Athens*

We propose to use alternative cosmic tracers to measure the dark energy equation of state and the matter content of the Universe [$w(z)\&\Omega_m$]. Our proposed method consists of two components: (a) tracing the Hubble relation using as standard candles the HII-like starburst galaxies, as an alternative to supernovae type Ia, which can be detected up to very large redshifts, $z \sim 4$, and (b) measuring the clustering pattern of X-ray selected AGN at a median redshift of 1. Each component of the method can in itself provide interesting constraints on the cosmological parameters, especially under our anticipation that we will reduce the corresponding random and systematic errors significantly. However, by joining their likelihood functions we will be able to put stringent cosmological constraints and break the known degeneracies between the dark energy equation of state and the matter content of the universe and provide a powerful and alternative avenue to measure the contribution to the global dynamics, and the equation of state, of the dark energy.

Accelerating Universe: Recent Observations and Implications for Extended Gravity Theories

Leandros Perivolaropoulos[*], **S. Nesseris**
Department of Physics, University of Ioannina

Observational probes of the accelerating universe indicate that the effective equation of state of dark energy is currently close to $w = -1$ and in fact it may have crossed the $w = -1$ line in the near past. Such a crossing is inconsistent with minimally coupled quintessence and models based on general relativity. It is also inconsistent with scalar-tensor theories if Newton's constant is increasing with time. Consistency with accelerating expansion data and with solar system tests implies new constraints on the first and second time derivative of Newton's constant.

Cosmological Magnetic Fields

Kerstin E. Kunze
Dep. de Fisica Fundamental, Universidad de Salamanca

In this talk I would like to comment on generation mechanisms of primordial magnetic fields during inflation and their effects on the cosmic microwave background.

Morning Parallel Session

Self-dual Maxwell Field in 3D Gravity with Torsion

Branislav Cvetkovic*, M. Blagojevic
Institute of Physics, University of Belgrade

We construct an exact solution for the system of self-dual Maxwell field coupled to 3D gravity with torsion. Using the canonical formalism with naturally regularized boundary conditions, we find finite expressions for its energy, angular momentum and electric charge.

A new Anisotropic Solution for Ellipsoidal Spaces

Taxiarchis Papakostas
Department of Physical Resources and Environment,TEI of Crete

We present a new stationary and axisymmetric solution representing a perfect fluid with heat flux in the case of ellipsoidal spaces, within the Carter's family [A] of solutions.

Gravitational Waves from White Dwarfs

Avetis Abel Sadoyan[1*], Mathew Benaquista[2], David Sedrakian[1]
[1]*Department of Physics, Yerevan State University*
[2]*Center for Gravitational Wave Astronomy, University of Texas at Brownsville*

TBA

General Relativistic Plasma as Window for Extra Dimensions

Sujit Chatterjee[1*], D. Panigrahi[2]
[1]*Physics Department, New Alipore Collegea*
[2]*Kandi Raj College, Mursidabad*

The well known (3+1) decomposition of Thorne and Macdonald is invoked to write down the Einstein-Maxwell equations generalised to (d+1) dimensions and to formulate the plasma equations in a flat FRW like spacetime in higher dimensions

(HD). Assuming an equation of state for the background metric we find solutions as also dispersion relations in different regimes of the universe in an unified manner both for magnetised(un) cold plasma. We find that for a free photon in expanding background we get maximum redshift in 4D spacetime and for a particular dimension in pre combination era. Further wave propagation in magnetised plasma is possible for a restricted frequency range only, depending on the number of dimensions and the dielectric constant of the plasma media remains constant, not sharing the expansion of the background. Further, analogous to the flat space case we observe the phenomenon of Faraday rotation, measurement of which, in principle at least, may act as a window for extra dimensions.

Sharp Bounds on the Critical Stability Radius for Relativistic Charged Spheres

Hakan Andreasson
Department of Mathematics, Chalmers University of Technology, Goeteborg

The problem of finding a lower bound on the radius R of a charged sphere with mass M and charge Q is investigated. Such a bound is referred to as the critical stability radius. Equivalently, it can be formulated as the problem of finding an upper bound on M for given radius and charge. This problem has resulted in a number of papers in recent years but neither a transparent nor a general inequality similar to the case without charge, i.e., $M \leq 4R/9$, has been found. In this paper we derive the surprisingly transparent inequality

$$\sqrt{M} \leq \frac{\sqrt{R}}{3} + \sqrt{\frac{R}{9} + \frac{Q^2}{3R}}$$

The inequality is shown to hold for any solution which satisfies $p + 2p_T \leq \rho$, where $p \geq 0$ and p_T are the radial- and tangential pressures respectively and $\rho \geq 0$ is the energy density. In addition we show that the inequality is sharp, in particular we show that sharpness is attained by infinitely thin shell solutions.

An Attractor in the Space of Cosmic String Loops

Malcolm Anderson
Department of Mathematics, Universiti Brunei Darussalam

Cosmic strings are filamentary distributions of Higgs field energy which for cosmological purposes can be modeled as relativistic matter sources concentrated on singular two-dimensional spacetime surfaces. The Allen-Casper-Ottewill (ACO) loop is a simple analytic solution of the Nambu-Goto equations of motion which has long

been suspected to have the lowest radiative efficiency of any cosmic string loop. At the level of the weak-field approximation, the ACO loop is known to evolve by self-similar evaporation, and the corresponding weak-field metric has recently been constructed. In this talk I will indicate how the weak-field metric generated by the evaporating ACO loop can be used to analyse the dynamics of a string loop whose initial shape is close to that of the ACO loop. In particular, I will show that small deviations from the ACO loop configuration are radiated away on a timescale much smaller than the evaporative timescale of the ACO loop. The evaporating ACO loop is therefore not just a self-similar equilibrium solution, but (unsurprisingly) an attractor in the space of cosmic string loops.

Afternoon Main Session

Binary Black Holes: Extreme Gravitational Physics Simulations

Pablo Laguna
Department of Astronomy and Astrophysics, Penn State University

A new era in astronomy will begin once gravitational wave interferometers such as LIGO detect first light. These detectors will give us a revolutionary view of the Universe, complementary to the electromagnetic and particle astrophysics perspective. In this new astronomy, the messengers are gravitational waves, waves such as those produced by binary systems consisting of black holes and/or neutron stars. The detection of gravitational waves is a formidable undertaking, requiring innovative engineering, powerful data analysis tools and careful theoretical modeling. In support of this theoretical modeling, there is an urgent need to develop generic numerical codes capable of assisting us in exploring where and how gravitational wave observations can constrain or inform our understanding of astronomical phenomena and gravity. This talk will focus on the latest developments in the effort to simulate compact object binaries involving black holes and the potential role of these simulations as tools in a multi-messenger astronomy.

Brane-World Black Holes

Panagiota Kanti
Physics Department, University of Ioannina

In the context of gravitational theories postulating the presence of extra, space-like dimensions in which our 4-dimensional brane is embedded, the existence of solutions describing black holes has been intensely studied. While in the case of warped extra dimensions the construction of analytic regular black hole solutions has proven to be extremely challenging, in the limit where the self-energy of our brane is small and can be ignored, such black hole solutions are known to exist. These solutions can be used as models to investigate the properties of black holes in the presence of extra dimensions, such as their decay process through the emission of Hawking radiation. The creation of miniature higher-dimensional black holes during the collision of highly-energetic particles has been suggested as a possible scenario, that could be realised even at the Large Hadron Collider (LHC). By using the same model solutions to describe the produced higher-dimensional black holes, we study possible observable effects of their decay process.

Gravitational Waves from Gauge-Invariant Perturbations of Spherically Symmetric Spacetimes

Paul Lasky
Center for Stellar and Planetary Astrophysics, Monash University

One difficulty associated with perturbations of spherical collapse models in General Relativity is attributed to the junction conditions required at the interface of the interior matter-filled region and the exterior vacuum region. This implies extracting information about gravitational waves at spacelike infinity is also a difficult task. In this talk, I present a method which eliminates the need for junction conditions in both the background and perturbed spacetimes, thereby allowing relatively simple modelling of gravitational waveforms. This is achieved by using a recently developed method that enables a single line element to be expressed for the entire spherically symmetric background spacetime. Perturbing this spacetime in a gauge-invariant manner implies junction conditions are not required at any stage of the perturbation. Wave equations are derived for the Newman-Penrose Weyl scalars which hold in both the matter filled regions of the spacetime as well as the vacuum exterior regions.

Simulations of BH-NS Mergers

Emmanouela Rantsiou[1*], S. Kobayashi[2], P. Laguna[3], F. A. Rasio[1]
[1]*Department of Physics and Astronomy, Northwestern University*
[2]*Astrophysics Research Institute, Liverpool John Moores University*
[3]*Department of Astronomy and Astrophysics, Penn State University*

We use a relativistic SPH code to study the mergers of stellar mass BHs with NSs. Such systems are thought to be one of the possible progenitors of short GRBs. One of our main results is that the formation of an accretion disk around the BH

that can result from such a merger (and which presence is a prerequisite for the short-GRB scenario) depends critically both on the spin of the BH and the orbital inclination of the NS prior to merger. We furthermore investigate the effect of the NSś EOS on the outcome of the merger and finally we extract the GWs emitted during these mergers.

Prompt GRB emission from gradual energy dissipation

Dimitrios Giannios
Max Planck Institute for Astrophysics, Garching

I calculate the emission expected from a Poynting-flux-dominated gamma-ray burst (GRB) flow in which energy is dissipated gradually by magnetic reconnection. In this picture, the energy of the radiating particles is determined by heating and cooling balance (slow heating model). Detailed radiative transfer calculations show that, at Thomson optical depths of order of unity, the dominant radiative process is inverse Compton scattering. Synchrotron-self-absorbed emission and inverse Compton dominate in the Thomson thin parts of the flow. The electrons stay thermal throughout the dissipation region because of Coulomb collisions (Thomson thick part of the flow) and exchange of synchrotron photons (Thomson thin part). The resulting spectrum naturally explains the observed sub-MeV break of the GRB emission and the spectral slopes above and below the break. The model predicts that the gamma-ray power-law tail has a high-energy cutoff typically at the $0.1-1$ GeV energy range that should be observable with GLAST. The model also predicts a prompt emission component in the optical and UV associated with the GeV emission. Observations of the prompt emission of GRB 061121 that cover the energy range from the optical to 1 MeV are explained by the model.

Matching of Analytical and Numerical Solutions for Neutron Stars of Arbitrary Rotation

George Pappas*, T. Apostolatos
Department of Physics, University of Athens

We demonstrate the results of the matching of the two soliton analytical solution against the numerically produced solutions of the Einstein field equations, that describe the spacetime exterior to rotating neutron stars, for arbitrary rotation. The matching procedure is based on constraining the multipole moments of the analytical solution, thus determining the values of the two soliton parameters. We then compare the metric components, the radius of the innermost stable circular orbit (R_{ISCO}), the rotation frequency $\Omega \equiv \frac{d\phi}{dt}$ and the epicyclic frequencies Ω_ρ, Ω_z.

Phenomenological Framework for Loop and Braneworlds Cosmologies

Marco Valerio Battisti*, **G.Montani**
ICRA-University of Rome "La Sapienza"

A common framework which is able to describe both loop cosmology and the braneworlds scenario is developed. In particular, such a scheme is based on a deformed Heisenberg algebra which is related to the κ-Poincaré one. From this point of view, the difference between the effective Friedmann dynamics of loop and brane theories can be recognized as the sign's freedom of the deformation term of the algebra.

Asymmetrically Warped Brane Models

Pavlos Pasipoularides
National Technical University of Athens

TBA

Early Viscous Universe with Variable Cosmological and Gravitational Constants in Higher Dimensional Spacetime

Goverdhan S. Khadekar*, **G. L. Kondawar, V. Kamdi, C. Ozel**
Department of Mathematics, RTM Nagpur University

In this paper we present a number of classes of solutions of the Einsteinś field equations with variable G, Λ and bulk viscosity for a Kaluza-Klein type of cosmological model. The solutions are obtained by using γ-law equation of state $p = (\gamma - 1)\rho$, where adiabatic parameter γ varies continuously as the universe expand. A unified description of the early evolution of the universe is discussed with number of possible assumption on the bulk viscous term and gravitational constant in which an inflationary phase followed by radiation-dominated phase. We also investigate the cosmological model with constant and time dependent bulk viscosity along with constant and time dependent gravitational constant. In all cases,the cosmological constant Λ found to be positive and decreasing function of time which suports the results obtained from recent supernovae Ia observations. The important physical behaviour of the early cosmological model has also been discussed in the frame work of higher dimensional spacetime.

Thursday, June 4 Morning Main Session

Loop Quantum Cosmology: An Overview

Abhay Ashtekar
Institute for Gravitation and the Cosmos, Penn State University

In loop quantum cosmology (LQC) of homogeneous models with at least one massless scalar fieeld, the scalar field serves as a natural 'internal' clock. When evolution is discussed with respect to this emergent time, the big bang singularity is naturally resolved. The fundamental equations of LQC provide a deterministic evolution from the pre-big-bang to the post-big-bang branch. This occurs because quantum geometry effects give rise to an unforeseen repulsive force. It is completely negligible in normal conditions but rises very quickly once the matter density ρ reaches about 1% of the Planck density $\rho_{\rm Pl}$ and overwhelms classical gravitational attraction. As a consequence, big bang is replaced by a quantum bounce. Once ρ drops below $\sim 1\%$ of ρ_{Pl}, the new force becomes negligible. As a result, although classical general relativity is completely inadequate in the Planck regime, it is an excellent approximation right till curvatures approach $\sim 1/l_{\rm Pl}^2$. In this talk, I will present an overview of the current status of loop quantum cosmology, emphasizing recent developments. These include: i) results on the covariant entropy bound; ii) a proof that in the $k = 0$ models, the matter density operator has an absolute upper bound $\rho_{\rm sup}$ which is approached arbitrarily closely at the bounce point; iii) sharpening of similarities with and dierences from the Wheeler De-Witt theory; iv) Inclusion of Bianchi I models which play a key role in the BKL conjecture.

The Self-Organizing de Sitter Universe

Renate Loll
Institute for Theoretical Physics, University of Utrecht

I will describe the construction of a theory of quantum gravity from a non-perturbative and background-independent path integral. At an intermediate stage, it uses a regularization in terms of Causal Dynamical Triangulations (CDT). The continuum limit of this formulation can be investigated with the help of computer simulations, which show that a de Sitter universe emerges on large scales. This means that the theory is able to dynamically generate "its own background", one of the holy grails of quantum gravity. The emergence is of an entropic, self-organizing nature, with the weight of the Einstein-Hilbert action playing a minor role.

Black Holes in Loop Quantum Gravity

Jorge Pullin
Department of Physics and Astronomy, Louisiana State University

We review recent work on the quantization of spherically symmetric space-times in loop quantum gravity including treatments of the exterior, the interior and complete coverings. We show how the singularity is removed and discuss other features of the resulting models.

Lattice Refining in Loop Quantum Cosmology

Mairi Sakellariadou
Department of Physics, King's College, London

TBA

Lovelock Theory and Codimension 2 Braneworlds

Christos Charmousis
LPT, Université de Paris-Sud, Orsay

We will give a short introduction to Lovelock theory, which generalises Einstein's general relativity in higher dimensions. We will examine the staticity theorem generalising Birkhoff's theorem in this theory and study the static black holes. We will then examine maximally symmetric braneworlds of codimension 2 in this context. In passing we will present solutions describing Lovelock regular instantons.

Area Spectrum of Rotating Black Holes via the New Interpretation of Quasinormal Modes

Elias Vagenas
RCAAM, Academy of Athens

Motivated by the recent work on a new physical interpretation of quasinormal modes by Maggiore, we utilize this new proposal to the interesting case of Kerr black hole. In particular, by modifying Hod's idea, the resulting black hole horizon area is quantized and the resulting area quantum is in full agreement with Bekenstein's result. Furthermore, in an attempt to show that the area spectrum is equally spaced, we follow Kunstatter's method. We propose a new interpretation as a result of

Maggiore's idea, for the frequency that appears in the adiabatic invariant of a black hole.

Morning Parallel Session

BTZ Strings in Codimension-2 Braneworlds

Bertha Cuadros-Melgar[1*], Eleftherios Papantonopoulos[2], Minas Tsoukalas[2], Vassilios Zamarias[2]
[1] *Universidad de Santiago de Chile*
[2] *National Technical University of Athens*

We consider a five-dimensional Einstein-Gauss-Bonnet action with an induced gravity term on a 2-brane of codimension-2. We show that this system admits BTZ-like black holes on the 2-brane which are extended into the bulk with regular horizons.

Regularized Codimension-2 Brane Cosmology

Vassilios Zamarias[1*], B. Cuadros-Melgar[2], E. Papantonopoulos[1] , M. Tsoukalas[1]
[1] *National Technical University of Athens*
[2] *Universidad de Santiago de Chile*

In this talk we consider a six-dimensional Einstein-Maxwell system compactified in an axisymmetric two-dimensional space with one capped regularized conical brane of codimension one. We study the cosmological evolution which is induced on the regularized brane as it moves in between known static bulk and cap solutions. Looking at the resulting Friedmann equation, we see that the brane cosmology at high energies is dominated by a five-dimensional ρ^2 energy density term. At low energies, we obtain a Friedmann equation with a term linear to the energy density with, however, negative coefficient in the small four-brane radius limit (i.e., with negative effective Newton's constant). We discuss ways out of this problem.

Black Hole Formation in Scalar Field Collapse

Roberto Giambò[1*], Fabio Giannoni[1], Giulio Magli[2]
[1]*Department of Mathematics and Computer Sciences, University of Camerino*
[2] *Politecnico, Milano*

The gravitational collapse of self-interacting homogeneous scalar fields models is analyzed under general conditions on the scalar field potential. The generic evolution is shown to form a singularity in a finite time, and the result is used to construct radiating star models of the Vaidya type. Some of these models may exhibit naked singularities, but instability with respect to initial data is shown to hold, resulting in genericity of black hole formation.

Finslerian Structure Versus Birefringence

Josef Skakala*, Matt Visser
School of Mathematics, Statistics and Computer Science, Victoria University of Wellington

Many of the toy models for ¨quantum gravity phenomenology¨that are currently under consideration exhibit Planck-scale breakdown of Lorentz invariance and/or Planck-scale birefringent (or multi-refringent) effects. Mathematically, these physical effects are often encoded in Fresnel equations and/or Finsler geometries (pseudo-Finsler spacetimes). In this work we wish to address the question of whether a single Finsler metric can (usefully) be used to simultaneously encode all the geometric information due to all the multi-refringent modes (in the same way that the Fresnel equations specify all the multi-refringent modes on an equal footing). Using the optical physics of bi-axial crystals as a guide, we shall demonstrate that for physical reasons one is often much better off dealing with a separate Finsler spacetime for each propagating mode, and not trying to assemble all the separate Finsler spacetimes into an overarching universal Finsler geometry. This result is somewhat unexpected, since as long as one is only interested in propagation- cone structure, a single universal Fresnel equation does encode the overarching causal structure.

Mesoscopic Structures in Quantum Gravity

Andrew Randono
Physics Department, Penn State University

In an effort to understand the nature of quantum de Sitter space, we explore the symmetry reduction of the generalized Kodama state. The system has a remarkably precise analogue with the non-relativistic formulation of a particle falling in a constant gravitational field that we exploit in our anaylsis. We find that the solution reduces to de Sitter space in the semi-classical limit, but the uniquely quantum features of the solution have peculiar property. Namely, the unambiguous quantum structures are neither of Planck scale nor of cosmological scale, but an intermediate length scale some twenty orders of magnitude larger than the Planck scale. We find a periodicity in the volume of the universe whose period, using the observed value of the cosmological constant, is on the order of the volume of the proton.

Afternoon Main Session

The Search for Gravitational Waves

James Hough
Institute for Gravitational Research, University of Glasgow

An extended data taking run involving the long baseline gravitational wave detectors - LIGO, Virgo and GEO 600 - has recently finished. GEO 600, and the 2km length LIGO detector at Hanford are carrying out a monitoring exercise known as Astrowatch while the 4km LIGO detectors and the 3km Virgo detector are undergoing minor upgrades to allow some increase in sensitivity. In this talk, current results from the data taking runs will be summarized, and the development of the detectors and plans for the future will be discussed.

Probes and Tests of Strong-Field General Relativity

Dimitrios Psaltis
Physics Department, University of Arizona

In contrast to gravity in the weak-field regime, which has been subjected to numerous experimental tests, gravity in the strong-field regime is largely unconstrained by experiments. Indeed, a large class of gravity theories can be constructed that obey the Einstein equivalence principle and cannot be rejected by solar system tests, but that diverge from general relativity in the strong-field regime. I show that such theories predict black holes and neutron stars with significantly different properties than their general relativistic counterparts. I then discuss how recent observations with current telescopes have provided interesting new constraints on scalar-tensor and braneworld gravity models that are comparable to solar-system and table-top experiments.

Time Evolution of Fast Rotating Stratified Newtonian Stars

Andrea Passamonti
School of Mathematics, University of Southampton

In this talk, I report our study on non-axisymmetric oscillations of rapidly rotating neutron stars. In Newtonian gravity, we investigate stratified neutron stars and their spectral properties focusing on composition gravity modes. In the final part of the talk, I will introduce our current research project on fast rotating superfluid neutron stars and discuss preliminary results.

Alfven QPOs in Magnetars

Hajime Sotani[1*], Kostas D. Kokkotas[1,2], Nikolaos Stergioulas[2]
[1]*Theoretical Astrophysics, University of Tuebingen*
[2]*Department of Physics, Aristotle University of Thessaloniki*

We investigate torsional Alfven oscillations of relativistic stars with a global dipole magnetic field, via two-dimensional numerical simulations. We find that a) there exist two families of quasi-periodic oscillations (QPOs) with harmonics at integer multiples of the fundamental frequency, b) the lower-frequency QPO is related to the region of closed field lines, near the equator, while the higher-frequency QPO is generated near the magnetic axis, c) the QPOs are long-lived, d) for the chosen form of dipolar magnetic field, the frequency ratio of the lower to upper fundamental QPOs is around 0.6, independent of the equilibrium model or of the strength of the magnetic field, and e) within a representative sample of equations of state and of various magnetar masses, the Alfven QPO frequencies are given by accurate empirical relations that depend only on the compactness of the star and on the magnetic field strength. Several of the low-frequency QPOs observed in the X-ray tail of SGR 1806-20 can readily be identified with the Alfven QPOs we compute. In particular, one could identify the 18Hz and 30Hz observed frequencies with the fundamental lower and upper QPOs, correspondingly, while the observed frequencies of 92Hz and 150Hz are then integer multiples of the fundamental upper QPO frequency. Furthermore, we also discuss our latest results with respect to the magnetars.

Neutron Star Equation of State via Gravitational Wave Observations

Charalampos Markakis[1*], Jocelyn S. Read[1], Jolien D. E. Creighton[1], John L. Friedman[1], M. Shibata[2], K. Uryu[3]
[1] *Physics Department, University of Wisconsin Milwaukee*
[2] *University of Tokyo, Japan*
[3] *University of the Ryukyus, Japan*

Gravitational wave observations can potentially measure properties of neutron star equations of state by measuring departures from the point-particle limit of the gravitational waveform produced in the late inspiral of a neutron star binary. Numerical simulations of inspiraling neutron star binaries computed for equations of state with varying stiffness are compared. As the stars approach their final plunge and merger, the gravitational wave phase accumulates more rapidly for smaller values of neutron star compactness. This suggests that gravitational wave observations at frequencies around 1 kHz will be able to measure the compactness parameter and place stringent bounds on possible neutron star equations of state. Advanced laser interferometric gravitational wave observatories will be able to tune their frequency band to optimize sensitivity in the required frequency range to make sensitive measures of the late-inspiral phase of the coalescence.

Afternoon Main Session

Self-Acceleration and Self-Tuning in 6D Brane Models

Antonios Papazoglou[1*], Ch. Charmousis[2]
[1] *ICG Portsmouth*
[2] *LPT, Université de Paris-Sud, Orsay*

We construct maximally symmetric codimension-2 brane models in six dimensions, where the bulk dynamics is dictated by Gauss-Bonnet theory. We classify the models according to their curvature and according to whether they have infinite or finite volume. We show that in all these models there is an induced cosmological constant term on the brane given by the Gauss-Bonnet coupling. Therefore, one obtains an accelaration of geometric rather that matter-related origin (self-acceleration). Furthermore, we show that in the same solutions, the curvature of the brane have some degree of insensitivity to the brane vacuum energy (self-tuning). We comment on the possible cosmological dynamics of such a model.

Black Holes on 3-branes of Codimension-2 and their Extension into the Bulk

Minas Tsoukalas
National Technical University of Athens

We concider a six dimensional codimension 2 brane world, with a Gauss-Bonnet term in the bulk and an induced gravity term on the brane. We examine the possibility of finding a localised black hole on the brane with a proper extention to the bulk.We find that one can have a black hole on the brane but due to the presence of the Gauss-Bonnet term there is a constraint relation which requires the presence of matter in the extra dimensions.

Friday, June 5

Morning Main Session

Hidden Symmetries of Higher Dimensional Black Holes

Valeri Frolov
Thoretical Physics Institute, University of Alberta

The most general known solution describing higher dimensional rotating black holes with NUT parameters in an asymptotically (anti) de Sitter spacetime is a Kerr-NUT-(A)dS metric. We demonstrate that this metric possesses a principal CKY tensor, that is a second rank closed conformal Killing-Yano tensor. This tensor generates a 'tower' of Killing-Yano and Killing tensors, which together with the existing Killing vectors are sufficient for the complete integrability of geodesic equations and the separation of variables in the Hamilton-Jacobi, Klein-Gordon and Dirac equations. We also show that these hidden symmetries, generated by the principal CKY tensor, allow one to solve the equations for a stationary string configurations and the equations for the parallel transport of the frame along geodesics in these spacetimes. These 'miraculous' properties of the higher dimensional Kerr-NUT-(A)dS metrics make them quite similar to the their 4-dimensional 'cousin'.

On a Spontaneous Breaking if Einstein's λ-Invariance as a Geometric Alternative to the Higgs Mechanism

Nikolaos Batakis
Department of Physics, University of Ioannina

A geometric mass-generating alternative to the electroweak Higgs mechanism is explicitly formulated in a 2T (4+4)-dimensional Kaluza-Klein construction set in Einstein-Cartan geometry. The standard-model results for the electroweak gauge-boson spectrum and masses are precisely reproduced without a Higgs or Higgs-like field. The entire Higgs sector has been replaced by a Goldstone-theorem environment, set by the spontaneous breaking of Einstein's λ-invariance along a time-like direction in the compactified dimensions.

Classical & Quantum 2+1 Axially Symmetric Gravity with a Λ term

Theodosios Christodoulakis*, **G.Doulis, T. Grammenos, E. Melas, G. O. Papadopoulos, A. Spanou, P. Terzis**
Department of Physics, University of Athens

The canonical analysis of 2+1 gravity plus a cosmologigal constant term is performed under the assumption of axial symmetry. Three first class constraines are found, one quadratic and two linear in momenta. These constraints are turned into quantum operators and the reasulting functional differential equations are complete integrated.

The Scenario of Collineations in General Relativity

Michael Tsamparlis
Department of Physics, University of Athens

A general scenario concerning the foundation of collineations (including the symmetries) in General Relativity is presented and discussed. Some basic results and trends are also presented.

Homogeneous and Isotropic Cosmologies in Higher Order Gravity

John Miritzis
Department of Marine Sciences, University of the Aegean

Homogeneous and isotropic models are studied in the Jordan and Einstein frames of the second order gravity theory. The late time evolution of the models is analysed with the methods of the dynamical systems.

A Mathematical Description of the Nature of the Dark Energy

Spyros Basilakos*, **Manolis Plionis**
Research Center for Astronomy and Applied Mathematics, Academy of Athens

Recent studies in observational cosmology have strongly indicated that we are living in a flat and accelerated Universe. In this talk, I will present alternative

views regarding the nature of the dark energy which is thought to be responsible for the current acceleration. In this framework, I will discuss several cosmological models which can describe well the evolution of the Universe i.e, from the Big-Bang (quantum regime) up to the present epoch.

Morning Parallel Session

Physical Existence of Signature Change Events and Consequences of an Absolute Time in Emergent Spacetimes from Bose Gas Hydrodynamics

Silke Weinfurtner
Department of Physics and Astronomy, University of British Columbia

We present an example of emergent spacetime as the hydrodynamic limit of a more fundamental microscopic theory. The low-energy, long-wavelength limit in our model is dominated by collective variables that generate an effective Lorentzian metric. This system naturally exhibits a microscopic mechanism allowing us to perform controlled signature change between Lorentzian and Riemannian geometries. We calculate the number of particles produced from a finite-duration Euclidean-signature event, where we take the position that to a good approximation the dynamics is dominated by the evolution of the linearized perturbations, as suggested by Calzetta and Hu [Phys. Rev. A 68 (2003) 043625]. Further we investigate the possibility of using the proposed signature change event as an amplifier for analogue "cosmological particle production" in condensed matter experiments.

Hidden Symmetries, Gravitational Anomalies, and Superalgebras of Dirac Type Operators on Curved Spaces

Mihai Visinescu
Department of Theoretical Physics, National Institute for Physics and Nuclear Engineering, Bucharest

The intimate relation between Killing-Yano tensors and non-standard supersymmetries is pointed out. The gravitational anomalies are absent if the hidden symmetry is associated to a Killing-Yano tensor. In the Dirac theory on curved spaces, Killing-Yano tensors generate Dirac type operators involved in interesting algebraic structures as dynamical algebras or even infinite dimensional algebras or superalgebras. The general results are applied to the 4-dimensional Euclidean Taub-NUT space. One presents the infinite dimensional superalgebra of Dirac type operators on Taub-NUT space that can be seen as a twisted loop algebra.

Emergent Continuum Spacetime from a Random, Discrete, Partial Order

Petros Wallden
Raman Research Institute, Sadashivanagar

There are several indications (from different approaches) that Spacetime in the Plank Scale could be discrete. One approach to Quantum Gravity, that takes this most seriously, is the Causal Sets Approach. In this approach spacetime is fundamentally a discrete, random, partially ordered set (where the partial order is the causal relations). In this talk, we examine how (and when) an effective continuum spacetime emerges at some scale from causal sets. In particular we examine how timelike and spacelike distances arise (in the case that the emergent spacetime is Minkowski), and how one can use this to obtain geometrical information in the general, curved spacetime, case.

How to fake $f_{NL} \neq 0$

Carla Sofia Carvalho[1,2*], **M. Bucher**[2], **B. van Tent**[2]
[1]*IST, Technical University, Lisbon*
[2]*LPT, Université de Paris-Sud, Orsay*

We present a general class of models for characterizing the non-Guassian properties of the CMB foreground contaminants. The formalism introduced allows one to define a statistical ensemble of foreground maps whose statisitical properties vary with galactic latitute. For this ensemble the bispectrum may be calculated by simply evaluated tree-level Feynman diagrams without recourse to Monte Carlo simulations. This property is possible because of the hierarchical characer of the algorithm. Using this model, we investigate what kinds of foregrounds could generate a bispectrum signal mocking the signal expected from primordial non-Gaussianity from inflation.

Gravitational Waves vs. Cosmic Strings

Kostas Kleidis
TEI of Thessaloniki and Aristotle University of Thessaloniki

The equation which governs the temporal evolution of a gravitational wave (GW) in curved spacetime, can be treated as the Schrdinger equation for a particle moving in the presence of an effective potential. When GWs propagate in an expanding Universe with constant effective potential, a critical value (k_c) arises in the comoving wave-number, which discriminates the metric perturbations into oscillating ($k > k_c$)

and non-oscillating ($k < k_c$) modes. The effective potential is reduced to a non-vanishing constant in a cosmological model which is driven by a two-component fluid, consisting of radiation (dominant) and cosmic strings (sub-dominant). It is known that the cosmological evolution gradually results in the scaling of a cosmic-string network and, therefore, after some time ($\Delta\tau$) the Universe becomes radiation-dominated. The evolution of the non-oscillatory GW modes during $\Delta\tau$, results in the distortion of the low-frequency GW power-spectrum from what it is anticipated in a pure radiation-model. On the other hand, following the evolution of the oscillating modes along this transition, we find that the corresponding high-frequency profile is also modified, resulting in a periodic function of the frequency.

Afternoon Main Session

Bjorken Flow from an AdS Schwarzschild Black Hole

George Siopsis*, **James Alsup**
Department of Physics and Astronomy, University of Tennessee

We consider a large black hole in asymptotically AdS spacetime of arbitrary dimension with a Minkowski boundary. By performing an appropriate slicing as we approach the boundary, we obtain via holographic renormalization a gauge theory fluid obeying Bjorken hydrodynamics in the limit of large longitudinal proper time. The metric we obtain reproduces to leading order the metric recently found as a direct solution of the Einstein equations in five dimensions. Our results are also in agreement with recent exact results in three dimensions.

Interacting Dark Energy and Dark Matter

Elcio Abdalla
Physics Institute, University of Sao Paolo

TBA

Chaos in Orbits: A Possible Identification of Non Kerr Black Holes

Theocharis Apostolatos*, **G. Pappas, T. Deligiannis**
Department of Physics, University of Athens

TBA

6+1 Lessons from f(R) Gravity

Thomas P. Sotiriou
Center for Fundamental Physics, University of Maryland

There has been a recent stimulus in the study of alternative theories of gravity lately, mostly triggered form combined motivation coming from cosmology/astrophysics and high energy physics. Among the proposed theories, one that has attracted much attention is f(R) gravity. It is certainly debatable whether such a simplistic modification of General Relativity can constitute a viable alternative theory of gravitation. However, it is quite straightforward to see the merits of such a theory when viewed as a toy theory whose role is to help us understand the implications and difficulties of beyond-Einstein gravity. Under this perspective, I review some of the main lessons we seem to have learned though the study of f(R) gravity in the recent past.

Evolution of Supermassive Black Holes in Hierarchical Cosmologies

Nikos Fanidakis*, **C. Baugh, S. Cole, C. Frenk**
Department of Physics, Durham University

Recent observations suggest that Supermassive Black Holes (SMBH's) reside at the centres of all spheroid galaxies. Intriguingly, their properties seem to correlate with the properties of the bulge, suggesting a single mechanism for the assembly of black holes and spheroids. We investigate the cosmological co-evolution of galaxies and their central SMBHs in hierarchical models of structure formation, using the GALFORM semi-analytical model. Our model successfully accounts for the observed SMBH - bulge relations and the evolution of the quasar luminosity function. We show how intrinsic properties of the SMBH, such as their mass and spin, evolve in the framework of the model, and demonstrate how the evolution of SMBHs plays a significant role in the shaping their host galaxy's size and appearance.

Geometric Properties of Magnetized Black Holes Event Horizons and Ergosurfaces

Ernesto Esteban
Department of Physics, University of Puerto Rico

We study the magnetized Kerr-Newman black hole event horizon and ergosurface geometry, and thus generalize the very well known findings of Smarr and Kokkotas. Analytical expressions for the Gaussian curvature, circumferences, and its respective embeddings were obtained for both surfaces. A graphical and nuimerical analysis was carried out to analyze and discuss the obtained results.

Afternoon Parallel Session

On the Tolman and Møller Mass-Energy Formulae in General Relativity

Petros Florides
Trinity College, Dublin

Two of the most satisfactory descriptions of mass–energy and its localization in general relativity are given in terms of Tolman and Møller formulae.The form of these two equations, as well as their derivation, are so utterly different that for thirty–five years, there was never even the slightest suspicion that there was any relationship between them. Yet, as it will be shown in this talk, for time–independent fields the two formulae are in fact identical.

Negative Mass and Repulsive Gravity in Newtonian Theory, and Consequences

Nikolaos Spyrou
Department of Physics, Aristotle University of Thessaloniki

In the context of the Newtonian theory of gravity, the dynamical equivalence of hydrodynamic flows with geodesic lines, in the interior of a bounded, gravitating perfect-fluid source, results in the possibility of negative mass and, hence, of repulsive gravity. The consequences are outlined for the overall picture of the Solar System and the large-scale cosmological, structures, and some predictions are attempted based on some current and mostly unexplained so far observational data.

Oscillations of Instabilities of Fast Rotating Neutron Stars

Erich Gaertig[1], **Kostas D. Kokkotas**[1,2*]
[1] *Theoretical Astrophysics, University of Tuebingen*
[2] *Department of Physics, Aristotle University Thessaloniki*

We will present new results from 2D simulations of oscillating relativistic stars. We will describe axisymmetric and non-axisymmetric perturbations for various equations of state and we will demonstrate the onset of the CFS rotational instabilities. We will discuss also the impact of the results in gravitational wave asteroseismology.

Poster Session

Recent Results on Short-Range Gravity Experiment

Maki Hata*, **Takashi Akiyama, Kazufumi Ninomiya, Jiro Murata**
Department of Physics, Rikkyo University

Recent experimental results from Newton-experiment at Rikkyo University will be presented. The present project is aiming to test Newtonś inverse square law in mm scale, and also to test weak equivalence principle, utilizing pico-precision displacement sensor with digital image analysis techniques. Preliminary physics results will be presented.

New Experimental Technique for Shor-Range Gravity Measurement

Ninomiya Kazufumi*, **Takashi Akiyama, Maki Hata, Jiro Murata**
Department of Physics, Rikkyo University

New experimental project (Newton-experiment) aiming to test Newton's inverse square law in mm to micron scale will be presented on technical aspects. Pico-precision displacement sensor using digital image analysis technique, which is originally developed for a high energy collider experiment. Conventional torsion balance bar apparatus and the position detector system will be presented.

Charged Cosmic Strings May Produce MHD Waves

Polixeni Nerantzi-Efstratiadou[1,2*], Demetrios Papadopoulos[1]
[1] *Department of Physics, Aristotle University of Thessaloniki*
[2] *Department of Mechanical Engineering, TEI of Serres*

We intend to examine MHD phenomena in the frame of a cylindrically-symmetric solution to the Einstein-Maxwell equations derived by B. C. Xanthopoulos. This solution represents the curved background around an electrified, rotating charged cosmic string which interacts with gravitational and electromagnetic waves. By means of a convenient NP-tetrad we have calculated the components of the electromagnetic field in terms of the Ernst potential E.

Lie Symmetries of Geodesic Equations

Michael Tsamparlis, Andronikos Paliathanasis*
Department of Physics, University of Athens

A theorem is proven which shows that the Lie symmetries of the geodesic equations are the projective symmetries of the background metric. The theorem holds for a general Riemannian space irrespective of the signature of the metric and the dimension of the space.

Inhomogeneous estimates for the perfect fluid Einstein's equations

Dimitrios Pliakis*, Taxiarchis Papakostas
TEI of Crete

In the perfect fluid model we impose growth of the velocity field measured with respect to the level sets of a given function. Then assuming a local maximal foliation we derive estimates for the lapse function (again with respect to the level sets of the given function) and the second fundamental form of the maximal slices. These are used then to derive estimates for the "blow-up time" and rate of the maximal foliation. The methods involved are standard PDE methods and use is made of a generalized Hardy inequality

Gravity as a Unification of Forces

Rasulkhozha Sharafiddinov
Institute of Nuclear Physics of Uzbekistan Academy of Sciences

Any of all possible types of charges corresponds in nature to a kind of the inertial mass. Such a mass-charge duality explains the coexistence of grand united rest mass and charge for the same neutrino equal respectively to its all the gravitational mass and charge which consist of the gravitoelectric, gravitoweak, gravitostrong and a range of others, innate components. From their point of view, a new grand unification theory has been created at the discussion of a question about unification of forces of a different nature. In this theory, the gravitational field must be naturally united gauge field of the unified system of the most diverse combinations of electromagnetic photons, weak bosons and strong gluons where the four pairs of forces of the micro world fundamental interactions are united. Some consequences and laboratory confirmations of the suggested theory have been listed which allow also to define the structure of the graviton as a grand united boson. Thereby, it gives

the possibility to directly look at the nature of gravitational matter elucidating the interratio of intraneutrino forces and the problem of elementary particle symmetries.

On Supermassive Objects Without Event Horizon

Leonid Verozub
Kharkov National University

In this paper the existing knowledge of maximal masses of degenarate configurations of self-gravitating Fermi-gas are revised. The consideration is based on a gauge-invariant generalization of Einsteinś equations of gravitation. It is shown that the theory allows existence of supermassive objects without event horizon. They are an alternative to the notion of black hole and perhaps are in galactic centers